

DEVELOPMENT OF A PROBLEM-BASED LEARNING BOOKLET SUPPORTED BY AUGMENTED REALITY FOR HIGH SCHOOLS

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ABSTRACT

This research is motivated by the need for learning media that can help students understand abstract and microscopic Virus material through systematic visual presentation. This research aims to develop a Problem-Based Learning (PBL)-based Booklet assisted by Augmented Reality (AR) on Virus material for Grade X high school students. This research uses the Development Research method with the Plomp development model, limited to the prototyping phase. Subjects were five validators and Grade X students. Data were obtained using expert validation sheets and student practicality questionnaires, analyzed descriptively by percentage calculations. PBL and AR combine problem-oriented learning activities with interactive visualization of abstract and microscopic Virus structures, as an alternative to conventional media. The booklet achieved 96% feasibility, categorized as very feasible, while the practicality test obtained 89%, categorized as very practical. However, this research was limited to measuring the feasibility and practicality of the developed booklet and did not directly examine improvements in students' conceptual understanding or problem-solving abilities. Thus, the AR-assisted PBL-based booklet met the criteria of being very feasible and very practical as a supporting medium for learning Virus material for Grade X high school students, while its effectiveness in improving conceptual understanding and problem-solving abilities requires further investigation.

Keywords: booklet; problem based learning; augmented reality

INTRODUCTION

21st century education demands student-centered learning that fosters students' critical thinking, creativity, communication, and collaboration abilities as essential competencies for facing current challenges (Aziziy et al., 2025; Maryamah et al., 2023; Sari et al., 2025). The implementation of the Independent Curriculum supports the direction of learning through student-centered learning and encourages active involvement in the learning process (Kalsum et al., 2023; Lestari et al., 2023; Maryamah et al., 2023). In Biology learning, learning media plays a role in helping to present material more clearly, interestingly, and in accordance

with the needs of students so that it can support students' understanding and involvement in the learning process (Indrati & Masing, 2025; Resti et al., 2024; Supriyadi et al., 2022). The use of learning media is particularly important for abstract Biology concepts that require visualization to help students understand objects or processes that are difficult to observe directly (Indrati et al., 2025; Laswi et al., 2024). Previous studies have demonstrated the potential of PBL to support students' problem-solving abilities and learning outcomes (Sapitri et al., 2024), while AR has been integrated with case-based learning to support Biology learning

outcomes and critical thinking (Zamima et al., 2025). PBL-based learning resources have also been developed to support students' critical thinking (Mahfudoh et al., 2025), while recent research has identified the need for PBL-based e-books assisted by AR to address abstract science materials and support problem-solving skills (Dewi et al., 2025). A review of AR implementation in Biology learning also highlights its potential for visualizing biological structures and processes, while further empirical testing of its effectiveness remains necessary (Hallaby & Syahputra, 2025). These studies provide a basis for further exploration of how PBL and AR can be integrated into a learning resource with complementary pedagogical functions. In this study, the Booklet structures the learning content, PBL facilitates problem-oriented learning activities, and AR provides interactive visualization of abstract and microscopic objects. This integration is particularly relevant to Virus material, which requires both contextual problem-solving activities and visualization of microscopic structures and processes.

Booklet is one of the learning media that presents material in a concise and concise manner and is equipped with pictures or illustrations so that it can help students understand the material being studied. In addition to presenting material systematically, (Rahmayanti et al., 2025; Sakinah et al., 2023; Sarinami & Zulyusri, 2022). *Booklets* can be used as teaching materials that support independent learning because they can be learned anytime and anywhere (Andini & Saifuddin, 2023; Sakinah et al., 2023).

Virus material is one of the Biology materials that has abstract and microscopic characteristics so that it requires

visualization support in understanding its structure, characteristics, and reproductive processes (Sholikha et al., 2024; Warouw et al., 2025). These characteristics can cause students to have difficulty understanding the concept of Virus because the objects and processes studied cannot be directly observed and are complex (Ami & Bahrudin, 2024; Sholikha et al., 2024). Misconceptions in Virus material are also still found in high school students, especially in the concepts of virus structure, genetic material, life cycle, and the role of viruses in life (Isyatul & Trimulyono, 2023). The use of visual and interactive media can be an alternative to help students understand the concept of Virus more concretely, especially in materials that are abstract and difficult to observe directly (Pitaloka et al., 2024; Warouw et al., 2025).

The difficulty of understanding complex Biology material is not only related to the characteristics of the material, but also to the amount of information that must be processed by students. Information with many elements processed simultaneously can increase cognitive load and put demands on limited working memory capacity, so the presentation of information needs to be optimally designed. Therefore, the use of media needs to be supported by a learning model that actively involves students in understanding and solving problems (Koć-Janucht et al., 2022). *Problem Based Learning* (PBL) places problems as part of the learning process and encourages students to solve problems, gather information, and acquire new knowledge (Taufik et al., 2022). The application of PBL in Biology learning can also enhance students' critical reasoning and problem-solving abilities by engaging them in learning activities centered on real problems (Ernanda et al., 2022; Suryadi et

al., 2023). In addition *Augmented Reality* (AR) can enrich the presentation of information through the interactively integration of digital objects with real environments, although its effectiveness against cognitive load is influenced by the type, features, and design of learning used (Buchner et al., 2022) .

The use of *Augmented Reality* (AR) on viral materials can be used to enrich the presentation of material through interactive visualization of digital objects and information. AR technology allows viral objects to be displayed in a three-dimensional form so that information about the structure and characteristics of viruses can be presented more concretely (Indriani et al., 2024). A number of studies have developed teaching materials by utilizing *Booklets*, *Problem Based Learning* (PBL), and AR through different combinations. Andriani et al. (2025) developing PBL-based *e-Booklets* on the subtopic of class X virus replication processes, while Sholikha et al., (2024) developing PBL-based AR media on Virus materials. In addition, Muliyani et al., (2024) developing AR-based *Booklets* that combine printed teaching materials with AR elements. These studies show that these three components have been utilized in the

development of teaching materials, but the integration of *Booklets*, PBLs, and AR in one product in high school class X Virus materials is still limited.

The results of initial observations at SMA Negeri 4 Pekanbaru and SMA Negeri 5 Pekanbaru showed that The available learning media were still limited to printed books, PowerPoint presentations, learning videos, and posters. Virus material is also still difficult to understand by students, while the learning process was predominantly conducted using the Inquiry model. Material analysis indicated that students' average learning outcomes in the Virus material were 77, while the results of the needs analysis showed that as many as 82% of students approved the development of teaching materials consisting of *Booklets* based on Problem Based Learning (PBL) assisted by Augmented Reality (AR). This condition strengthens the need for the development of teaching materials that combine concise material presentation, problem-based learning, and interactive digital visualization. Therefore, this study seeks to develop a PBL-based *Booklet* assisted by AR for Virus material in Grade X of high school that meets validity and practicality criteria for use in learning.

METHODS

This research is a Development Research that aims to produce learning media in the form of Problem-Based Learning (PBL)-based *Booklets* assisted by Augmented Reality (AR) on Virus materials for Grade X high school students. This study employed the Plomp development model, which consists of three stages: preliminary research, prototyping phase, and assessment phase. However, this research was limited to the prototyping

phase, which focused on the development, revision, and formative evaluation of the product. The formative evaluation consisted of self-evaluation, expert review, one-to-one evaluation, small group evaluation, and field test to determine the validity and practicality of the developed *Booklet*. The development process was not continued to the assessment phase; therefore, this study did not evaluate the

effectiveness of the developed Booklet on students' learning outcomes..

The research was conducted at SMA Negeri 4 Pekanbaru and SMA Negeri 5 Pekanbaru from July to September 2026 during the first semester of the 2026/2027 academic year. The developed Booklet was specifically intended for Grade X students and focused on Virus materials. The student participants were selected through coordination with the Biology teachers at each school. The participating classes were recommended by the Biology teachers based on the suitability of the class with the research schedule and the ongoing Biology learning of Virus material. The main criterion for participation in the practicality test was that the students had already studied the Virus material, so they had relevant prior learning experience to understand and evaluate the developed Booklet. This criterion was also used to ensure that the participants represented the intended users of the developed learning media. The practicality test involved 84 students, consisting of 41 students from SMA Negeri 4 Pekanbaru and 43 students from SMA Negeri 5 Pekanbaru.

The five validators consisted of one material expert, one media expert, one Biology Education lecturer serving as a learning expert, and two Biology teachers from SMA Negeri 4 Pekanbaru and SMA Negeri 5 Pekanbaru. The material expert was a permanent lecturer of the Biology Education Study Program with an S3 qualification and expertise in Virus material. The media expert was a permanent lecturer of the Biology Education Study Program with an S3 qualification and expertise in educational technology and learning media development. The learning expert validators consisted of one Biology

Education lecturer with an S3 qualification and two high school Biology teachers who were actively teaching. Each validator assessed the developed Booklet using a validation sheet according to their respective areas of expertise. The material expert assessed the accuracy and suitability of the Virus content, the media expert assessed the media and visual aspects, while the learning experts assessed the suitability of the Booklet with Biology learning. The scores from all five validators were combined to determine the overall validity of the product. The validity percentage was calculated by comparing the total score obtained (TSe) with the total maximum score (TSh) using the formula $V = TSe/TSh \times 100\%$.

The preliminary research stage was conducted to identify learning conditions and the needs for learning media to be developed. The analysis included curriculum analysis, needs analysis, student characteristics analysis, and Virus material analysis. The Virus material was selected as the focus of development because the preliminary research indicated that students needed learning support to understand the abstract and complex concepts of Virus. Therefore, the developed learning media was specifically designed to facilitate students' understanding of Virus concepts through PBL-based learning activities assisted by AR. Information was collected through learning observations, interviews with teachers and students, student needs analysis questionnaires, and documentation of learning outcomes. The results of these analyses were used as the basis for determining the characteristics and requirements of the PBL-based Booklet assisted by AR in accordance with the learning conditions, Virus learning content,

and characteristics of Grade X high school students.

The prototyping phase was conducted to develop and refine the PBL-based Booklet assisted by AR through formative evaluation. The formative evaluation consisted of self-evaluation, expert review, one-to-one evaluation, small group evaluation, and field test. The self-evaluation was conducted to examine the initial prototype in terms of content, presentation, design, language, and completeness. The prototype was then reviewed by material, media, and learning experts to assess its validity. After revision based on expert feedback, the prototype was evaluated through one-to-one and small group evaluations to identify its readability, clarity, and practicality. The final formative evaluation was conducted through a field test involving 84 students from SMA Negeri 4 Pekanbaru and SMA Negeri 5 Pekanbaru to determine the practicality of the developed Booklet. The development process ended at the field test stage and was not continued to the assessment phase.

Data collection techniques use observation, interviews, questionnaires, and documentation. The research instruments are in the form of observation sheets, interview guidelines, student needs analysis questionnaires, expert validation sheets, student evaluation questionnaires, and practicality test questionnaires. Validation sheets are used to obtain expert assessments of material, media, and learning aspects, while practicality questionnaires are used to find out students' responses after using *the Booklet*. The

validation and practicality instruments use the Likert scale.

The collected data were analyzed using quantitative descriptive methods. Expert validation data were processed by determining the percentage of the obtained score relative to the maximum possible score, using the following formula:

$$V = \frac{TSe}{TSh} \times 100\%$$

The results of the validation percentage were then interpreted based on the validity criteria, namely 85%–100% including the category of very valid, 69%–84% valid, 53%–68% quite valid, 37%–52% not valid, and 20%–36% invalid. Meanwhile, the practicality test data were analyzed by determining the percentage of assessment results based on the following formula:

$$P = \frac{F}{N} \times 100\%$$

The practicality percentage results were subsequently interpreted according to the established criteria, namely 85%–100% very practical, 69%–84% practical, 53%–68% quite practical, 37%–52% not practical, and 20%–36% impractical. The results of the validation analysis were used as a basis for product revisions, while the results of the practicality test were used to determine the practicality of the developed PBL-based Booklet assisted by AR. As the research was limited to the prototyping phase, no assessment of the effectiveness or learning outcomes of the developed Booklet was conducted.

RESULTS AND DISCUSSION

Characteristics of AR-assisted PBL-based Booklets

The results of the development are in the form of *Problem-Based Learning* (PBL)-based Booklets assisted by *Augmented Reality* (AR) on Virus materials for high school grade X students. The booklet is prepared as a printed teaching material that

presents Virus material in a concise and systematic manner, equipped with learning activities based on PBL syntax, AR features, and evaluation. The AR feature on certain pages uses *markers* to display digital visualizations of Virus materials. The main display of the developed product is presented in Figure 1

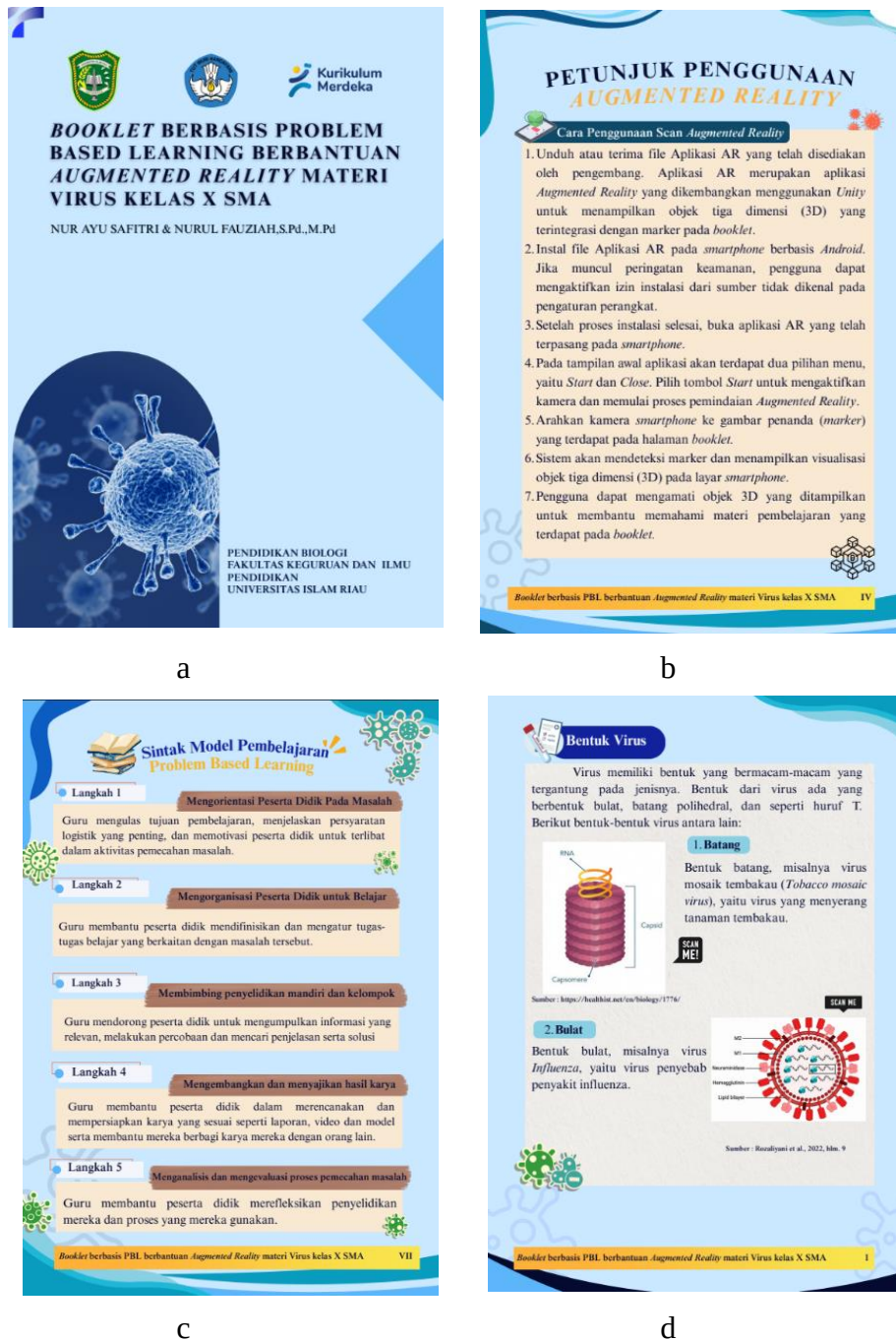


Figure 1. Main display of AR-assisted PBL-based Booklet: (a) Booklet cover; (b) AR usage instructions (c) PBL syntax (d) AR scan form

Booklet developed has a look that combines material presentation, PBL activities, and AR features. Covers use themed designs *Virus Case File*, while the contents *Booklet* contains Virus material that is presented concisely and systematically. Learning activities are arranged according to PBL syntax and equipped with investigation and evaluation activities. AR features are characterized by *Marker* on a specific page that can be scanned to display the visual object of the Virus material in digital form.

Self Evaluation

Stages *self-evaluation* carried out through a review of the initial product *Booklet* based *Problem Based Learning* (PBL) assisted *Augmented Reality* (AR). The study included 12 indicators, namely the cover, the title of the material, the learning objectives, and the order of presentation *Booklet* AR-based PBL-based, supporting illustrations and images, viral material, design *Booklet*, writing, evaluation, answer keys, and bibliographies. The results of the review are used as a basis to identify and improve the parts of the product that still need improvement before entering the stage *expert review*.

Booklet Validation based on Expert Review

The results of the AR-assisted PBL-based *Booklet* feasibility assessment by expert validators are presented in Table 1. The assessment involved three validators, including a material expert, a media expert, and a learning expert.

Tebel 1. Results of Product Validation

Validator	Percentage	Category
Media Member	96,60%	Highly Worth It
Material Expert	93,80%	Highly Worth It

Learning Expert	99%	Highly Worth It
Average	96,47%	Highly Worth It

Table 1 presents the validation results, indicating that the Problem-Based Learning (PBL)-based booklet assisted by Augmented Reality (AR) achieved feasibility scores of 96.60% from the media expert, 93.80% from the material expert, and 99% from learning experts. The overall average validation results were 96.47% with the category of very feasible. The results showed that the developed product had met the feasibility criteria from the media, materials, and learning aspects so that it could be continued at the evaluation stage of students.

The assessment of media experts obtained a percentage of 96.60% with a very feasible category. These results show that the media aspect of the *Booklet* has met the assessed eligibility criteria, especially in the presentation of the appearance and visual components of the product. The presentation of teaching materials that are structured and supported by visual components can help students in understanding the information conveyed. These results are in line with Sarinami & Zulyusri (2022) those that show that booklets can be used as supporting teaching materials in Biology learning after meeting the set validity criteria.

The material aspect obtained a feasibility percentage of 93.80% with a very feasible category. The results show that the Virus material presented in the *Booklet* is in accordance with the aspects assessed by the validator. The material is presented concisely and systematically so that it can support the delivery of the Virus concept in learning. The characteristics of the Virus material which are abstract cause

the presentation of the material to need to be supported by visual forms that can help students understand the concept. Warouw et al. (2025) explained that understanding the concept of the Virus can be a challenge for students because the characteristics of the material are not easy to observe directly.

The learning aspect obtained a percentage of 99% with the category of very feasible. The results show that the Booklet has fulfilled the learning aspects assessed, including the application of Problem Based Learning (PBL) syntax in learning activities. The implementation of PBL provides space for students to be involved in the learning process through problem-solving oriented activities. Xu et al. (2021) found that the implementation of Problem Based Learning can encourage students' active participation in the instructional process.

The use of Augmented Reality (AR) represents a feature that supports the presentation of Virus material in the Booklet. AR enables objects or visualizations to be presented interactively, helping students understand concepts that cannot be easily observed directly. Indriani et al. (2024) reported that incorporating AR into Virus learning can facilitate the visualization of Virus objects and make the learning experience more interactive.

Evaluation and Practicality Test

Product evaluation is conducted through several stages, namely one-to-one, small group, and field testing. The one-to-one stage is carried out to obtain initial input related to the comprehension and readability of the Booklet, while the small group is used to see students' responses in using the product in small groups. Furthermore, a *field test* was carried out to determine the level of practicality of the *Booklet* in wider use.

One to one

The one-to-one stage was carried out through interviews to obtain students' responses to the Problem Based Learning (PBL)-based Booklet assisted by Augmented Reality (AR). The responses obtained included aspects of appearance, readability, presentation of material, learning activities, use of AR, and ease of use. The results of the interviews showed that students gave positive responses to the Booklet developed.

The Booklet display is considered attractive, easy to read, and has a systematic presentation of the material. The use of images, colors, layouts, and 3D objects through AR is considered to help students understand abstract Virus material. This finding is in line with Setiawan et al. (2025) explaining that AR can help visualize abstract Biology concepts to be more real and easy to understand. PBL-based activities are also considered to help students understand the material through problem solving, in line with Wijnia et al. (2024) showing that problem-based learning can support students' motivation.

The ease of use of the Booklet and the AR feature also received positive responses. Students stated that the Booklet is practical to use and the AR feature is easily accessible, although there is input related to the need for mobile phones to display 3D objects. The input is used as a consideration in improving the product before proceeding to the next stage of evaluation.

Small group

The small group evaluation involved 10 students, consisting of five students from SMA Negeri 4 Pekanbaru and five students from SMA Negeri 5 Pekanbaru. At this stage, students were asked to use the *Booklet* and provide assessments through

questionnaires on aspects of design, readability, presentation, images, language, materials, motivation, and integration of PBL and AR. The results of student assessments at *the small group* stage are presented in Table 2.

Table 2. Small group *Evaluation Results*

Indicator	Percentage (%)	Category
Booklet Design	96%	Very Practical
Text Readability	91	Very Practical
Presentation Clarity	98	Very Practical
Image Quality	96	Very Practical
Use of <i>Fonts</i>	92	Very Practical
Language Use	95	Very Practical
Collapse	95	Very Practical
Presentation of Materials	97	Very Practical
Motivation	91	Very Practical
AR-assisted PBL-based booklet	96	Very Practical
Average	95	Very Practical

The results of the small group evaluation in Table 2 show that Problem-Based Learning (PBL)-based booklets assisted by Augmented Reality (AR) obtained an average percentage of 95% with the very practical category. All indicators assessed were in the very practical category with percentages ranging from 91% to 98%. These results show that the Booklet can be used well by students in small groups reviewed from the aspects of design, readability, presentation, images, font use, language, collapse, material presentation, motivation, and PBL and AR integration. These results are in line with Prihatin et al. (2024) the one that obtained a practicality level of 86.33% in the development of Biology digital textbooks

and is included in the very practical category.

The clarity of the presentation obtained the highest percentage of 98%. These results show that the information and materials presented in the Booklet can be well understood by students. The systematic presentation of the material helps students follow the information and learning activities contained in the Booklet. As-Sahra & Rusmini (2025) explained that the use of booklets can be a form of media innovation in Biology learning because it presents learning information through a more structured form of teaching materials.

The readability of the text obtained a percentage of 91%. These results show that the text in the Booklet can be read and understood by students even though it is one of the indicators with the lowest percentage at the small group stage. Readability is an important part of teaching materials because the presentation of information needs to be adjusted to the ability of students to understand the text. Sudiati (2023) It shows that readability is an aspect that needs to be considered in teaching materials for the secondary school level because the characteristics of the presentation of the text can affect the ease of students in reading the material.

Language use obtained a percentage of 95%. These results show that the language used in the Booklet can be understood by students. The use of language that is in accordance with the characteristics of students supports the delivery of material to be easier to understand. The score also shows that improvements in the development stage have resulted in the presentation of language that is acceptable to students in small groups.

Motivation obtained a percentage of 91% and became one of the indicators with the lowest percentage. These results remain in the category of very practical and show a positive response of students to the use of Booklets. The integration of PBL in learning activities can provide a learning experience that actively involves students through problems that must be solved. Hugerat et al. (2021) shows that the application of PBL in Biology learning can increase the learning motivation of secondary school students.

AR-assisted PBL-based booklets obtained a percentage of 96%. These results show that the integration of PBL and AR in the product is well received by students. PBL provides problem-solving-oriented learning activities, while AR provides visual support to the material presented. Sholikha et al. (2024) shows that the integration of PBL-based AR in Virus materials can help visualize abstract and microscopic concepts and obtain test results with very feasible categories.

Field Test

The field testing stage was conducted following product revisions based on the findings from the one-to-one and small group evaluations. This test involved 84 students. The assessment used a questionnaire to assess the practicality level of the Booklet according to several assessment indicators. Table 3 presents the results of the Booklet practicality test.

Table 3. Results of the Practicality Test

Indicator	Percentage (%)	Category
Booklet Design	88	Very Practical
Text Readability	87	Very Practical
Presentation	90	Very Practical
Clarity		Practical
Image Quality	89	Very Practical

Use of <i>Fonts</i>	89	Very Practical
Language Use	87	Very Practical
Collapse	89	Very Practical
Presentation of Materials	89	Very Practical
Motivation	90	Very Practical
AR-assisted PBL-based booklet	90	Very Practical
Average	89	Very Practical

Results of the *field test* in Table 3 show that *Booklet* based on *Problem-Based Learning* (PBL) assisted by *Augmented Reality* (AR) obtained an average practicality percentage of 89%, categorized as very practical. The average practicality decreased from 95% in the *small group* test to 89% in the *field test*. This decrease may be associated with the broader number of participants and the more varied testing context in the *field test*, which involved 84 students from two schools compared with only 10 students in the *small group* test. The broader field-test setting allowed a wider range of student responses to be obtained, resulting in a lower average percentage. These results show that the *Booklet* can be used well by students in learning conditions that are closer to the actual classroom situation. The practicality of the product can be seen from three indicators that obtained a very practical category, namely *Booklet* appearance/design at 89%, text readability at 87%, and clarity of presentation at 89%.

Display/design indicators *Booklet* obtained the highest percentage, which was 89.63% in the category of very practical. The results showed that the use of colors, images, layouts, and designs *Booklet* can be well received by students. Visual display is important in learning viral material because some concepts are abstract and require

visual assistance to facilitate understanding. Fajriani et al. (2021) shows that the use of AR can help learners build representations of concepts through a combination of writing, pictures, and diagrams. Supriyadi et al. (2022) reported that AR-based media used in biology instruction can support learners' visual communication and motivation.

The text readability indicator obtained a percentage of 87%, while the clarity of presentation obtained 89.27%, both of which were categorized as very practical. These results indicate that the text in the *Booklet* could be read and understood by students, while the presentation of materials, images, and learning activities could be followed during the learning process. The ease of reading and clarity of presentation may support students in accessing and processing information about Virus material, particularly when understanding concepts that require visual representation. The clarity of presentation is also supported by the application of PBL syntax, which directs students to identify problems, analyze information, and develop solutions through learning activities. However, these findings only reflect students' perceptions of the ease of

using the media and do not directly demonstrate an improvement in students' conceptual understanding of Virus material. Therefore, the relationship between the practicality of the *Booklet* and students' conceptual understanding requires further investigation through an effectiveness test. Hanida & Rachmadiarti (2022) shows that PBL-based teaching materials that contain authentic problems and learning activities obtain excellent practical responses from students. Thus, the integration of PBL and AR in *Booklet* not only supports the presentation of materials, but also provides a more interactive learning experience.

Results *field test* overall shows that *Booklet* AR-assisted PBL-based has met the practicality aspect based on student responses. The high percentage of display, readability, and clarity of presentation shows that the product can be used as supporting teaching materials for viral materials. The use of AR complements the presentation of abstract material through visualization, while PBL provides a problem-solving structure of activities. *Booklet* developed has met the criteria of being very practical for use in the learning of virus material

CONCLUSION

This study produced a *Problem-Based Learning* (PBL)-based *Booklet* assisted by *Augmented Reality* (AR) on Virus material for Grade X high school students. The validation results from five validators obtained an average percentage of 96.47%, categorized as very feasible. The practicality test through a *field test* involving 84 students obtained an average percentage of 89%, categorized as very practical, indicating that the *Booklet* can be used to support learning of Virus material.

However, this study was limited to two schools and only covered the prototyping phase of the Plomp development model without proceeding to the assessment phase to empirically examine the effectiveness of the product. Therefore, further research is needed to test whether the PBL-based AR-assisted *Booklet* can reduce misconceptions about Virus material and improve students' conceptual understanding.

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