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Development of Supplementary Basic Physics Practicum Based on Problem-Solving Method Assisted with Augmented Reality (AR) Technology

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Abstract

Physics practicum is an important activity in basic physics courses that involve contextual physics concepts, such as cases in coastal areas which can demand students' problem-solving skills. Covid-19 has caused basic physics practicum activities to become difficult to carry out in a laboratory scale, thus alternative solution is necessary to perform practical activities in the Covid-19 situation, namely by utilizing Augmented Reality (AR) technology. AR can help visualize physics concepts and practicum activity procedures relevant to practicum activities. This study aimed to develop an AR-assisted practicum guidebook product oriented toward a problem-solving method by presenting several cases of natural potential in local coastal areas. This study used an R&D method with a 4D model. However, this study was limited to the development stage. Data were collected with validation sheets and student response questionnaire sheets. These data were then analyzed with descriptive qualitative data analysis technique. Based on the data analysis results, many students had difficulties in carrying out physics practicum activities during the Covid-19 pandemic. This occurred due to the unaccessible practicum video procedures in the guidebook during the offline condition. Furthermore, the practicum procedure guidebook was only in narrative text, unable to stimulate high-level thinking skills by presenting coastal area cases. Students must be introduced deeper to the potential of coastal areas and their relation to physics concepts.

Keywords: supplementary practicum, problem-solving, augmented reality, coastal area

INTRODUCTION

Basic Physics practicum is an important part of Basic Physics 1 and 2 courses. Practicum is a learning way for proving the theory (Darmaji, Dwi Agus Kurniawan, Astalini 2019). When carrying out practicum activities, students can observe, predict, interpret data, use tools and materials, plan practicums, and communicate the data acquisition (Suryaningsih 2017). Basic Physics Practicum always uses a practicum guidebook, which can be used as a learning resource (Darmaji, Dwi Agus Kurniawan, Astalini 2019).

According to Arifah (2014), the practicum guidebook is an important part of successful practicum activities, thus laboratory practices will not run properly without it (Sudarman & Saparuddin 2018). The practicum guidebook is intended to expedite and provide information for assistance or learning materials to guide students in practicum activities (Arifah et al. 2014). During the Covid-19 pandemic, direct practicum activities are difficult to carry out due to health protocol implementation difficulties for a laboratory-scaled practicum. Also, the "dry laboratory" as a practicum place cannot fully facilitate all relevant practicum subjects.

Based on the preliminary study survey involving seven universities in Indonesia, students have difficulties in joining the practicum procedures as a narrative text in guidebooks. Augmented reality technology is considered to assist practicum procedures (Johan et al. 2021). The limitations of lecturers and practicum assistants in managing practicum classes with a relatively large number of students also contribute to these difficulties. The unavailability of supplementary tools that can help gain hands-on practicum experience is one of the problems that cause difficulties for students in conducting a practicum.

The essence of physics is not only a collection of facts and principles but also ways to obtain physicists' facts, principles, and attitudes (Koes 2003). Presenting contextual examples of physics concepts closed to the life of coastal areas is expected to ease the students understanding of the meaning of physics concepts relevant to basic physics practicum activities. Various phenomena in coastal areas can be explained using physics concepts as a source of physics problems in practicum activities. The problem-solving skill is one of the higher-thinking skills required in the industrial era 4.0. The practicum activities are still based on verification without high-level thinking involvement, such as problem-solving and critical thinking.

In the industrial era 4.0, technology plays an essential role in various lifelines, including the education aspect (Matsun et al. 2018). The development of the industrial revolution 4.0 emerged with the digitization of the education system in every education element to adjust to current changes (Zidniyati 2018). One of the technologies that can be used to support and facilitate students to receive more experience in practicum activities is augmented reality (AR) technology. Augmented reality (AR) in education has become an innovative and promising field in many studies and practices due to its emphasis on imposing virtual information in real environments by creating a different context from traditional learning and providing completely new ideas about learning (Chang et al. 2022). Augmented Reality is a rapidly growing field that aims to fully integrate virtually with the real environment (Pai et al. 2016). In line with this opinion, Wang (2017) explained that Augmented reality (AR) is a technology that visually added the real-world environment by projecting computer-generated information. The positive effects of learning with augmented reality (AR) systems in various learning contexts have been the focus of recent studies (Thees et al. 2020). The use of augmented reality technology as learning media is quite effective (Marcel 2023).

This technology can bridge students to take part in all practicum subjects through real visual practicum activities, that are displayed through augmented reality technology, and inserted as supplementary media in the practicum guidebook. Visualization of AR-assisted practicum activities can help students understand practicum procedures, besides reading the procedures. The AR technology facilitates students not to depend on assistants or supporting lecturers to reduce interactions and decrease the Covid-19 virus distribution. Augmented reality can be accessed via mobile phones without an internet connection.

Based on the description above, the strict physical distancing requirements greatly affect the laboratory-scaled practicum activities. Interaction between practicum instructors and practicians must be limited, which requires innovations in the practicum work guidebooks

METHODS

Locations

This study was conducted at Bengkulu University. This study involved physics students in a basic physics course.

Design and Procedures

The method used in this study was the Research and Development (R & D) method. This study had three stages: defining, designing, developing, and disseminating. These steps are described in FIGURE 1.

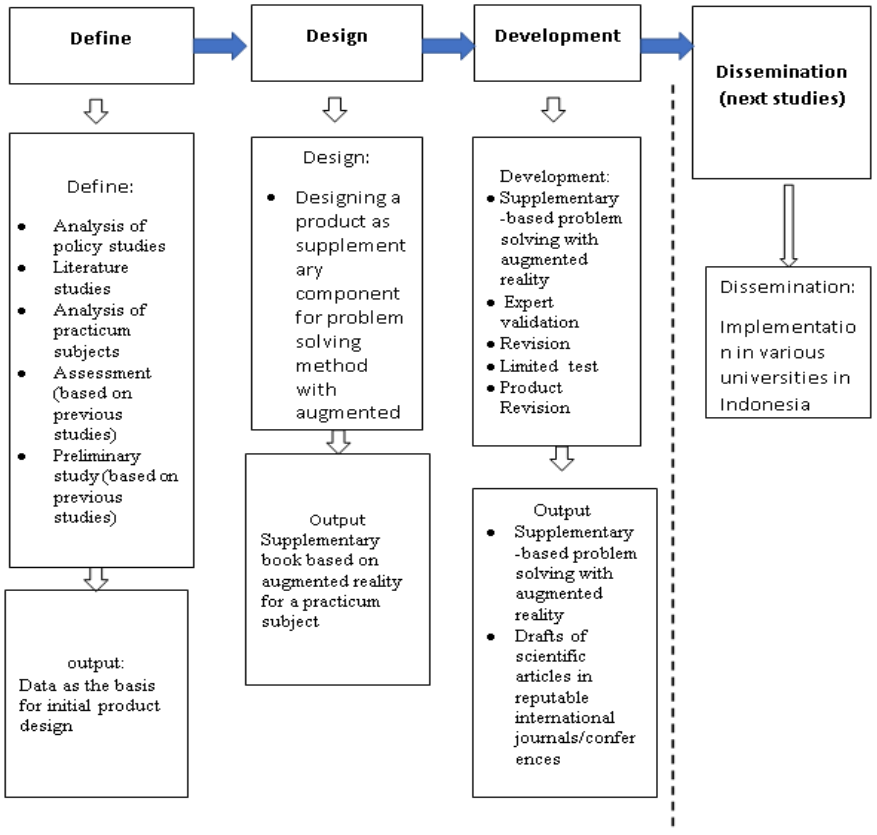


FIGURE 1. Study Flow

At the define stage, several activities have been carried out, such as policy analysis, need assessment, and preliminary study. In this study, the physics concept analysis in practicum, the concept related to media visualization, and the use of augmented reality as a learning medium, specifically practicum activities. Potential phenomenon analysis in coastal areas and tropical rain forests can be used as problem-solving cases in several basic physics practicum activities. At this stage, a literature study was also carried out to obtain a theoretical basis for developing the product.

At the design stage, the product design and study instruments were developed. Moreover, the initial product design was created. Videotaping procedures and practicum procedure videos, available from various other sources, created augmented reality. In addition, various visualizations related to natural phenomena in coastal areas were added according to physics concepts and practicum.

At the development stage, the product was validated by involving experts from three universities in Indonesia, namely Jember State University, Indonesian Educational University, and Tanjungpura University. Revisions were designed based on the input of experts. Only limited trials were carried out based on the time and technical limitations in field trials during a pandemic. Then, the student responses were collected regarding the use of the product being developed, thus dissemination stage can be carried out in a further study.

Instruments

Instruments developed in this study included validation and student questionnaire sheets.

Technical Data Analysis

Data were analyzed based on the qualitative approach. Technical analysis validation was performed to measure the feasibility and student response with a Likert scale questionnaire to convert the questionnaire as qualitative data. Through this scale, the variables were converted into variable indicators. Then, these indicators were used as a starting point for compiling items as questions or statements (Sugiyono 2016). The Likert scale interpretation scores can be seen in TABLE 1.

TABLE 1. Likert Scale Interpretation (Sugiyono 2016)

Interpretation	Score
Very Good	4
Good	3
Bad	2
Very Bad	1

This scale was applied to measure the validation level of the physics practicum model using Augmented Reality technology, categorized as good or bad. Validation values were determined using the following formula:

$$\text{Validation (V)} = (\text{score} / \text{total maximum score}) \times 100\ \% \quad (1)$$

The validity results were matched with the criteria, as seen in TABLE 2. The product was categorized as good if meeting the criteria with a percentage of ≥ 51%.

TABLE 2. Validity Criteria (Hayati, Budi & Handoko 2015)

Percentage	Interpretation
0% - 25 %	Very Not Good
26 % - 50 %	Not Good
51% - 75 %	Good
76% - 100 %	Very Good

RESULTS AND DISCUSSION

The needs analysis questionnaire

Data for needs analysis were collected using questionnaires and open-ended questions, involving seven universities in Indonesia with 91 respondents. These universities are Bengkulu University, Indonesia Open University, UPI, Jember University, Tanjungpura University, Sriwijaya University, and STKIP Bima. In addition, the needs analysis involved the Physics Education Study Program in Bengkulu University from the class of 2020 and 2021 with a total of 57 students as respondents.

Based on the questionnaire analysis from 57 respondents at Bengkulu University, practicum was carried out during the pandemic with activity procedures using simple experiments independently at their homes, as stated by the 57.1% of respondents. Furthermore, 85.7% of respondents stated that the practicum activities during the pandemic were not conducted in the laboratory. FIGURE 2 shows that 60% of respondents found difficulties to carry out practicum activities during the pandemic period. This condition needs further innovation in practicum activities during a pandemic, including guidebooks.

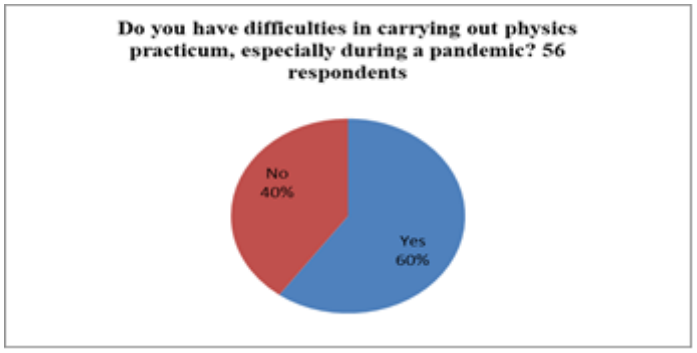


FIGURE 2. Responses related to difficulties in carrying out practicum

In carrying out practicum activities, the practitioner used the guidebook. According to the following questionnaire data, practitioners found difficulties in understanding the guidebook procedures.

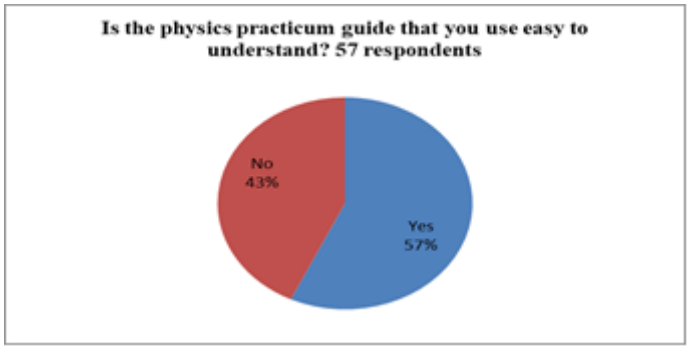


FIGURE 3. Responses related to difficulties in understanding the guidebook

Based on FIGURE 3, 43% of the total respondents still found difficulties in understanding the available practicum guidebook. A guidebook helps the implementation of practicums that provides information to support the learning process and instructions regarding procedures for preparing, implementing, and reporting practicums (Novita 2020). According to Rustaman (2003), practicum instructions are tools needed to facilitate learning activities in the laboratory to achieve learning objectives and reduce the risk of accidents caused by a lack of image representation of practicum activities. Procedures for practicum activities are only presented as narratives without pictures or videos. Students perceived that the practicum guidebook should be equipped with minimum visualization and practicum procedure video. Hayati (2015) supported that, the use of multimedia, information/teaching materials through text can be memorized properly if accompanied by pictures and videos. Also, Johan et al. (2018) stated that animated videos can help understand scientific concepts that remain unable to observe directly. Video animations can be loaded in augmented reality. Augmented reality can help create teaching materials visually from concepts, unobserved directly. Augmented reality (AR) continues to show its impact on education. Recent studies mentioned the positive learning impacts of augmented reality (AR) systems in various learning scenarios (Thees et al. 2020). The following student responses can be seen in FIGURE 4.

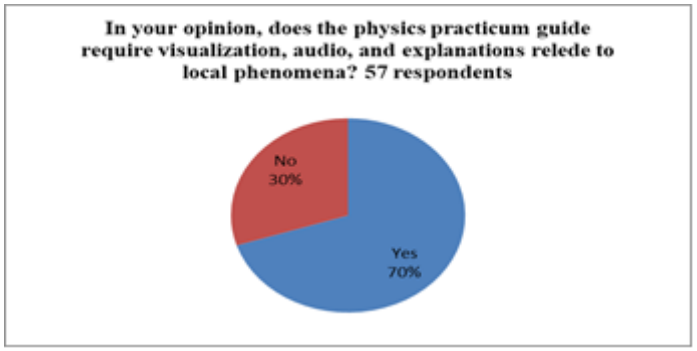


FIGURE 4. Responses regarding the need for visualization and exploration of local phenomena in coastal areas implemented through practicum activities

Based on FIGURE 4, 70% of the total respondents agree that the physics practicum guide requires visualization, audio, and explanations related to local phenomena. The other responses can be seen in FIGURE 5.

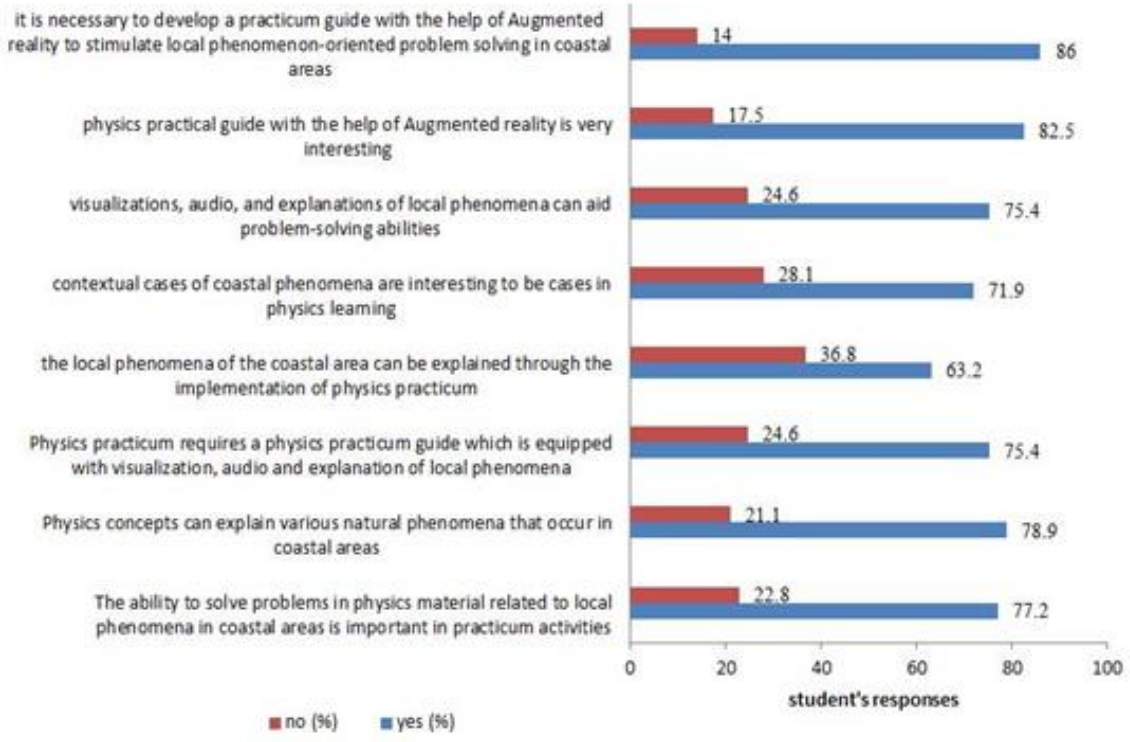
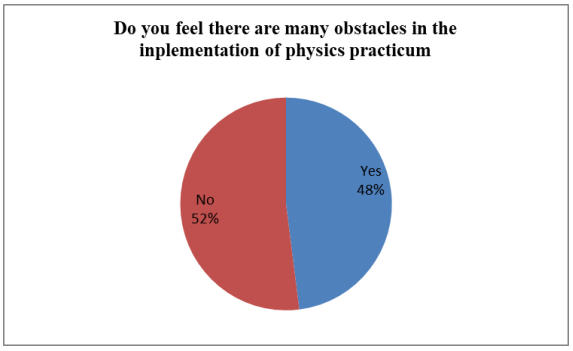


FIGURE 5. The Questionnaire responds for the needs of physics education study program practitioners at Bengkulu University.

Based on the results in FIGURE 5, 78.9% of respondents agreed that the concept of physics is related to various phenomena in coastal areas. The 63% of respondents also stated that physics practicum activities should explain various phenomena that occur in coastal areas. According to Arifin et al. (2022), the utilization of the coastal area potential is highly important to stimulate the formation of the student character through phenomena that exist in the coastal environment. The phenomenon in coastal areas is an interesting context as a case in physics learning, including basic physics practicum activities. This is following Koes (2003) that physics is not only just collecting facts and principles, but also obtaining facts and principles with certain attitudes. This is presented from the 71.9% of respondents who agreed on this matter. Difficulties in understanding guidebooks in narratives can be

bridged by the existence of innovative practicum guides, assisted by visualization such as practicum procedure videos packaged in Augmented Reality technology, that can be accessed without internet connection. This condition is presented from the 86% of respondents who agreed for practicum guides assisted by augmented reality and coastal phenomena utilization as a case for more interesting practicum activities with high-level thinking skills. Sudarman & Saparuddin (2018) supported that video tutorials should accompany practicum to attract the students' attention, be easy to remember, and train high thinking skills. Augmented reality can enrich teaching materials through various videos and real conditions related to physics concepts, thus helping facilitate the concept understanding (Pujianto 2019). In accordance, (Windyariani 2020) mentioned that the use of AR technology can effectively improve the students' higher-order thinking skills (HOTS), either in the ability to analyze, evaluate, or create.

The need analysis results involving classes of 2020 and 2021 in the physics education study program are relevant to the results of needs analysis involving 91 students/practitioners from various campuses in Indonesia. Based on FIGURE 6, some students still have difficulties participating in the practicum activities, especially during the Covid pandemic.



If the answer of point 16 is yes, then write down what obstacles you face!

Answer:

Distance to the practicum site, internet network, and environmentalinfluence of covid 19

FIGURE 6. Responses related to obstacles in practicum activities during the pandemic

Based on the results in FIGURE 5, 78.9% of respondents agreed about the concept of physics that should be related to various phenomena in coastal areas. The 63% of respondents also stated that physics practicum activities should explain various phenomena that occur in coastal areas. According to Arifin et al. (2022), the utilization of coastal area potential is significant for further learning material that can stimulate the formation of the students' character through phenomena that exist in the coastal environment. Phenomenon in coastal areas is an interesting context to be used as a case in physics learning, including basic physics practicum activities. This was followed by Koes (2003) that the nature of physics, namely physics, is not only just a collection of facts and principles, but also obtaining these facts, principles, and attitude of physicists. This theory was proved as 71.9% of respondents agreed on this matter. Difficulties in understanding guidebooks as narratives can be bridged by the existence of innovative practicum guides, assisted by visualization as practicum procedure video packaged in Augmented Reality technology that can be accessed without internet connection. This condition is presented from the 86% of respondents who agreed for practicum guides assisted by augmented reality and coastal phenomena utilization as a case for more interesting practicum activities with high-level thinking skills. Saparuddin (2018) supported that video tutorials should accompany practicum to attract the students' attention, be easy to remember, and train high thinking skills.

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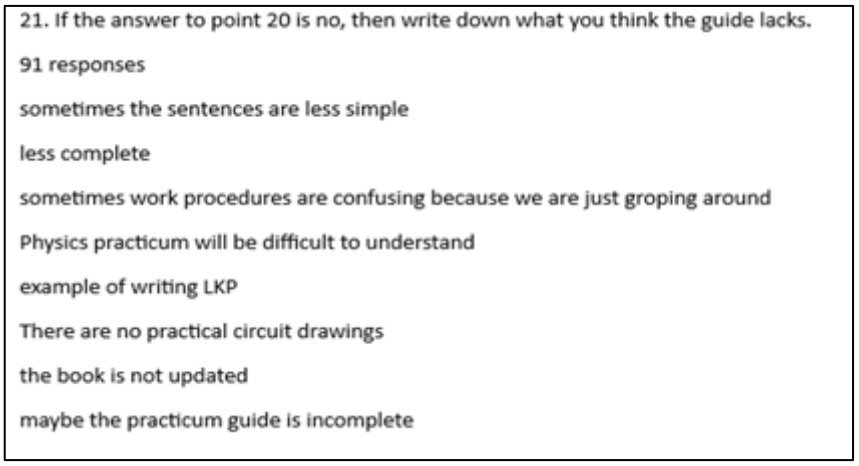

FIGURE 7. Responses to an open-ended questions in questionnaire

Based on FIGURE 7, the constraints and difficulties of the practitioner in following the practicum procedures are also caused by the practicum guidebook in narratives, whereas the sentences in the text are also difficult to understand. There are no actual figures or videos of practical activities that can help practitioners carry out the practicum procedures. According to Qurrotaini et al. (2020), videos in the learning process aim to help communicate the messages conveyed and provide a more efficient understanding for students, thus attracting their attention and fostering the learning motivation and curiosity. In addition, the use of images will be more effective, if the images are adjusted to the child's level, in terms of details, colors, and backgrounds that are necessary for interpretation, so it will be very appropriate and effective in helping students to understand more quickly on a concept in the learning process (Amir 2016). The guidebooks are also rarely updated, let alone using technological assistance in accordance with the industrial era 4.0. In the needs analysis, a guidebook equipped with augmented reality technology is shown in FIGURE 8. The use of Augmented Reality media in teaching materials can stimulate the mindset of students to think critically about problems and events that exist in everyday life and visualize the abstract concepts (Ilmawan 2016).

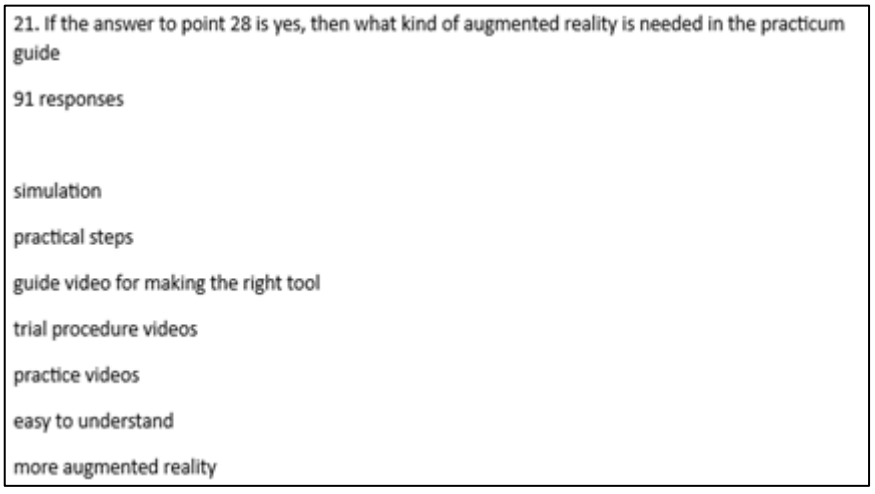

FIGURE 8. The need for AR to visualize practicum procedures based on guidebooks

Based on FIGURE 8, 78% of respondents agreed that augmented reality is needed in the practicum guidebook to help visualize practicum procedures. Based on the open-ended questionnaire, practicum requires the Augmented reality which can visualize experimental procedures, that makes practitioners easier to carry out each practicum test. According to respondents, the practicum guidebook with augmented reality as practicum procedure videos helped them carry out the stages of physics practicum easier. This is in accordance with Anggraini (2019), that learning through visualization is very

important to clarify aspects of understanding, increase interest, and involve the students more in the surrounding environment, as proven by 100% of agreed respondents.

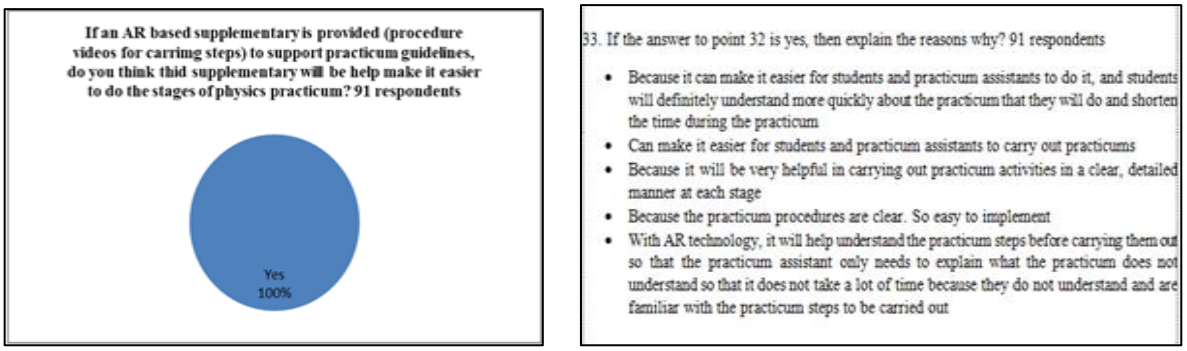

FIGURE 9. AR can help facilitate practitioners and assistants in carrying out the practicum activities

Analysis of Practicum Guides Available at Bengkulu University

Practicum activities in basic physics courses are facilitated by practicum guidebooks for practitioners and instructors in carrying out the practicum activities. Available guidebooks are relevant for practicum activities, but not for during the pandemic period, which requires physical distancing and independent working. The available practicum guidebook is equipped with a material summary, procedures as narratives, and analytical questions. In general, the design of the practicum guidebook can be seen in FIGURE 4.1.

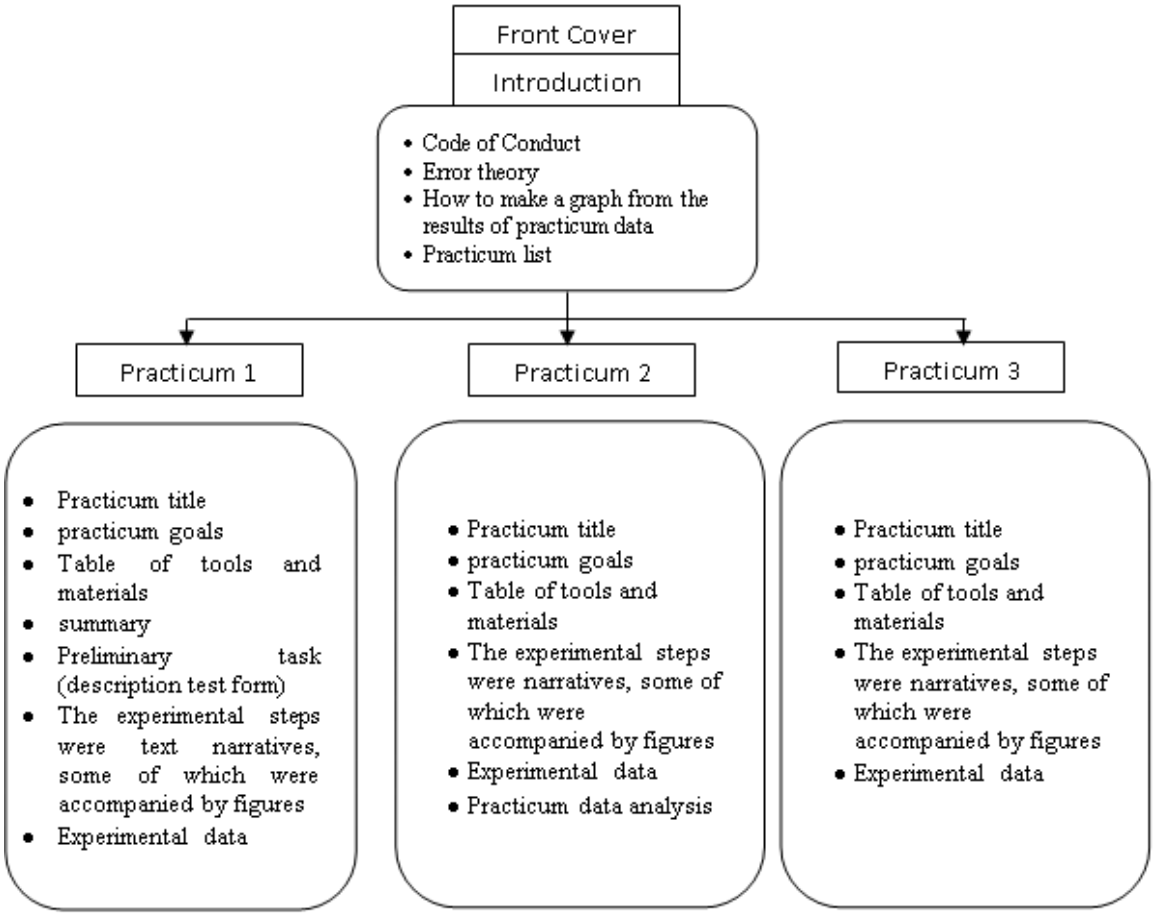

FIGURE 10. The practicum guidebook design used by practitioners

Based on FIGURE 10, the guidebook used by the practitioners is still only as a text book. Only a few are equipped with figures, but remain impractical in nature. The guidebook also does not include all practicum subjects with data analysis. There are no stimulations for problem-solving capability by presenting cases in accordance with the practicum topic. The guidebook only focuses on presenting the procedures for practicum activities as narratives. This causes difficulties in doing practicum and dependence on assistant guidance. However, the interaction between practitioners and assistants are extremely limited during the pandemic. In addition to the guidebook in FIGURE 4.11, guidebook can be supplied in dual mode.

Dual mode manual for face-to-face and virtual practicum do not cover all practicum subjects. There are only four available experimental subjects (2 basic physics experiments 1 and 2 basic physics experiments 2) of 16 basic physics 1 and 2 experiments with dual mode, namely face-to-face practicum and virtual practicum. The general design of the dual mode practicum guide can be seen in the following figure:

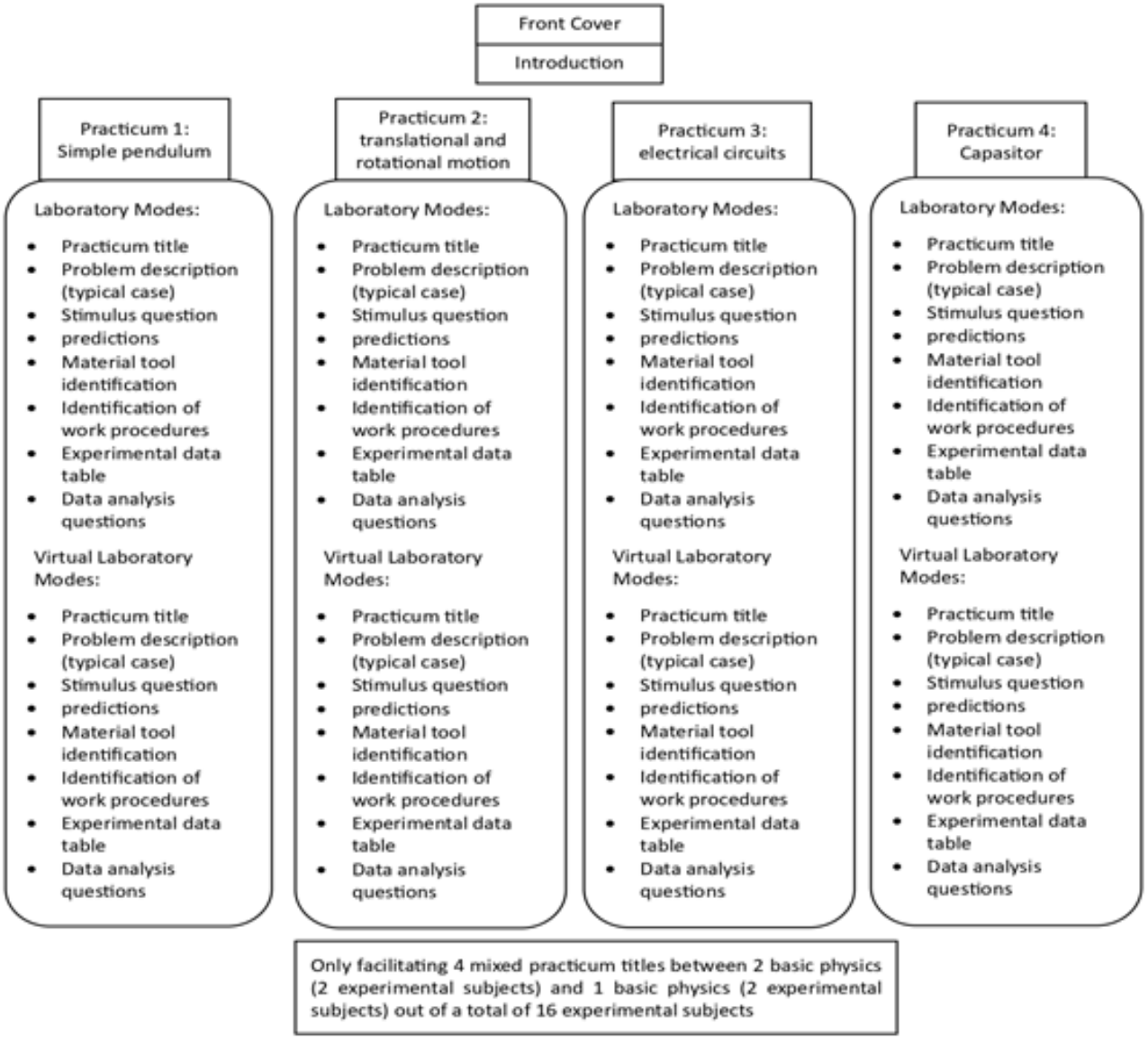

FIGURE 11. dual mode practicum guide design

Based on FIGURE 11, the practicum guide with dual mode cannot facilitate all practicum subjects. The guide only covers 25% of the total basic physics 1 and 2 practicum subjects. This indicates that the practicum guidebook cannot be used as the only practicum guidebook for basic physics 1 and basic physics 2 due to incomplete practicum subjects that must be followed by all practitioners. Practicum activities during the pandemic also could not be facilitated optimally by using a dual mode physics practicum guidebook. This condition was occurred from the steps provided in the guidebook. The procedure needs to be designed by the practitioners themselves. This can indeed facilitate the high thinking, but time-consuming. This is less relevant for conditions during the covid pandemic because the opportunities for physical interaction will be longer and more numerous. Physical interaction during practicum should be minimized. In dual mode with a virtual lab, the practicum procedure uses *PheT*. Based on the analysis results of virtual practicum activities using the *PheT* application, this application does not facilitate all practicum activities in basic physics practicum 1 and basic physics 2. During this pandemic period, practitioners should receive all practicum experiences for all experimental subjects. Based on the analysis results of two available practicum guidebooks, the existing practicum guidelines are unable to facilitate practicum activities during pandemic optimally. Practicum activities during pandemic must comply with all the provisions the covid cluster team sets.

Thus, it is necessary to develop a practicum guidebook to facilitate practicum activities during the pandemic. Highly-thinking capability is needed in the 4.0 era, which needs to be stimulated through learning and practical activities. One of the higher thinking skills that can be trained through practicum activities is problem-solving capability. According to Fitriyah et al. (2018), the students' problem-solving abilities can be increased by conducting a practicum and using the practicum tools. Bengkulu is located on the western coast of Sumatra as a coastal area with lots of local potential and unique coastal natural phenomena. Natural phenomena as local coastal area potentials are extremely relevant problem cases for Bengkulu University students. The presentation of problem cases that focuses on the potential of coastal areas can provide broader insights for Bengkulu students about the natural wealth of coastal areas.

Based on the questionnaire analysis results, it is necessary to develop a physics practicum guidebook that can facilitate safe practicum activities during the covid-19 pandemic period. In addition, practicum guidebooks can be developed with an orientation towards ability stimulation to solve problems and raise the local potential of coastal areas as cases. FIGURE 4.13 is an alternative solution for the general design of relevant practicum guidebook during the Covid-19 pandemic. An example of a practicum guide for experimental linear measurements can be seen in FIGURE 4.12.

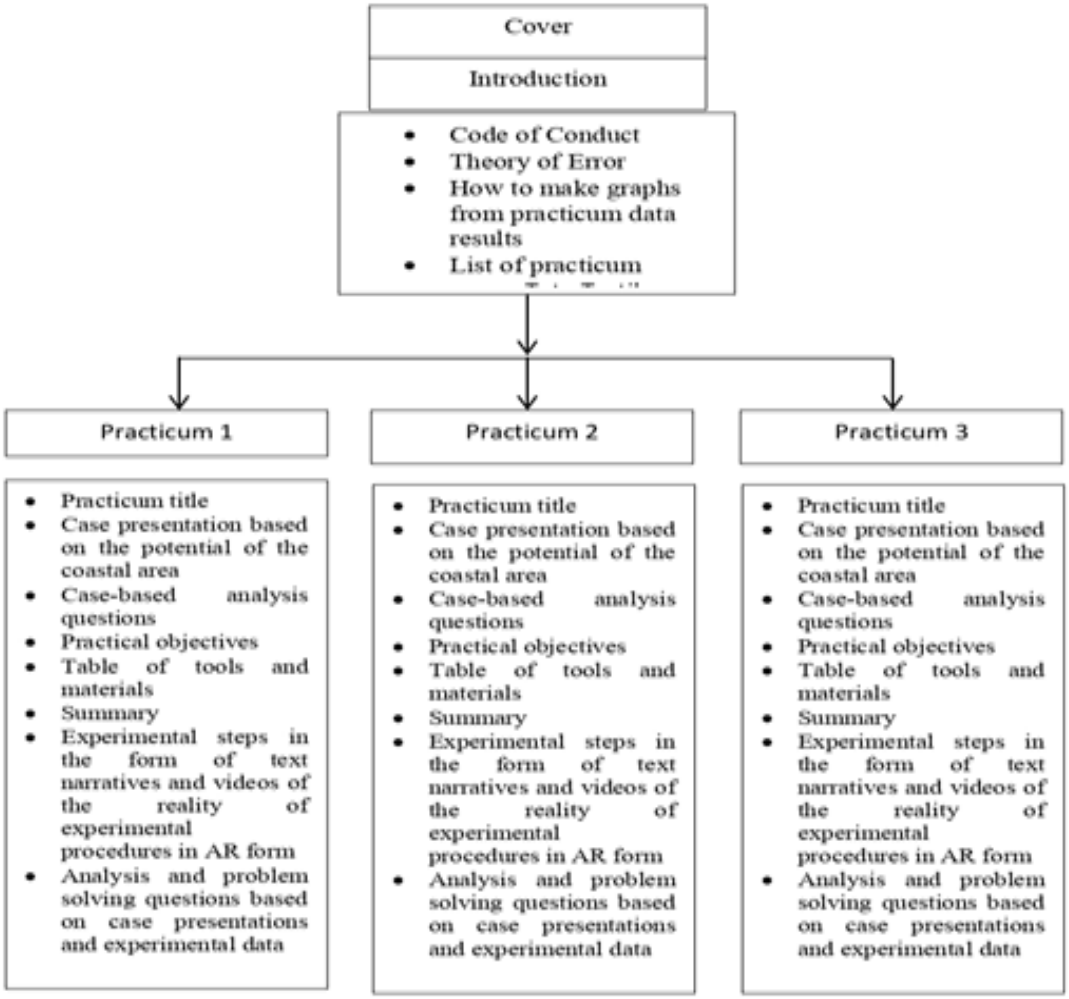

FIGURE 12. General Design of Practicum Guidebook to facilitate practicum activities during the Covid-19 pandemic with augmented reality technology and local potential in coastal areas

Based on FIGURE 12, the design of the practicum guidebook offers a solution for practicum activities during the Covid-19 pandemic with the Augmented Reality (AR) technology. AR helps visualize the laboratory procedure videos offline. The use of animated videos is very useful for students in understanding difficult lessons (Noviyanto et al. 2015). This video can help replace the assistant's duties and minimize the physical interaction during the practicum. In addition, it will be easier for the practitioner to follow the practicum procedures by providing audiovisual for time-saving. The augmented Reality can be used in various activities, such as presentations, object estimation, equipment performance improvement, tool performance stimulation, etc. Some of these examples are an illustration of the use of Augmented Reality in general (Afifah et al. 2019). Based on Afifah (2019), the advantages of Augmented Reality are: 1) More interactive, 2) More effective to use, 3) More widely implemented in various media, 4) Simpler object modeling, due to only displaying a few objects, 5) Higher cost due to unstable creation, and 6) Easy to operate. In addition, (Ryza 2017) stated that this application has the advantage of providing direct experience for students, presenting the object as a whole, and providing a clear picture of the organizational structure. The case presentations are oriented to the local potential of coastal areas for stimulating the problem-solving skills. Also, this tool can create insights for practitioners who live in the coastal area of Bengkulu on the potentials of the coastal area.

CONCLUSION

Based on the data analysis results, many students find difficulties in carrying out the physics practicum activities during the Covid-19 pandemic. One of the causes is the unavailability of practicum guidebook that presents practicum procedure videos offline. Based on the analysis results of the available practicum guidebooks, the guidebook presents the practicum procedures, but only in the form of narrative texts, thus not supporting the high-order thinking skills by utilizing case presentations in coastal areas. Students must be introduced deeper to the potential of coastal areas and their relation to physics concepts. Innovation of the Augmented Reality-assisted practicum guidebook can help visualize the practicum procedures offline and explain the concrete concepts. Thus, it is necessary to develop an innovative Augmented Reality-assisted practicum guidebook oriented towards solving local potential cases in coastal areas.

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