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Investigation of facilities and students' readiness in supporting implementation of nodemcu-based bifocal modeling physics practicum

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Abstract: This research was carried out to get overviews which deal with facilities and students' readiness to support the implementation of NodeMCU-based bifocal modeling physics practicum. The location of this research was in a senior high school in Bandung District, Indonesia. The subjects of this research were physics teachers and students of that school enrolled in 2020/ 2021. This research was a case study, the data of which were collected through interviews, observation, and questionnaire. Interviews and observation were focused to gather information due to the school facilities supporting the implementation of NodeMCU-based bifocal modeling physics practicum. Questionnaire was used to reveal the readiness of students in accepting implementation of NodeMCU-based bifocal modeling physics practicum. Based on the data analysis, it was found that the school facilities meet technical specifications of NodeMCU, so the implementation of NodeMCU-based bifocal modeling physics practicum may be potentially supported by the school facilities; most students also own facilities (smartphones and laptops/ computers) which may be potentially utilized as output peripherals for displaying visualized physics phenomena and simulated physics data from a tool of NodeMCU-based bifocal modeling physics practicum; students are willing to accept the implementation of NodeMCU-based bifocal modeling physics practicum in physics learning, because it 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; NodeMCU; Physics Practicum

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Introduction

The 21st century life has changed every sectors of life. The applications of advanced technologies and science in various sectors are characteristics of the 21st century life (Wilson, Scalise, and Gochyyev 2015; Akmar et al. 2021). The openness and globalization are parts of the 21st century, so it is also called knowledge age, in which the efforts of fulfilling the life demands are globally networked and information-driven (Triling & Fadel, 2009). There is a notable statement due to the 21st century, i.e. the 21st century is an age, in which the transition from industrial age to the knowledge age happens. This transition needs process-oriented skills, well known as 21st century skills (Erdem, Bağcı, & Koçyiğit, 2019). These skills consit of critical thinking (CT) skills, problem solving skills, creativity and innovation, as well as communication and collaboration (Wilson et al., 2015). The skills also cover life and career skills, learning and innovation skills, as well as information media and technology skills (Daryanto & Karim, 2017).

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The 21st century learning is expected to play role in preparing students to have a set of 21st century skills, so they are capable and skilled enabling them to adapt with such life (Sujito, Liliasari, Suhandi, & Soewono, 2021). Hence, the learning in the 21st century should be organized in such a way so students possess skills or ways of thinking and working, tools for working, and skills for living. Creativity and innovation, critical thinking, problem solving, decision making, as well as learning to learn and metacognition are ways of thinking. Communication and collaboration skills are ways of working. Information and communication technology (ICT) literacy or digital literacy are tools for working. Meanwhile, ways of students to live as a good citizen who can proceed life and career normally, has personal and social responsibility, and have cultural awareness are skills for living (Wilson et al., 2015)

The Regulation of Education and Culture Minister 103/2014 on Learning in Primary and Secondary Education mandated that the learning process in Indonesia should be conducted by giving students experiences due to scientific approach applications. Scientific approach can be well implemented in a physics learning. It is because, by learning physics scientifically, students can understand the essence of physics as a scientific product (body of knowledge) consisting of scientific facts, concepts, principles, laws, theories, models, and formulas, the essence of physics as a scientific process (way of investigating) done by scientists in acquiring the knowledge, and the essence of physics as a scientific attitude (way of thinking) done by scientists in doing a scientific process (Sutrisno, 2006). By applying scientific approach in physics learning, teachers organize a learning in such a way so students carry out a set of scientific activities, consisting of observing, questioning, collecting information/ experimenting, associating, and communicating. This kind of learning approach is expected to be able to meet the demands of 21st century life.

A method of physics which enables to facilitate students with what aforementioned above is practicum or laboratory work. Through practicum, students can demonstrate basic principles of physics, know various measuring devices, conduct a scientific experiment, and develop certain practical skills (Gupta, 2013). Physics practicum can involve students in acquiring experimental experiences, help students in developing basic skills and operating laboratory devices as well as mastering physics concepts, understanding the roles of direct observation, and developing collaborative learning skills (Vilaythong, 2011). In practicum, students identify problems, formulate scientific questions and hypothesis, design experiment, collect and analyze data, as well as draw conclusions. Practicum also gives students inquiry experiences, by which students can improve the concept understanding due to a given scientific concept, skills of doing investigation, and procedural knowledge (Hofstein & Lunetta, 1982).

Dealing with the needs of giving students meaningful knowledge and skills through various methods of learning, today's learning should be adapted to the advanced existing technology, especially ICT technology. The application of such technology, including computer and digital learning technology has proven to positively facilitate students in developing problem-solving abilities. It can also stimulate critical, creative, and innovative ideas in physics learning (Ma'ruf, Setiawan, Suhandi, & Siahaan, 2020). ICT technology and computational science and engineering (CSE) technology can be employed as a tool for solving various physics learning problems, including problems due to the implementation of physics practicum in senior high school level because the limitations due to the time to organize practicum activities, laboratory instruments and devices, laboratory room, and laboratory assistant or technician (Katili, Sadia, & K, 2013).

ICT or CSE technology can be adopted into a learning method, by which students can conduct project-based scientific activities, which enable theoretical and abstract physics concepts can be visualized, so the quality of learning increases (Vieira, Magana, García, Jana, & Krafcik, 2018). The technology can also be utilized to design a learning which allows students to observe both microscopic and macroscopic phenomena through their interaction with real experiment and a computer model, from which students are possible to develop a critical perspective of scientific models. The design of learning is possibly organized in a set of practicum activities that apply bifocal modeling framework. It use advanced technologies, consisting of CSE technology and sensors. Bifocal modeling framework has been adopted in various science learning set-up. It has proven to significantly improve the conceptual understanding and metamodeling knowledge of students. In this case, metamodeling knowledge is knowledge due to scientific modeling allowing students to answer questions about how and why scientific models are used, as well as the strengths and limitations of such models (Fuhrmann, Schneider, & Blikstein, 2018).

Bifocal modeling framework can become potential solution to several problems of physics practicum, which is an important part of physics learning method expected to give positive contribution in preparing students with knowledge and skills needed to adapt with the demands of 21st century life. Hence, the adoption of bifocal modeling framework in developing a physics practicum should be deeply studied. A study dealing with the potential adoption of bifocal modeling framework in developing a physics practicum, may be oriented for getting overviews as the basis of bifocal modeling practicum development. One of overviews needed is about the facilities and students' readiness in supporting the implementation of bifocal modeling physics practicum. A sensor device as the main part of a bifocal modeling tool needs a microcontroller hardware that should be adapted to the facilities found at school or those owned by students. A microcontroller hardware that is potentially used to develop the sensor device of bifocal modeling-based physics practicum tools is NodeMCU. Hence, this study was carried out to reveal the availability of facilities and students' readiness in supporting implementation of NodeMCU-based bifocal modeling physics practicum in senior high school. In this research, an assumption that real part of bifocal modeling experiment is not the main concern of this research. In this case, the laboratory instruments, tools, and kits for doing a real experiment are presumably available and are in good condition or at least tools and materials to do a real physics practicum can be considerably provided easily. However, for getting a holistic overview, they will be directly observed.

Method

This research was a case study which used qualitative methodology. A case study research offers some advantages, among others are enabling high potential validity, having strong procedures to bring up new hypotheses, enabling to examine causal mechanisms in the context of individual cases, and having capability to address causal complexity in a specific context (Starman, 2013). The location of this research was in senior high school in Bandung District, West Java, Indonesia. Two physics teachers and students all students of grades 10, 11, and 12 enrolled in 2020/2021 were the subjects of this research.

Data collection in this research was carried out through interviews, questionnaire, and observation. Interviews were conducted with teachers for gathering qualitative information dealing with the facilities owned by the school and students which may be potentially used in implementing NodeMCU-based bifocal modeling physics practicum. Questionnaire was used to reveal the students' readiness in accepting the implementation of NodeMCU-based bifocal modeling physics practicum and facilities owned by students potentially utilized in doing NodeMCU-based bifocal modeling physics practicum. Meanwhile, observation was done to seek information due to the school facilities which can be used to support the implementation of NodeMCU-based bifocal modeling physics practicum. The data collected through interviews, questionnaires, and observation, were focused on data which deals with the facilities fulfilling the NodeMCU technical specifications compared to the criteria of bifocal modeling framework. The data obtained from interviews and observation was sorted, simplified, categorized and analyzed descriptively and qualitatively. The data obtained from questionnaires was analyzed in percentage and interpreted qualitatively.

Results and Discussion

This research revealed at least three main findings, i.e. findings dealing with facilities owned by students potentially used to support implementation of NodeMCU-based bifocal modeling physics practicum; findings dealing with school facilities potentially used to support implementation of NodeMCU-based bifocal modeling physics practicum; findings dealing with the student's readiness due to the implementation of NodeMCU-based bifocal modeling physics practicum. These three findings are described below. However, for making the findings more meaningful, the description of this research findings will be preceded by paragraphs related to bifocal modeling framework and NodeMCU.

Bifocal Modeling Framework

Bifocal modeling framework (BMF) is a science learning approach. It is inquiry-driven which expects students to design, compare, and examine the relationships between data obtained from a real experiment and data generated by computer models. In doing a learning implementing bifocal modeling framework, students are potentially involved in doing main activities, namely design, construct, and interact. In design activities, students formulate questions related to a phenomenon under investigation, generate hypotheses as well as design a real experiment and computer model connected by a sensor-based device (Fuhrmann et al., 2018). Generally, the bifocal modeling framework is illustrated in Figure 1.

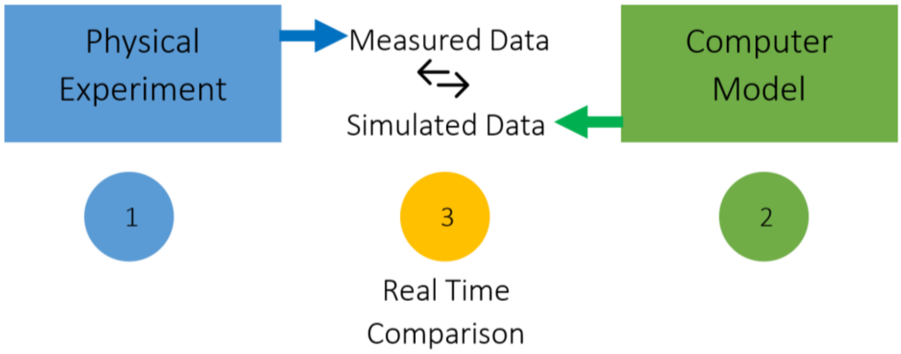

Figure 1. Bifocal modeling framework

The aim of bifocal modeling implementation in a science learning is to facilitate students to compare the data obtained from a real experiment to the data generated from a simulated/ computerized model. 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 readymade or student-designed models (Blikstein, 2014). Bifocal modeling framework can be adapted in such a way which depends on the characteristics of the phenomenon under investigation. It may use different computer languages, computer hardware, and sensor devices.

NodeMCU

Internet of Things (IoT) is a big platform, by which everyday devices are transformed into informative automated system (Patel & Devaki, 2019). It allows connection among devices using internet with ability to gather and exchange data. These devices are usually connected with micro-controllers like Arduino, sensors, actuators, and internet connectivity (Kashyap, Sharma, & Gupta, 2018). One ot the best ways to develop an IoT device with less integrated circuits to add is by choosing "NodeMCU". NodeMCU is an open-source firmware and development kit playing an important role in designing a proper IoT product using few script lines (Dahoud & Fezari, 2018).

A node NodeMCU board consist of multiple GPIO (general purpose input/ output) pins that allow us to connect the board with other peripherals and are capable of generating PWM (pulse-width modulation), I2C (inter integrated circuit), SPI (serial peripheral interface), and UART (universal asynchronous receiver-transmitter) communications (Dahoud & Fezari, 2018). Physically, a type of NodeMCU board, i.e. NodeMCU V3 is shown in Figure 2.

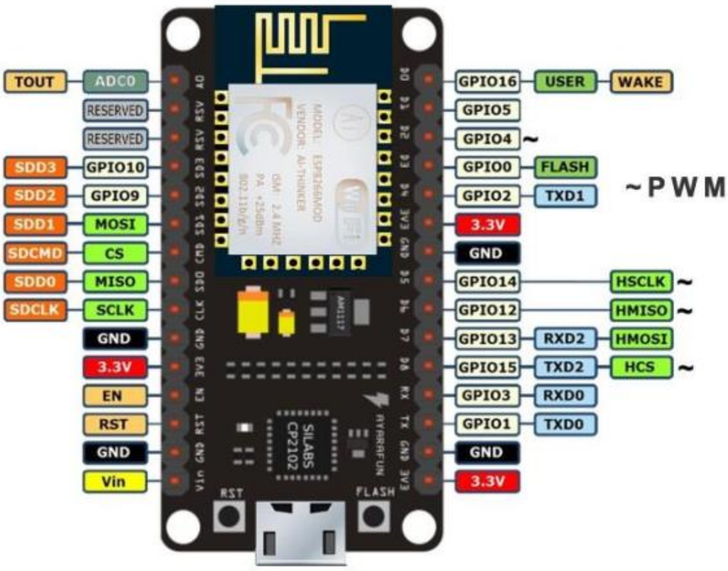

Figure 2. The board of NodeMCU V3

NodeMCU is potentially used as the sensor-based device in developing a bifocal modeling-based tool. It is because, NodeMCU is programmable by LUA language and also C language by using Arduino IDE (Efendi & Chandra, 2019; Wicaksono, 2017). NodeMCU enables sensor connection, such as PIR (passive infrared receiver) sensor for detecting motion, LDR (light dependent resistor) sensor, DHT11 (temperature and humidity sensors), and relay (Wicaksono, 2017). Hence, it can be connected to a physical experiment, from which the values of physical quantities are able to be simulated and the physical phenomena due to the experiment can be visualized on output peripherals, such as computer and smartphone screens.

NodeMCU is available in various package styles. The most popular one is ESP8266 core. Referring to the information found in the website at address https://www.make-it.ca/nodemcu-details-specifications/ and information summarized from Efendi & Chandra (2019) and Patel & Devaki (2019), the technical specifications of NodeMCU ESP8266 related to the facilities potentially supporting the implementation of NodeMCU-based bifocal modeling physics practicum are presented in Table 1.

Table 1. Summarized technical specifications of NodeMCU ESP8266

	Specifications	Description of facilities
USB connector	Micro USB	It needs micro USB cable.
USB to serial converter	CH340G/ CP2102	It needs USB A to B cable or CP2102 cable.
Input voltage	4.5 - 10 volts	It needs voltage source more than 10 volts.
Wifi built-in	802.11 b/g/n standard	It needs smartphone or computer/ laptop having wireless connection.
Drivers	CH340G/ CP2102 drivers	It needs operating systems, such as Windows, Mac, Linux, and Android.
Internet connection	Cable or wireless	It needs internet with LAN cable or wifi connection.

Results of Observation

Objects of school facilities observed in this research were of laboratory room, laboratory equipment, computer laboratory, and internet facilities. One of observation activities to school facilities is shown in Figure 3. Table 2 shows the results.

Figure 3. Laboratory observation

Table 2. Results of observation

Objects of observation	Description of facilities
Laboratory room	Physics laboratory is also functioned as other laboratories (chemistry and biology laboratories). It is good enough for conducting physics experiment in term of its equipment availability. Its area is about 30 m^2. There is no laboratory assistant in the laboratory.
Laboratory equipment and facilities	Measuring instruments, observation tools, and laboratory kits are found in the laboratory. The electricity source supplying the electric need for the laboratory is 2,200 VA.
Computer laboratory	There is a room functioned as a computer laboratory, in which 25 computers are found. Operating system used in every computer is Windows 10 Home Single Language The computers are well connected with LAN connection. In the computer laboratory, various types of cable (connector) are found, such as printer cable (A to B cable) and micro USB cable. A USB wifi wireless adapter is also found in the computer laboratory.
Internet connection	There is internet connection transmitted to the whole area of the school by using 3 wifi transmitter modules. The connection of the internet using the wifi transmitter is relatively good.

Based the data in Table 2 compared to the technical specifications of NodeMCU ESP8266 shown in Table 1, it can be said that the school facilities are possible to support the implementation of NodeMCU-based bifocal modeling practicum in physics learning. Facilities dealing with USB connector and USB to serial converter, such as printer cable (A to B cable) and micro USB cable were found in computer laboratory. NodeMCU which has been programmed can be easily connected to computers and laptops by using USB cable (Dewi, Rohmah, & Zahara, 2022). Voltage input for operating NodeMCU-based device can be supplied from the 2,200 VA electricity source in the laboratory. A USB wifi wireless adapter for connecting NodeMCU-based device through the wifi-built in module in the NodeMCU board, is also available in the computer laboratory. The wifi internet connection in that school is good enough for enabling the data gathered by NodeMCU-based device online to the cloud. This wifi connection enables nodeMCU-based devices to be connected to smartphones (Muchlis & Toifur, 2017). Windows 10 installed in the computers found in computer laboratory enables NodeMCU drivers (CH340G/ CP2102) can function well.

Results of Interviews

Interviews with two physics teachers were preceded by a brief explanation and discussion related to bifocal modeling-based practicum framework, NodeMCU as part of IoT, and the needs of developing bifocal modeling-based physics practicum tools to support the 21st century learning demands. The interviews were also focused on the school facilities as well as facilities may be owned by students which are possible to support the implementation of NodeMCU-based bifocal modeling physics practicum. Based on the interviews, it was revealed that the school has good enough facilities which can potentially support the implementation of NodeMCU-based bifocal modeling physics practicum. According to teachers, internet and computer infrastructures in that school are relatively good and students can utilized them with the guidance of teachers. However, teachers could not ensure that all facilities in that school fulfill the requirements for operation the Node-MCU-based device. It is because, teachers consider that micro-controller technology, including Node-MCU technology is something new for them. Due to the facilities owned by students, teachers ensure that every student in that school has smartphone which can be used as the device for displaying the simulated/ modeled data or visualization produced by a NodeMCU-based bifocal modeling device.

Results of Questionnaire

Just like the interviews, questions in the questionnaire were preceded by a brief explanation related to bifocal modeling-based practicum framework, NodeMCU as part of IoT, and the needs of developing bifocal modeling-based physics practicum tools to support the demands of 21st century learning. The explanation was expected to give students general overviews of bifocal modeling practicum, NodeMCU, and the demands of 21st century learning, so the students can answer all questions appropriately. Questionnaire in this research was given to students at grades 10, 11, and 12 online by using Google form. The students involved in answering the questionnaire were 79. Table 3 shows the results.

Table 3. Results of questionnaire

No.	Statements	Responses (%)	
		Agree	Disagree
Part I: Readiness of in accepting the implementation of NodeMCU-based bifocal modeling physics practicum			
1.	Physics practicum can help students to more understand physics concepts.	100	0
2.	Physics practicum can help students foster the curiosity to a given physics phenomenon.	84.81	15.19
3.	Students' motivation to learn physics increases when teachers implement practicum method.	92.60	7.4
4.	Computer visualization can help students to understand various physics concepts.	100	0
5.	Combining real experiment and simulated computer models can make students obtain holistic understanding of physics concepts.	97.47	2.53
6.	I have read the explanation due to bifocal modeling practicum, NodeMCU, and demands of 21st century learning. I generally understand that explanation.	84.81	15.19
7.	The use of NodeCMU-based device as a part of bifocal modeling practicum tools will make physics learning become more qualified.	100	0
8.	The use of NodeCMU-based device as a part of bifocal modeling practicum tools potentially enables students become more motivated in learning physics.	92.60	7.4
9.	The use of NodeCMU-based device as a part of bifocal modeling practicum tools potentially enables students become more easy to understand physics concepts.	92.60	7.4
10.	Students are willing to accept the implementation of NodeMCU-based bifocal modeling physics practicum in physics learning.	100	0
Part II:			
11.	I have smartphone having Wi-fi connection system which enables other wireless device to connect with.	100	0
12.	I have laptop/ computer having Wi-fi connection system which enables other wireless device to connect with.	50.63	49.37

No.	Statements	Responses (%)	
		Agree	Disagree
14.	I am willing to use my smartphone for learning.	100	0
15.	I am willing to use my laptop/ computer for learning.	100	0
16.	I can operate my smartphone in various ways, including connecting it to internet or other network systems.	100	0
17.	I can operate my laptop/ computer in various ways, including connecting it to internet or other network systems.	84.81	15.19

Questionnaire analysis revealed that students are curious to a certain physics phenomenon when the learning is organized by practicum. Through practicum, students can better understand physics concepts. Practicum enables students to be more motivated in learning physics. Students also are helped to understand physics concepts by the use of computer visualization. Students consider that the combination of real experiment and simulated computer models facilitates students to obtain holistic understanding of a given physics concept. According to students, the implementation of NodeMCU-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 NodeMCU-based bifocal modeling physics practicum in physics learning.

The analysis of the questionnaire also reveals that all students have smartphone having Wi-fi connection system which enables other wireless device to connect with. About fifty percent of students also have laptop/ computer having Wi-fi connection system. Students can operate their smartphone and laptop/computer. They also have willingness to use their smartphone and laptop/ computer for learning. Smartphones and laptops/ computers owned by students can be part of facilities needed to implement NodeMCU-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.

Conclusion

Based on the data analysis, the following conclusions were drawn: (1) the school facilities meet some requirements needed to operate NodeMCU devices based on the technical specifications of NodeMCU, so the implementation of NodeMCU-based bifocal modeling physics practicum may be potentially supported by the school facilities, (2) most students also own facilities in the form of smartphones and laptops/ computers which may be potentially utilized as output peripherals for displaying visualized physics phenomena and simulated physics data from a tool of NodeMCU-based bifocal modeling physics practicum, (3) students are willing to accept the implementation of NodeMCU-based bifocal modeling physics practicum in physics learning, because it potentially increases physics learning quality, increase students’ motivation to learn physics, and help students to easily understand physics concepts.

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