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Development of Bifocal Modeling Practicum to Harmonic Vibrations as Innovation in Physics Learning

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Abstract

The era of Industry 5.0 requires physics education to adapt to technological advancements. Students often struggle to understand abstract concepts due to the limitations of tools and methods of learning that are less interactive. This research aims to develop a prototype for a harmonic vibration practical that integrates the Internet of Things (IoT), Augmented Reality (AR), and Virtual Reality (VR) into a single Bifocal Modelling device. This approach allows students to see the application of physics concepts in real-time, enriching their learning experience. The method used is Research and Development (R&D), which consists of Analysis, Design, Development, Implementation, Evaluation (ADDIE). The research results indicate that the use of this technology can enhance student engagement and help them understand the differences between the ideal model and real phenomena. Thus, students not only learn theory but also experience firsthand that makes learning more engaging. In addition, the integration of this technology equips students with the 21st-century skills needed in an increasingly complex job market. This research is expected to provide solutions to the challenges in physics teaching and pave the way for further research related to the application of technology. In this way, the integration of technology in physics education can prepare students to face the complexities of the modern workforce.
Keywords: *bifocal modelling; harmonic vibrations; innovation in physics learning; IoT; 21st-century skills*

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INTRODUCTION

The rapid development of technology in the era of Industry 5.0 demands significant changes in the approach to learning, particularly in the fields of science and technology. The main focus in this era is on 21st-century skills, which include critical thinking, collaboration, communication, creativity, and digital literacy [1],[2],[3]. The education sector is faced with a significant challenge in preparing students to navigate the complexities of an increasingly dynamic and technology-based job market. However, in reality, many students still struggle to master scientific concepts, particularly in the field of physics, which is often viewed as abstract and difficult to understand [4],[5]. Physics is a branch of science that studies natural phenomena [6]. Therefore, concepts in physics involve ideas that cannot be observed directly, characteristics that are abstract, quantitative, exploratory, and predictive. Understanding physics concepts requires a combination of knowledge, skills, and attitudes [7]. Some physics concepts such as simple harmonic motion require a deep understanding. It cannot be obtained only through theoretical explanations. For example, simple harmonic motion is used to understand the consequences of vibrations and waves.

Students' understanding of physics concepts can be improved using practical-based learning, but limited tools and facilities pose problems and challenges in implementation [8],[9],[10]. To address this issue, bifocal modeling has emerged as an innovative approach for the future of physics education that shows great promise. Physics education through bifocal modeling is one of the promising innovations. Bifocal modeling is a learning approach that integrates real physical experiments with computer models or simulations using Internet of Things (IoT) in real-time. This approach allows students to understand physics concepts through direct observation and interaction with data [11],[12],[13]. Students can not only understand physics concepts theoretically but also see how those concepts are applied in the real world. Bifocal modeling develops the 21st-century skills that are highly needed in this modern era. However, research related to its application in the context of physics education is still very limited. Most existing research focuses more on the use of real practical tools or computer simulations, without a deep integration between bifocal modeling technology and current technologies such as the Internet of Things (IoT), Augmented Reality (AR), and Virtual Reality (VR) [14].

Research conducted by Blikstein [13] shows that bifocal modeling can help students better understand the differences between ideal models and real phenomena, thereby encouraging a deeper understanding of science [15]. Meanwhile, Fuhrmann et al. [12] demonstrate that the use of bifocal modeling in science education at the secondary school level can enhance student engagement and strengthen their critical thinking skills. Nevertheless, both studies have yet to highlight how to implement bifocal modeling. In fact, technologies have great potential to enrich students' learning experiences and make physics education more interactive and engaging. One of the weaknesses of previous research is the lack of studies that integrate practical work with AR and VR technology in physics education. In addition, Internet of Things (IoT) technology allows the devices used in experiments to connect and collect data in real-time. The data collected by these sensors can then be analyzed and used to create an ideal model that can be compared with real-time data [12].

The integration of this technology allows students to see firsthand how physical phenomena occur in the real world, how theoretical concepts are applied, and how to explore physics concepts through experiences that are more tangible, interactive, and relevant to everyday life. Students are not only able to understand concepts but also to experience them directly through more intuitive visualizations [16]. This has become something important in enhancing critical thinking skills, problem-solving, and digital literacy. However, in reality, research on bifocal modeling is still very limited. Existing research tends to emphasize the use of computer simulations and traditional hands-on tools in education. Current research often ignores the potential of modern technological developments. Example, research by Wang et al. [17] shows that the learning simulation-assisted learning can increase students' comprehension, but limitations in real-time experience and interactivity is obstacle that need to be solved. Research by Sunardi et al. [15] also highlights the same things, use of AR and VR in science education especially in physics learning is still limited.

Although many previous research has examined the use technology in the learning, it has not yet take up about integrated modern technology in the learning especially physics learning. The research concerning modern technologies in real-world applications such as IoT, AR, and VR is still not explored. Therefore, this gap indicates that an urgent need to develop physics practicum by integrating IoT, AR, and VR in bifocal modelling framework. This learning approach will influence to students enhance. They will have expected to gain a richer and deep learning experience. So, the integration of this technology is also expected to comprehension student's 21st-century skills, such digital literacy and critical thinking which are crucial in the era of the 5.0 Industrial Revolution [18].

The purpose of this research is to analyse existing gaps with developing and implementing bifocal modelling prototype based on AR, VR, and IoT. The product resulting from development is to expected to assist student for understanding abstract physical phenomena in a more interactive and intuitive way, as well as to help the teacher delivery material more effectively. The hope for future is that the research will be able to address the difficulties in comprehension physics concept, face, helping students develop 21st-century skills that are crucial in the future.

METHOD

The method used is Research and Development (R&D) [19]. The main objective is development a bifocal modelling as a learning approach in physics through a more experience of interactive and real-time data-driven learning. This prototype is developed to assist students in comprehension the concept vibration dan wave. The model used in this research is ADDIE (Analysis, Design, Development, Implementations, Evaluation).

The initial step is the analysis. The aim of this step is to identify learning problems. The action taken at this steps are interviews with physics teacher, distributing questionnaire to student to identify learning difficulties, and observing the learning proses in the classroom. In addition, Literature review was conducted to explore research that has been conducted by other researchers related to bifocal modelling, AR, VR, and IoT. So, a literature review was also conducted on teaching methods and techniques for the topic of vibration and wave. A technical needs assessment was carried out by identifying necessary hardware such as IoT sensors and AR/VR devices, evaluating the availability of technological infrastructure, and determining supporting software for real-time data visualization. Curriculum analysis was also performed to ensure alignment between the developed teaching materials and the competency goals outlined in the national independent curriculum.

The second step is the design phase. The design stage involved planning the components needed to develop the bifocal modeling tool. This began with listing the tools, materials, and mediaincluding both hardware and software required for creating an Android-based bifocal modeling application. The specific topic within physics chosen for the tool was vibrations and waves. A design was then created for the Android-based bifocal modeling tools, ensuring that the layout, functionality, and pedagogical aims supported the intended learning outcomes.

The third step is the development phase.The development stage is carried out by creating a bifocal modeling tool based on an android application for the topic of vibration. The steps taken are developing learning materials, multimedia, activities, and resources; creating prototypes of materials and evaluation tools; and testing materials to ensure quality. Designing a practical tool that includes hardware (ESP32, 1 set of simple harmonic motion practical, sensors, interfaces, monitor screens or smartphones) and software (Arduino). This tool allows students to conduct real experiments and connect them to digital simulations.

The fourth step is the implementation phase. Implementations; This stage is carried out by implementing bifocal modeling with vibration material in the actual environment; providing training to teachers on how to use materials and technology; observing student responses. The development results were tested on fifth semester physics education students at a university in Malang consisting of 28 students. Data collection and analysis conducted on the Bifocal Modeling lab tool involved a series of systematic tests to evaluate the effectiveness and efficiency of the tool in an educational context. Quantitative data were collected through measuring the tool's performance during a limited trial that included completion time and accuracy of experimental results. In addition, qualitative feedback from users was integrated through questionnaires and interviews to capture their experiences and perceptions. The analysis of descriptive statistics was applied to summarize the data of qualitative, while the analysis of thematic was used qualitative data to identify certain patterns. It would be a valuable input. The result of analysis would be provided in-depth insights about strengths and weaknesses, and recommendation bifocal modelling sustainability.

The last steps is phase of evaluation. At this steps, the researcher carried out formative assessment during the learning process to get feedback and to assessing the achievement of learning objective. The result of evaluation used to revise and improve learning methods in the future. The evaluation steps used to quality control mechanism ensure that product being developed is truly practical, effective, and valid before it is widely used.

RESULTS AND DISCUSSION

The Results Pre-Study

Three steps taken to identifying the problems in learning concept of vibrations and waves are direct observation in the classroom, surveying students, and interviewing physics teachers. This research involved interviews with three physics teachers from different school teaching 11th-grade classes. The interviews focused on the challenges educators face in delivering the material and the teaching strategies they employ. According to the teachers, student often struggle to grasp the abstract concept of vibration and wave, particularly harmonic motion, because these concepts are difficult to visualize and are not visible to naked eye. Additionally, most schools lack adequate experiments to effectively demonstrate these concepts. It is essential for helping students grasp concepts and internalize abstract concepts through concrete application. However, constrained instructional time severely restricts the implementation of practical sessions, and increasingly difficult to conduct hands-on sessions -activities proven to markedly strengthen conceptual mastery. Consequently, students' comprehension remains superficial and fail to develop depth.

This research employed methodology of quantitative survey with a sample of 120 grade 11 physics students who had studied the concepts on mechanical vibrations and wave phenomena. The research instrument was carried out by digitally through Google Forms. It was designed to:

1) identify difficulties of specific learning in vibrations and wave phenomena, and 2) evaluate conceptual understanding levels. The quantitative findings are visualized in Figure 1.

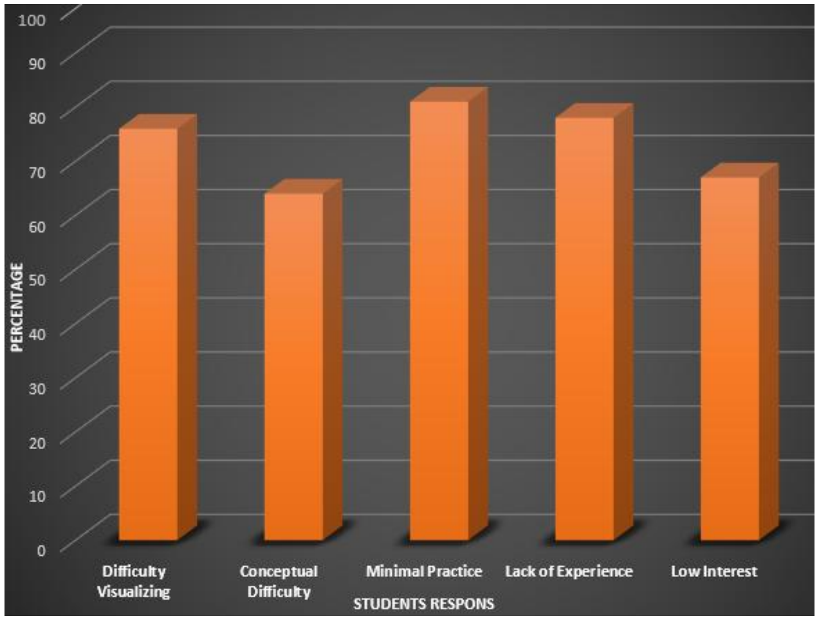


Figure 1. Survey Results on the Causes of Conceptual Difficulties

An observational research was conducted across three eleventh-grade classroom vibration and wave learning. It is aim to evaluate student responses to instructional methodologies, and identify learning barriers. The observations revealed several important findings. First, limited educational interaction dynamics were evident between learners and educators, with the instructional process dominated by monologic approaches and constrained opportunities for Questions and answers or interactive discussion. Second, about learning media, teachers only use whiteboards and static illustrations without using additional supplementary physical models. There are no digital simulations that can facilitate conceptual comprehensions. This has an impact on student engagement which is low. This is indicated by the majority of students showing passive. Student activities only focus on taking notes without showing cognitive involvement in the learning process. This is seen to be very clear when the teacher presents a conceptual example of simple harmonic motion. Students have difficulty understanding abstract principles due to the absence of direct demonstrations or practicums.

Literature Study

Bifocal Modeling is an approach to practical learning thata develops ideal simulation models based on data obtained from real phenomena models [12]. The models involves conducting experiments based real and simulated simultaneously. Research by Blikstein [20] shows that Bifocal Modeling can help students for understanding the difference between real phenomena and ideal model, enhancing their deep comprehension of physics concepts. This research emphasizes the importance of the interaction between data of ideal models and real-time data to enrich students' learning experiences [5],[11],[12].

A comprehensive analysis of AR technology integration indicates the success of this method in stimulating students' learning interest while providing cognitive scaffolding in constructing a deep learning of complex science concept. Wu et al. study [21] demonstrated AR's capability in representing 3D object, which is particularly relevant for conceptual understanding of physics such as wave dynamics. In parallel This technology also stimulates learning motivation through an immersive learning approach.

VR in science education has opened a new chapter in more lively and impactful physics learning. This research revealed how classrooms are transformed into immersive laboratories through the use of VR to simulate the physical phenomena. This sensory experience becomes a golden bridge connecting the abstract world of physics theory with students' concrete understanding [22]. On the other hand, digital revolution brings a breath of fresh air through IoT which changes physics practicums to be more dynamic. Sunardi [15] has been documented how intelligent sensor networks in harmonic motion experiments not only sharpen data accuracy but also train the younger generation in digital data literacy [5].

The literature study conducted includes an evaluation of various learning models to teach the concept of vibrations and waves. Research by Ouahi et al. showed that learning process involving practical activities is more effective in improving student understanding compared to the learning process with lecture method. In addition, learning methods that emphasize exploration and experimentation have been proven effective in helping students understand physical phenomena in depth [23].

Technical Needs Evaluation Results

The first stage is to identify the hardware. The steps taken are to select several devices to support the development of the bifocal modeling tool. The main component is IoT-based sensors. The selected sensor is TCRT5000 5. This sensor operates by emitting infrared light ($\lambda \approx 950$ nm), which is then reflected by the target object. The intensity of this reflection is detected by a phototransistor, producing either an analog or digital output. In physics experiments, this working principle is beneficial for detecting the presence, distance, or motion of objects without physical contact. In addition, this sensor is compatible with IoT platforms such as Arduino, ESP32, and NodeMCU. For example, in a simple harmonic motion experiment, this sensor can detect the position of a pendulum in real-time by calculating changes in the intensity of IR reflections from a metal surface attached to the pendulum. The integration of TCRT5000 with IoT technology opens up opportunities for more sophisticated experiments. In this study, the TCRT5000 sensor was combined with ESP32 to send spring oscillation data to the cloud in real-time. This approach not only improves accuracy compared to manual methods using a stopwatch, but also enables advanced data analysis such as automatic calculation of kinetic and potential energy. The successful implementation of this tool is determined by an internet connection that requires a minimum internet speed of 10 Mbps. On the other hand, a Local Area Network (LAN) setup is required to facilitate easy connection between IoT devices and AR or VR hardware to ensure good interaction and smooth data flow. In term of device compatibility, the system demands a computer with sufficient specifications, including at least an Intel i5 processor, 8 GB of RAM, and a graphics card capable of supporting VR applications. This ensures that system can process data effectively and run AR or VR applications in real time. Representative classroom is needed for VR practice activities and AR demonstrations. This allows students to fully engage with the technology in an optimal learning environment. This condition facilitates with technological devices through an ideally designed learning setting.

Certain software is essential for effective data visualization and making learning more interactive and engaging. Platform such as Unity or Unreal Engine are developed to create immersive AR or VR applications that offer deep learning experiences. Software such as Turbo C+, MATLAB or Python are used to visualize data obtained from IoT sensor in real-time. The result obtained provide a clear and detailed representation of the measurement data. For mobile AR content, the Vuforia and AR.js frameworks enable more lively learning interactions through mobile devices, and enhance the learning experience of students with augmented visuals. Equally important is the integration with Learning Management System (LMS) such as Moodle or Google Classroom, so that the bifocal modelling prototype can function in harmony with the existing platform. This model allows for efficient distribution of educational materials. Teachers or educators are able to collect and track student learning outcomes smoothly, making it easier for teachers to monitor students progress and engagement.

Curriculum Analysis

Implementation of curriculum emphasizes development of more flexible and contextual student competencies. The Digital Pedagogy Platform emphasizes to use of digital tools for collaboration and presentation. Technology is not just a tool, but an integral part of strengthening 21st century skills. Students are expected to be able to analyze technology-based data and solve problems through digital simulations. Innovative projects is carried out in order to understand physics concept. Basic Competency (BC): For the material on vibrations and waves, the relevant BC includes understanding fundamental concepts, applying formulas, and analyzing physical phenomena in everyday life.

The teaching materials developed in the bifocal modeling prototype are designed to align closely with the competencies outlined in the Merdeka Curriculum. One key aspect is the use of technology, where the integration of Augmented Reality (AR) and the Internet of Things (IoT) provides students with a real-world context for understanding the concepts of vibrations and waves, thus supporting the curriculum's objective of enhancing students' digital literacy. Additionally, the prototype employs a contextual approach that enables students to observe and interact with physical phenomena in their environment, fostering a deeper understanding of how physics applies to everyday life. This hands-on approach supports the curriculum's goal of applying knowledge to real-world scenarios. Furthermore, the teaching materials are designed to cultivate essential 21st-century skills, such as critical thinking, problem-solving, creativity, collaboration, and communication, which are integral to the Independent Curriculum and prepare students for the challenges of the future.

Discussion

The teacher feels that physics learning on the topic of vibrations and waves requires innovation that can help students understand the concepts more concretely and practically. They suggest the use of visual aids and technology that can enhance students' understanding through simulations or real-time data [24],[25]. From the results of this survey, it can be concluded that the majority of students find the concepts of vibration and waves difficult to understand without concrete aids. They also feel that practical-based learning methods can help them better understand the material and increase their interest in physics. Observation results show that physics learning process has not involved students directly and is still theoretical without any inquiry process on the concept of vibration and waves. This is due to the limited tools and materials for the practicum. The dominance of teacher-centered approach places teacher as a source of learning [26],[27],[28].

Analysis of the three diagnostic approaches in identifying learning problems revealed that students face significant obstacles in understanding vibration and wave material [21]. Some of the main causal factors include limited teaching aids, low utilization of technology, and dominance of theoretical teaching approaches and the use of teacher-dependent learning approaches. Amid these challenges, developing 21st-century skills in students is must to prepare them for era of the 5.0 industrial revolution. Competencies that need to be strengthened include critical thinking skills, problem solving, creativity, communication, collaboration, and digital literacy [29], [30], [31]. Therefore, the development of innovative learning media—such as Augmented Reality (AR) and the Internet of Things (IoT)—that are able to visualize physics concepts interactively, realistically and in real-time is an urgent need in science education.

Based on these needs, a prototype of a practical device that integrates AR, VR, and IoT technologies with simple harmonic motion experiments has been designed. As stated in the research of Sunardi et al. [15], the development of a holistic learning approach that combines the three technologies is considered important to create a more interactive and meaningful learning experience for students. That results show that the combination of harmonic motion practicums with AR, VR, and IoT technologies shows promising prospects in improving students' conceptual understanding of abstract physics phenomena. However, further studies are needed to examine the implementation and real impact of this approach in various educational settings [2], [32], [33]. The initial stage of developing this prototype can be seen in Figure 2.

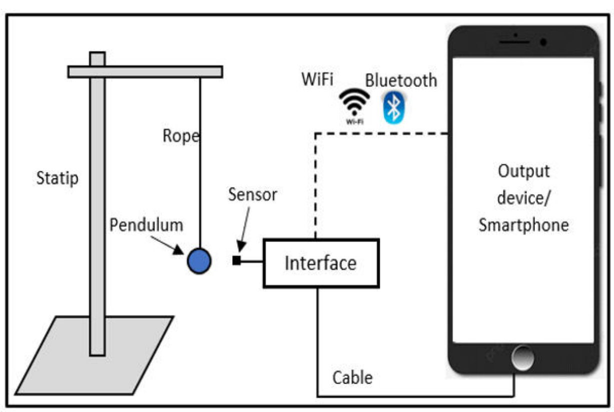
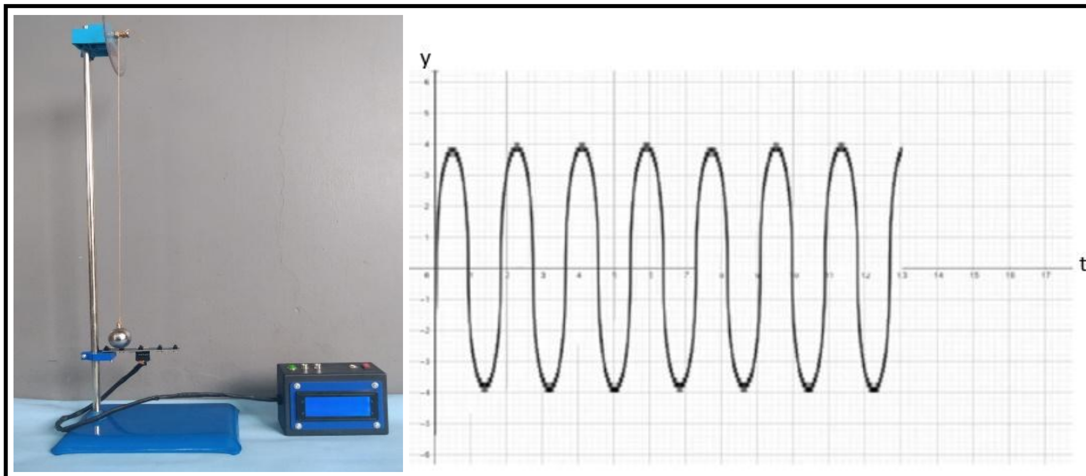


Figure 2. Prototype Design of the Simple Harmonic Vibration Practicums

The subsequent phase involves implementing the prototype into a functional device suitable for classroom application. The initial stage is to conduct preliminary testing to ensure that all hardware and software are functioning properly and integrated [14],[34],[35],[36]. This approach involves students in investigating physical phenomena through alignment between physical experiments and digital models. The benefits obtained using this approach are that students can make direct observations of two physical phenomena, and they are given the opportunity to connect observations with computer simulations. The implementation of this approach is flexible and can be adjusted to the learning objectives. Therefore, various implementation models need to be developed, where students are involved in designing and carrying out physical experiments in different ways. Bifocal modeling development has been used in various physical phenomena to improve students' understanding and skills in science.

Based on the description and design of the prototype in Figure 2 above, a bifocal modeling aids based on the Android application were developed for a simple harmonious pendulum swing trial. The main component is that there is a set of physical experimental devices that include pendulum swing practicum kit, which includes stative, metal balls (as penders), ropes, and degrees. In addition, this system is equipped with sensor -based interface devices, which include various components such as nodemcu boards, ESP8266, ESP32 Dev Kit V1, TCRT5000 sensor module with five channels, and 9V - 2A DC adapter. This device is designed to connect experimental devices with digital devices. The output of this experiment can be displayed through a digital output device, which is an Android smartphone. With a combination of this component, bifocal modeling aids allow students to conduct experiments in an interactive and effective way. Based on the design in Figure 2, the following prototype of the following tools was successfully developed.



(a) (b)

Figure 3. (a). Prototype of bifocal modeling tools of the Simple Harmonic Vibration Practicum; (b). The graphics plot produced by the Bifocal Modeling Tools of OHS

Figure 3 (a) shows a set of practical tools equipped with this Bifocal Modeling Tools. It's aid based on the Android application for simple harmonious pendulum swings are designed to explore the relationship between deviations and time on the swing. The use of this tool allows various difficulties that arise when studying the theoretical physical phenomena associated with the graph of the function $y = f(t)$ can be resolved effectively. This allows students to directly observe the swinging pendulum movement. Bifocal modeling tools can take advantage of the assumption that the pendulum swings harmoniously during a certain period with a maximum deviation angle of 15°. Various physical quantities, such as periods, frequencies, and deviation of pendulum angles, can be measured and displayed in real-time on the output device. The right combination of tools and technology is able to support a better understanding of physical concepts involved in simple harmonious pendulum swings.

Graph $y = f(t)$ as Figure 3 (b) can be displayed in real-time and follow changes in input parameters in the form of deviations. Changes in the angle of this deviation will be reflected in the amplitude of the graph $y = f(t)$, which adapts according to the variation of the angle. This allows students to see firsthand how changes in the intersection affect the graphical shape. The relationship between deviations (y) and time (t) is displayed as a sinus function, not cosine. This is done by setting the sensor reading time to record data when the pendulum is at the point of balance, just after being released from the maximum deviation position. Therefore, at t = 0 (initial time), the pendulum deviation is at the minimum value, which is y = 0. Graphic amplitude $y = f(t)$ will remain constant throughout the pendulum swing, based on the assumption that the pendulum movement is simple. Bifocal modeling aids can provide a clearer understanding of the dynamics of pendulum swing and functional characteristics.

Validation of the Bifocal Modeling Physics Practicum Tools is carried out at an expert judgment consisting of 2 lecturers and 1 high school level teacher. The results of the validation or expert judgment of the Physics Practicum Tools are known that all validators provide "appropriate" responses for each component of Bifocal Modeling Physics Practicum Assessment. All validators also provide assessment recommendations with the category "practicum tools can be used in physics learning". The next step is a trial conducted in a limited basis. Limited trials were conducted to 28 students at one of the State Campuses in Malang City. This trial is focused on making improvements to Bifocal Modeling Physics Practicum Tools for the implementation of Inquiry Laboratory Physics for simple harmonious pendulum swing material. The analysis of the N-gain results indicates an improvement in N-gain at the concept understanding level. The average N-gain for concept understanding in the context of simple harmonic pendulum learning is 0.7150, which falls into the high category. Furthermore, the learning of harmonic motion using Bifocal Modeling Physics Practicum has a significant impact.

This is evidenced by the effect size testing of the bifocal modeling physics practicum on the enhancement of students' conceptual understanding of simple harmonic pendulum material. Using Cohen's formula, a Cohen's d value of 3.77 was obtained. This result signifies that physics learning employing the bifocal modeling practicum method has a strong influence on improving conceptual understanding of simple harmonic pendulum material. The effectiveness of learning that utilizes the bifocal modeling practicum method shows that 61.11% of students achieved a high N-gain (0.70) in their conceptual understanding. This outcome is categorized as medium. This shows that students have understood the harmonic vibration sub-material through the discovery process they have done. Analysis of the qualitative data found shows that students' awareness emerged when they carried out practical activities with bifocal modeling and paid more attention to the limitations of the model. When comparing manual practicums with bifocal modeling practicums, students were able to use bifocal modeling experiments as instruments to improve the inquiry process through physical and virtual models. This shows that experimental activities can foster conceptual understanding and problem solving in science education (Physics). We expect that it is necessary to combine real and virtual experiments especially their specific functions for physics learning tasks of various types of experiments. Other studies also confirm that the combination of real (direct) and virtual (computer simulation) experiments has proven to be very helpful in gaining conceptual understanding [37],[38].

The results showed several findings of limited trials of Bifocal Modeling Physics Practicum. Constraints on the use of the bifocal modelling application, including the slow running application on a smartphone with an Android system under Android 12. Bifocal Modeling Practical Tools cannot be run perfectly when the internet network used is weak, and Bifocal Modeling Practicum Tools for simple harmonious pendulum swings have not yet been shows a different graph of $y=f\ (t)$ for different amplitude values. Bifocal modeling physics learning is different from methods that only use computer simulations, such as PHET [38]. In this learning, students not only interact with computer models, but are also involved in real physical experiments. This allows them to improve scientific models based on direct observation, thus developing a deeper understanding of physical phenomena [12],[39]. Students can find physical data from direct observation and visualization of phenomena in real-time with help of sensor devices connected to the output device. To ensure the effective implementation of physics laboratorium utilizing bifocal modeling approaches, two critical requirements must be addressed. First, comprehensive training programs must be established to equip both educators and learners with the necessary competencies in employing AR or VR technologies and IoT sensors for physics experiments. Second, a monitoring and evaluation framework should be developed to systematically assess the pedagogical impact of these technologies. A successful bifocal modeling prototype depends on hardware configurations, technological infrastructure, and compatible software. These resources are anticipated to facilitate delivering deep learning, interactive, and conceptually profound learning experiences.

CONCLUSION

Prototype bifocal modelling tools are innovative solution to equip students with 21st-century skills and become challenge in physics education, especially in understanding physics concepts. Bifocal modelling tools are integration of Internet of Things (IoT), Augmented Reality (AR), and Virtual Reality (VR). Development of bifocal modelling for simple harmonic motion materials prepare an alternative solution to problems of physics learning. Prototype was successfully realized through a combination of Internet of Things, Augmented Reality, and Virtual Reality. This study discovery that method not only enhance level of comprehension of students but also improve their educational experience manner real-time visualization and increased interactivity level. Adoption of technology will encourage the mastery of competencies of 21st century that crucial and important in responding to challenges of contemporary workforce. Impacts that need to be anticipated are improving students' physics cognition as well as preparing a competent generation responding the industrial revolution 5.0. Therefore, it is recommended that the results of the study be followed up immediately by implementing bifocal modeling practicums on students at the high school level. Besides that, other developments were carried out using bifocal modeling methods and approaches to other physics concepts.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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