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Development of E-VIRA (e-module virus integrated reality-augmented): Enhance mental models and problem-solving skills

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Abstract. Based on the analysis, students lack references and in-depth, relevant material content, and still use open printed materials. This results in students' mental models of virus material being unscientific, and their problem-solving skills being low. For this reason, an e-module integrated with Augmented Reality (AR) can be an effective solution. This study aims to develop E-VIRA (E-Module Virus Integrated with Augmented Reality) to improve students' mental models and problem-solving skills. The research method employed is Research and Development (R&D), utilizing the ADDIE stages from inception to development and trial. Data collection instruments include expert validation sheets and cloze tests (for readability). Data analysis techniques are carried out descriptively and quantitatively to calculate the percentage of validity and readability. Participants were selected using purposive sampling, involving grade X high school students. The results showed that E-VIRA was very valid, with a percentage of 97% and 96% from expert validators, and a readability level of 82%. Thus, E-VIRA shows good feasibility and validity. The recommendation of this study is to continue the trial of E-VIRA on a larger scale to measure effectiveness in significantly improving students' mental models and problem-solving skills, as well as explore its application to other abstract biological concepts.

Introduction

Biology learning enables students to connect with significant environmental and everyday issues. According to Azizah & Alberida (2021) and Fu'aida et al. (2023), one of the key aspects is the virus material, which is closely related to the daily lives and problems faced by students. Several research results show that virus material is one of the most difficult biological concepts for students to understand (Fauzi & Mitalistiani, 2018). The abstract nature of viruses causes this difficulty and cannot be observed directly (Ami & Bahrudin, 2024). Students often have difficulty understanding the abstract and microscopic aspects of viruses (Sholikha et al., 2024). Several research results show that virus material is one of the most difficult biological concepts for students to understand. The abstract nature of viruses causes this difficulty and cannot be observed directly (Ami & Bahrudin, 2024). Students often have difficulty understanding the abstract and microscopic aspects of viruses (Sholikha et al., 2024).

Based on the results of interviews with two biology teachers for grade X at a State Senior High School in Bandung City on October 29, 2024, researchers obtained an overview of the learning

process, especially on virus material. Based on the interview results, it was noted that class learning of virus material involved group discussions and assignments, where students presented the material they had studied. The obstacles in teaching virus material were that students lacked references, and the content of the virus material was not deep enough to illustrate. In addition, the teaching materials used in the learning process of virus material were based solely on printed materials. This was supported by the answers to the student questionnaire regarding the learning process of virus material; students felt that virus material was challenging to learn, and the use of teaching materials was not interesting. Students had difficulty relating the concept of viruses to everyday life. To overcome this, it is necessary to analyze the mental models of students. The construction of students' knowledge is a study of mental models. A mental model is a person's internal representation in accessing their knowledge structure (content knowledge and daily experiences), which is used in solving problems (Atikah et al., 2023). Understanding the conception of knowledge in a person can be achieved by analyzing their mental model (Hamdiyati et al., 2018; Suhardita et al., 2024).

Based on the results of a preliminary study conducted by researchers in October 2024 regarding students' mental models at SMAN 7 Kota Bandung with 33 samples, it can be seen that the average mental model of students on the structure of the virus analyzed using the drawing-writing technique is at the drawing 2-writing 1 level (42.42%) which amounted to 14 students with a total of 33 students. So it can be concluded that students still have a mental model that is far from the scientific level of the virus material. In this regard, it is essential to find solutions to improve students' mental models. Not only technical expertise and mastery of subject matter concepts, students need to be equipped with a broader range of skills to prepare themselves to face challenges in the 21st century, such as problem-solving skills, critical thinking, communication, collaboration, creativity, and innovation, identified as crucial 21st-century skills (Indraswati et al., 2020; Nurhayati et al., 2024; Widana et al., 2023). One of them is problem-solving skills. Problem-solving skills can be defined as an individual's skills in using their thinking process to solve problems (Rukhmana, 2021). Furthermore, problem-solving can be interpreted as a thinking process to overcome difficulties and achieve expected goals (Rahayu & Ismawati, 2019; Sumandya et al., 2025).

In reality, in the field, students' problem-solving skills are still low (Purnadewi & Widana, 2023). Based on the results of a preliminary study conducted by researchers in October 2024 regarding students' problem-solving skills at SMAN 7 Kota Bandung with 33 samples, the average problem-solving skills of students were in the low category with a score of 47.42. This is supported by several recent research results, which show that students' problem-solving skills in biology, especially those related to viruses, are generally inadequate. A study of grade X students found that problem-solving skills were in the "unskilled" category, with an average score of 53% (Marini et al., 2022). Likewise, a study of grade 11 students revealed "lacking" problem-solving skills in various indicators (Palennari et al., 2022). At the university level, a study showed that 57% of students had "inferior" problem-solving skills in biology (Usman et al., 2022). Based on these findings, there is a need for targeted interventions to improve students' problem-solving skills, especially in biology learning.

In this case, various efforts to improve the quality of learning continue to be carried out, especially in biology learning, such as developing electronic teaching materials (modules) (Prihatiningtyas & Tijanuddarori, 2021). E-modules have emerged as effective digital teaching materials in the 21st-century educational landscape (Mirah et al., 2025). These interactive and self-study materials offer greater flexibility, accessibility, and engagement for learners (Istiqoma et al., 2023; Lastri, 2023). E-modules have emerged as effective digital teaching materials in the 21st-century educational landscape. These interactive and self-study materials offer greater flexibility, accessibility, and engagement for learners. This shows that e-modules have been widely integrated with the use of technology.

Currently, digital technology-based teaching materials are being hotly discussed, one of which is Augmented Reality (AR). Augmented Reality (AR) technology has emerged as a powerful tool to enhance learning in schools by visualizing abstract concepts more clearly. AR combines real and virtual environments, overlaying 3D objects onto the real world to create an interactive and engaging learning experience (Fawad et al., 2021; Jadhav et al., 2020). AR enables the integration of learning material representations into students' mental models, so that parts that the naked eye cannot reach can be depicted through AR visualizations (Wildan, 2023).

Based on the literature review presented, the novelty of this study lies in the development of E-VIRA (E-Module Virus Integrated Reality-Augmented) as an integrated effort to address two significant challenges in biology learning: students' low mental models of abstract virus material and their lack of problem-solving skills. Although the development of e-modules and the use of Augmented Reality (AR) technology have been widely studied separately, this study offers an innovative approach by integrating both elements specifically in the context of virus material. This aims to provide a more interactive and visual learning experience, which is expected to bridge the gap in understanding the abstract concept of viruses and simultaneously improve students' ability to solve problems related to biology.

In this context, the implementation of AR-integrated e-modules can be an effective solution to help students understand these concepts better. By using AR, students can see 3D models of viruses and interactions in real environments, allowing students to learn more interactively and enjoyably (Susanti, 2022). Furthermore, the results of other studies show that students are more interested when using modern technology in learning (Juanengsih, 2022). Therefore, the purpose of this study is to develop E-VIRA (E-Module Virus Integrated Reality-Augmented) to improve students' mental models and problem-solving skills. Based on these objectives, this study aims to investigate the validity and practicality of the E-VIRA in enhancing students' mental models and problem-solving skills.

Method

The research method employed is Research and Development (R&D), incorporating ADDIE instructional stages. In the ADDIE instructional stages, there are five stages, namely: (1) analyze, (2) design, (3) develop, (4) implement, and (5) evaluate. However, the scope of discussion in this article is limited to the development stage, to comprehensively present the process of needs analysis, design, and initial development of e-modules that have been compiled and supported by relevant empirical evidence. Each stage is evaluated against development activities that have a positive impact on the quality of the product being developed. This research was conducted at SMAN 7 Bandung City, during the 2025 academic year in the even semester. The research subjects in this study were 17 grade XI students, and then interviews were conducted with science teachers related to the researcher. The sampling technique employed was purposive sampling, where students were selected from schools in the exact research location, provided they had previously participated in learning about virus material, so that they could provide more targeted feedback on the readability and understanding of the e-module's content.

The development steps with the ADDIE instructional stages as a whole are presented in the following figure.

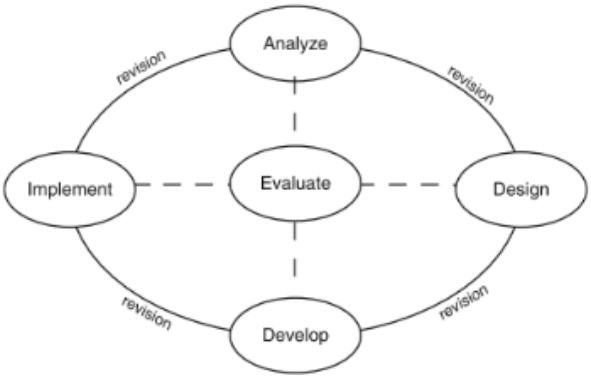

Image 1. ADDIE Approach Development Chart

A summary of each stage of analysis, design, and development is provided in Table 1.

Table 1 Summary of instructional stages carried out

Instructional Phase	Activity
Analyze	• Needs analysis • Material analysis
Design	• Determination of material • Creating an e-module outline • Determining the object of Augmented Reality viral content • Unity Augmented Reality application • Determine other supporting applications or websites
Develop	• Realizing the e-module product of virus material that has been designed into an e-module that is ready to use • Validation of the products used • Trials

Complete details regarding the types of instruments used in this study can be seen in Table 2.

Table 2 Instruments used in the research

No.	Measured Aspects	Data source	Data collection technique	Type of Instrument
1.	Condition of teaching materials in schools	Teacher	Interview	Interview guidelines
2.	Eligibility e-module developed	Lecturers and expert teachers	Distributing closed questionnaires	Closed questionnaire
		Learners	Distributing closed questionnaires	Closed questionnaire
		Legibility e-modul	Distributing cloze tests	Cloze test

The assessment results obtained from the validation test are calculated and converted into a percentage using the following formula.

$$N = \frac{k}{Nk} \times 100\%$$

Information:
N : percentage of aspect
K : value of aspect
Nk : value to be achieved

The readability level of E-VIRA (E-Module Virus integrated with Reality-Augmented) was tested using the cloze test technique. In compiling this test instrument, several words were removed from the sentences in the text. The cloze test is considered capable of measuring the readability level of a teaching material because it can represent students' understanding of a discourse or reading. Three texts from E-VIRA developed by the researcher were selected to be included in the readability test instrument. Details regarding the readability test instrument grid can be seen in Table 3.

Table 3E-Module Readability Test Instrument Grid

No.	Topics	No. Text
1.	Understanding Viruses	Text I
2.	Virus Structure	Text II
3.	The Role of Viruses	Text III

The deletion of words on the E-VIRA readability test instrument is carried out consistently and systematically, with a focus on the ninth syllable, aiming to improve students' mental models and problem-solving skills. The results of the e-module validation calculations that have been carried out are then adjusted to the eligibility criteria, as shown in Table 4.

Table 4 Validity Criteria

Interval (%)	Criteria
$81.26\% < N \leq 100\%$	Very Valid
$62.51\% < N \leq 81.25\%$	Valid
$43.76\% < N \leq 62.50\%$	Quite Valid
$25\% < N \leq 43.75\%$	Not Valid

The readability test result data is determined using the following formula.

$$TK = \frac{\text{Score acquisition}}{\text{Maximum score}} \times 100\%$$

Information:
TK : Readability level
Score acquisition : Total correct answers from respondents
Maximum score : Total correct answers contained in the instrument

Interpretation of the results of students' readability tests on the cloze test is grouped into categories, as can be seen in Table 5.

Table 5 Decision Criteria for E-Module Readability Test

Percentage	Information
Readability Rate > 57%	High
44% ≤ Readability Level ≤ 57%	Medium
Readability Rate < 44%	Low

Results and Discussion

The research conducted is a product development research that follows systematic stages by the previously established instructional stages. Through this process, information is gathered on the e-module's feasibility and user response, enabling it to be ready for use in learning. Module development is carried out using the ADDIE instructional stages, namely a development stage that includes five main stages: analysis, design, development, implementation, and evaluation. However, the scope of discussion in this article is limited to the development, with the aim of comprehensively presenting the process of needs analysis, design, and initial development of e-modules that have been compiled and supported by relevant empirical evidence. Each stage is evaluated against development activities that have a positive impact on the quality of the product being developed. The following is a description of the stages taken by researchers in the process of developing an augmented reality integrated virus e-module.

Analyze Phase

At this stage, researchers focus on identifying the specific needs of the users of the developed product, namely, students and teachers. Explains that this analysis includes an evaluation of the feasibility and requirements needed for the development of teaching materials. The primary purpose of this stage is to identify problems that arise in the learning process and to compile the specifications of the required product. By understanding the needs and characteristics of users, researchers can ensure that the product developed is relevant and can address the challenges in the environment. The analysis stage is a process of describing what will be done and becomes the basis for the following stages. The analysis carried out at this initial stage includes interviews with biology teachers and an analysis of teaching material needs. The purpose of this stage is to assess the needs of teaching materials, the characteristics of students, and the teaching materials.

Analysis of Teaching Material Needs

Based on the results of interviews with two biology teachers for grade X at SMAN 7 Bandung City on 29 October 2024, researchers obtained an overview of the learning process, especially on virus material. Based on the interview results, it was noted that class learning of virus material involved group discussions and assignments, where students presented the material they had studied. The obstacles in teaching virus material were that students lacked references, and the content of the virus material was not deep enough to illustrate. In addition, the teaching materials used in the learning process of virus material were based solely on printed materials. This was supported by the answers to the student questionnaire regarding the learning process of virus material; students felt that virus material was challenging to learn, and the use of teaching materials was not interesting. Students had difficulty relating the concept of viruses to everyday life.

Learning Material Analysis

Findings from interviews and student needs analysis revealed challenges faced by teachers and students in delivering and understanding educational materials. The problem lies in the lack of teaching resources to effectively illustrate virus content. Viruses are a key component of the final biology curriculum (CP) in Phase E, which focuses on empowering students to design solutions to problems related to biodiversity, viruses, biotechnology advances, ecosystem dynamics, and environmental change. These learning objectives were further detailed and transformed into core subjects in the virus-themed curriculum.

Design Phase

The electronic planning process involves several key steps: determining the material, creating an e-module outline, identifying the Augmented Reality content object, preparing the Unity Augmented Reality application, and selecting other supporting applications or websites. After the validation

instrument is developed, the instrument is consulted and validated by expert educators. Feedback and recommendations from these experts are then incorporated to refine the instrument to suit the research effort.

The material in the developed e-module is adjusted to the Learning Outcomes that students want to achieve, and is developed into clear learning objectives. In this case, the e-module that the researcher developed for Biology material for SMA/MA class X, with the title "E-VIRA (E-Module Virus Integrated Augmented Reality) to improve students' mental models and problem-solving skills".

The material in the e-module that the researcher developed is presented, using images and animated videos to provide varied representations. The variations presented in the learning material aim to represent or introduce a concept in a way that facilitates the diversity of students' learning styles and increases the attractiveness of the e-module to users. After determining the material to be presented in the e-module, the researcher then makes an outline and layout of the e-module design. The outline is prepared by compiling the scope of the material in the e-module that is adjusted to the AR visualization and problem-solving skills that are trained based on learning achievements.

At the design stage, research instruments are also designed to assess the feasibility of the e-module. Some of these instruments include e-module validity test questionnaires, cloze test instruments, mental model instruments, problem-solving skills instruments, and student response questionnaires. The e-module validity test questionnaire was created to collect feedback from experts or validators regarding the quality of the e-module that the researcher developed.

During the analysis phase, researchers focused on identifying the specific needs of students and teachers. The main obstacles identified in the field were a lack of adequate references, the abstract nature of the virus material, and the difficulty of visualizing it directly, and a reliance on uninteresting printed teaching materials, which made it difficult for students to relate the concept of viruses to their daily lives and made the virus material difficult to learn. The results of teacher interviews and student questionnaires consistently show that existing teaching methods have not been able to overcome conceptual difficulties with viruses and have not stimulated problem-solving skills.

Develop Phase

The stage after designing the e-module is the development stage. The purpose of this stage is to transform the designed product into an e-module ready for use. The primary focus of this development is to create an integrated augmented reality e-module to improve students' mental models and problem-solving skills, which are declared feasible or valid after being evaluated by the validators. The results of the e-module development are illustrated in the following Image.

Image 2. E-VIRA Cover Display

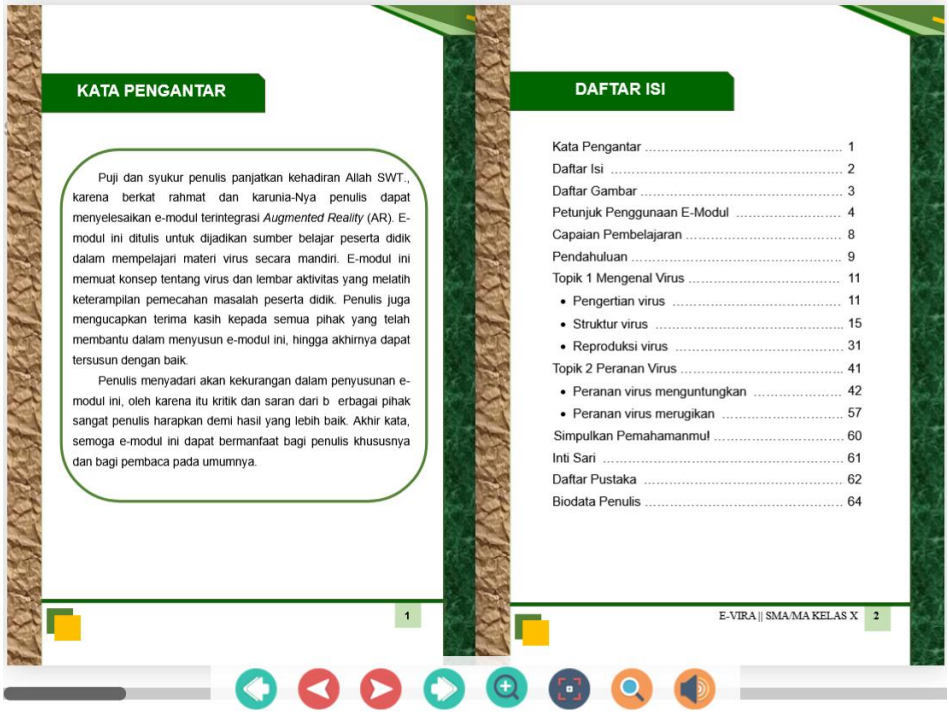

Image 3 Foreword and Table of Contents in E-VIRA

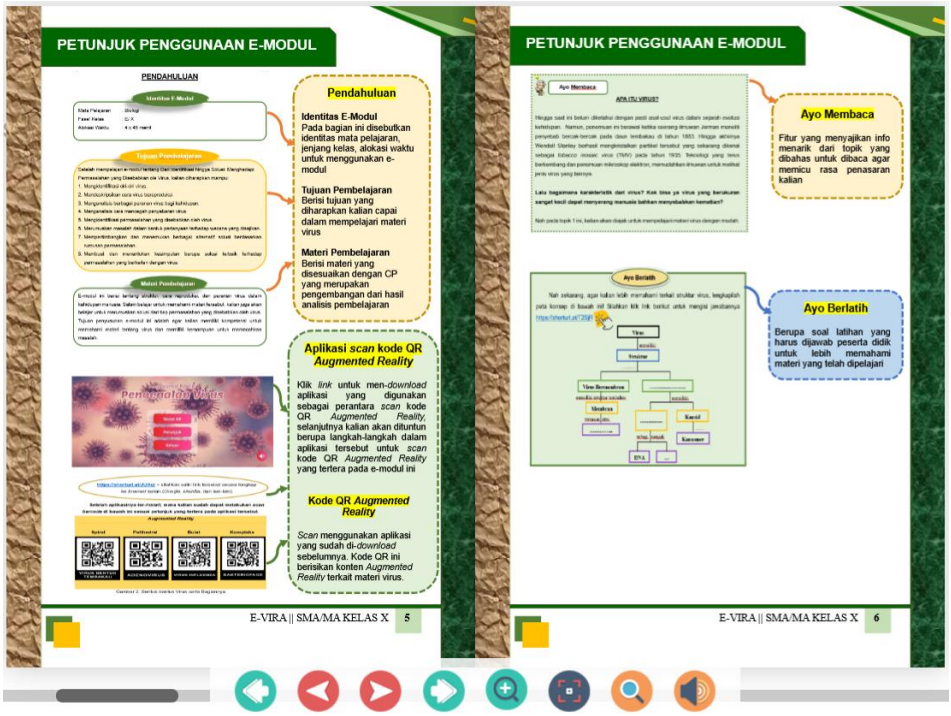

Image 4. Instructions for Using E-VIRA

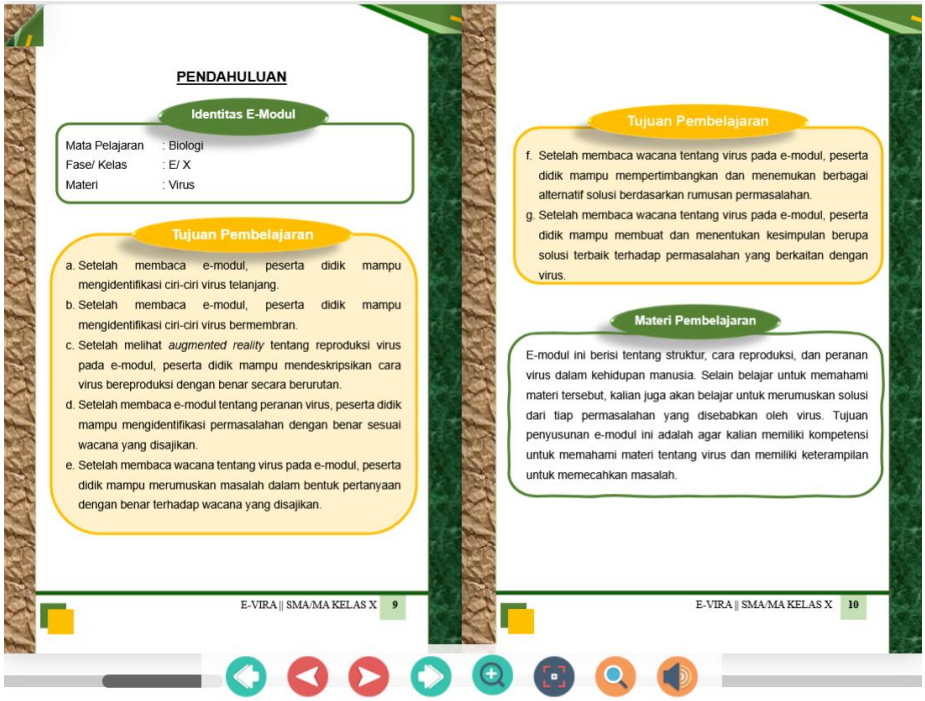

Image 5 Introduction Section of E-VIRA (E-Module Identity, Learning Objectives and Learning Materials)

Image 6 Augmented Reality Barcode Display on E-VIRA

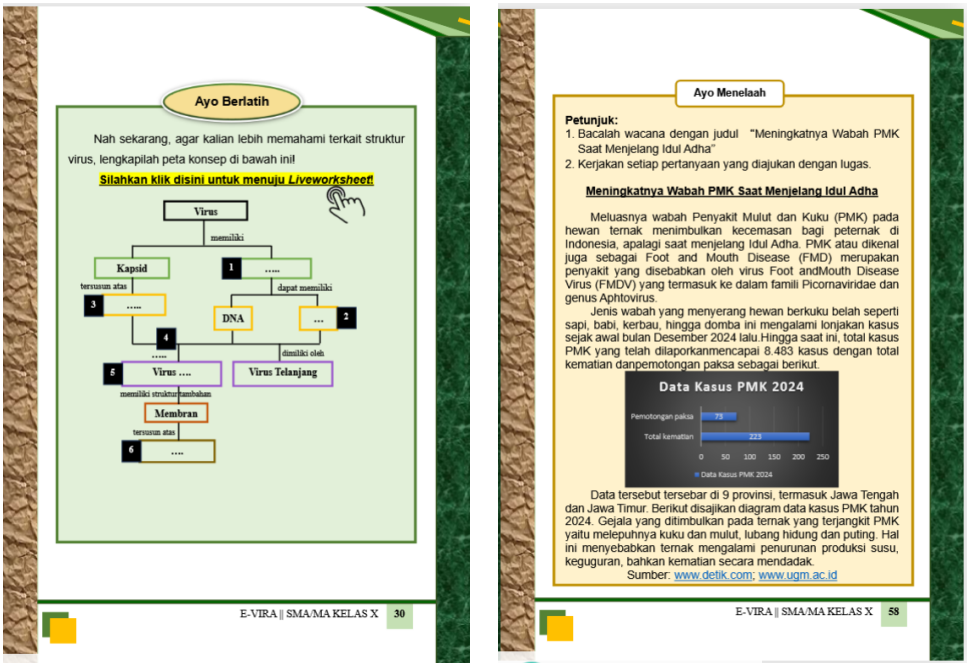

Image 7 Concept Map Test, Practice, and Problem Solving Skills Test

After the product is developed, the next stage involves validation by experts, who use assessment sheets from media and material experts to evaluate the feasibility of the e-module product. The developed augmented reality integrated virus e-module has been validated by two expert validator lecturers, namely material experts and media experts.

The validation results of the Augmented Reality-based learning module on cell material can be seen in Table 6.

Table 6 Results of E-Module Content Validity

No.	Aspect	Validators		$\bar{x}$ Validator Score	Σ Maximum Score	$\bar{x}$ Percentage (%)	Interpretation
		V1	V2				
1.	Compliance of Material with the Independent Curriculum	11	12	11.5	12	96	Very Valid
2.	Accuracy of Material	18	18	18	20	90	Very Valid
3.	Update of Material	8	8	8	8	100	Very Valid
4.	Encouraging Curiosity	8	8	8	8	100	Very Valid
		Average				97%	Very Valid

The augmented reality integrated e-module achieved an average value of 97% with very feasible or valid criteria, encompassing four key aspects: the suitability of the material to the independent curriculum, the accuracy of the material, the up-to-dateness of the material, and the encouragement of students' curiosity. This shows that the content of the learning e-module is under learning objectives, the systematic presentation makes it easier for students to understand the material, the language used in the module is easy to understand and the e-module on the augmented reality integrated virus material is suitable for use in the learning process to improve students' mental models and problem-solving skills. This statement is based on several research results that explore the development and effectiveness of augmented reality (AR) integrated electronic modules in education. These modules have been created for various subjects, including physics (Purwandari et al., 2021), thematic learning (Mahmud & Cempaka, 2022), chemistry (Mashami et al., 2021), and automotive technology (Setyono et al., 2023). Research consistently shows that AR-integrated modules are a viable and effective learning resource. These modules have been found to enhance critical thinking skills (Mashami et al., 2021), improve learning outcomes (Setyono et al., 2023), and receive positive responses from learners (Mashami et al., 2021; Purwandari et al., 2021). These modules typically include features such as 3D visualization, interactive content, and integrated assessments (Mahmud & Cempaka, 2022; Setyono et al., 2023). Validation processes involving experts consistently assess these modules as highly valid and suitable for use in learning (Mahmud & Cempaka, 2022; Mashami et al., 2021; Purwandari et al., 2021; Setyono et al., 2023).

The assessment of the e-module's feasibility in terms of construct validity involves various aspects related to the learning structure developed. Several indicators considered in the assessment of the construct validity of the augmented reality integrated e-module include graphic feasibility and language feasibility. The results of construct validity for each assessment indicator are shown in Table 7.

Table 7E-Module Construct Validity Results

No.	Aspect	Validators		$\bar{x}$ Validator Score	Σ Maximum Score	$\bar{x}$ Percentage (%)	Interpretation
		V1	V2				
Graphic Eligibility							
1.	Module Size	7	8	7.5	8	94	Very Valid
2.	*Cover* Design	22	22	22	24	92	Very Valid
3.	Content Design	41	43	42	44	95	Very Valid
Average Graphics Eligibility Aspect						94	Very Valid
Language Eligibility							
4.	Straightforward	11	11	11	12	92	Very Valid
5.	Communicative	4	4	4	4	100	Very Valid
6.	Dialogic and Interactive	8	8	8	8	100	Very Valid

No.	Aspect	Validators V1	V2	$\bar{x}$ Validator Score	Σ Maximum Score	$\bar{x}$ Percentage (%)	Interpretation
7.	Conformity to Student Development	8	7	7.5	8	94	Very Valid
8.	Conformity with Language Rules	7	8	7.5	8	94	Very Valid
9.	Use of Terms, Symbols or *Icons*	8	8	8	8	100	Very Valid
Average Language Eligibility						97	Very Valid
Average Construct Validity						96	Very Valid

The results of the E-VIRA construct validity indicator obtained a percentage of 96% with very feasible or valid criteria. In graphic feasibility, it includes three aspects of assessment, namely e-module size, cover design, and content design, obtaining a percentage of 94%. This indicates that the e-module's size and cover design present a good, attractive appearance.

Previous research shows that learning modules designed with attractive covers and illustrations can significantly increase student engagement and learning outcomes. According to Arifin's (2019) research, modules with attractive visual designs, including covers, are considered clear and of high quality by experts. Furthermore, according to McCartney et al. (2022). Modules designed to highlight the application of biological knowledge in careers can improve the identity and self-confidence of science students. In addition, modules with discovery image covers have shown effectiveness in increasing student interest and learning outcomes in plant biology (Suryandari, 2022).

The design aspect of the text message (content) in the e-module shows the appropriateness of the type of color, spacing, and font size, the accuracy of text presentation, and word choice. Recent research has shown that well-designed modules that combine images, text layout, and appropriate overall design significantly improve learning outcomes (Budi Ningrum & Rahmi, 2021). In various subjects, including geography, Indonesian, and foreign languages, graphical presentation of content consistently ranks high in material evaluations, often categorized as "very good" or "very appropriate" (Mahmud & Cempaka, 2022; Safitri et al., 2021). These findings underscore the importance of visual elements in creating engaging and effective educational resources.

In terms of language feasibility, the developed augmented reality integrated e-module obtained a percentage of 97% which is classified as very feasible or valid. This shows that the developed e-module uses straightforward, communicative, dialogic, and interactive language, and is under correct rules.

The construct validation assessment of the AR integrated virus e-module developed is included in the valid category of 96%. This means that the e-module is suitable for use as teaching material in terms of design, layout, typography, and placement of illustrations and images with several revisions. Improvements to this booklet focus on providing facts related to cells, tissues, and organs in plants from the author's environment. The provision of these facts and examples is in the form of photographs, making it easier for students to understand the material on the structure and function of plant tissue.

An augmented reality integrated e-module is also measured based on the readability level of the developed e-module. The readability level of the e-module is determined through a readability test conducted with a limited trial on students, so that researchers can obtain a better picture of the readability level of the AR integrated e-module directly. This test is carried out using the cloze test method, which involves deleting some words from a sentence in a text. In this study, the researcher

selected three texts from the e-module to assess its readability level, as developed through a cloze test. A total of 35 respondents from class XI participated in this stage, with the criterion that students had received material about viruses in previous classes.

During the development of E-VIRA, researchers encountered several obstacles in the field, particularly in the process of integrating Augmented Reality (AR) into the e-module. One of the technical challenges was ensuring the compatibility of the AR application with various student devices that had different specifications. In addition, during the readability test phase, it was found that some students still needed initial guidance in operating the AR feature because they were not yet familiar with the technology. Nevertheless, there was a notable positive aspect in the field: the students' high enthusiasm for using this module. The students felt that the 3D visualization of the virus displayed through AR made the previously abstract material more concrete and easier to understand. Teachers also reported that E-VIRA helped them explain material that had previously been difficult to visualize using only printed materials or standard presentations.

The results of the AR integrated e-readability test are in Table 8.

Table 8E-VIRA Reability Test Results

Text Number	Readability Percentage (%)	Interpretation
Text I	89	High
Text 2	77	High
Text 3	81	High
Average	82	High

Based on the results of the feasibility analysis of E-VIRA (E-Module Virus integrated with Augmented Reality) shows that in terms of quality and readability, the developed e-module shows good performance, as revealed in the results of the validity and readability tests that have been explained previously. In the validity test, E-VIRA can be grouped into the very feasible or valid category with a content validity of 97% and a construct validity of 96%. Meanwhile, the level of readability of E-VIRA, which was carried out through a readability test using a cloze test instrument, obtained a high category of 82%. Thus, E-VIRA has shown a good level of feasibility and validity, in line with the characteristics contained therein.

Product Advantages Compared to Previous Research

Compared to similar products in previous research, E-VIRA has several distinctive advantages. Based on literature reviews, previous studies by Mashami et al. (2021); Setyono et al. (2023) have shown that AR-based modules are effective in improving learning outcomes and critical thinking skills. However, E-VIRA's advantage lies in its approach that combines microscopic and abstract virus content with problem-solving skills training based on real-life contexts. In addition, E-VIRA not only relies on 3D visualization but also incorporates concept evaluation through concept maps, problem-solving exercises, and mental model assessments, which have not been widely used in similar products. This integrative approach makes E-VIRA superior in terms of strengthening the relationship between science concepts and their applications in life.

Despite its many advantages, E-VIRA also has limitations. This module is designed explicitly for problem-based learning (PBL) or inquiry learning models that emphasize problem solving and concept exploration. Therefore, its use is less than optimal if applied to conventional learning models or lectures that have minimal interaction. In addition, dependence on digital devices and internet connections is also a potential obstacle in schools with limited technological infrastructure. The use of AR requires devices that can run applications stably, so students without adequate devices risk experiencing gaps in their learning experience.

Based on the results and field findings, further research is strongly recommended to conduct quantitative empirical effectiveness tests through direct implementation in the classroom to precisely measure improvements in students' mental models and problem-solving skills, as well as to investigate the perceptions and experiences of both students and teachers during the use of the module. Additionally, exploring the potential for adapting and developing AR-integrated e-modules for other similar abstract biological concepts, or even conducting comparative studies with conventional teaching methods, would enrich our understanding of E-VIRA's innovative contributions to enhancing the quality of education.

Conclusion

Based on the content validity of the developed E-VIRA, construct validity, and readability level, this study has successfully developed E-VIRA (E-Module Virus Integrated Reality-Augmented) which is stated to be very feasible and valid for use in the learning process, as evidenced by the average score of 97% and 96% from expert validators, and the readability level of 82%. Thus, E-VIRA has shown a good level of acceptability and validity, in accordance with the characteristics it contains. It can be concluded that the validity of E-VIRA (E-VIRA module integrated with Augmented Reality) in improving students' mental models and problem-solving skills is valid for use in the learning process, as evidenced by the assessment results of two expert validators.

Given the proven validity and feasibility of E-VIRA, further research is strongly recommended to conduct quantitative empirical effectiveness tests through direct implementation in the classroom to precisely measure improvements in students' mental models and problem-solving skills, as well as to investigate the perceptions and experiences of both students and teachers during the use of the module. Additionally, exploring the potential for adapting and developing AR-integrated e-modules for other similar abstract biological concepts, or even conducting comparative studies with conventional teaching methods, would enrich our understanding of E-VIRA's innovative contributions to enhancing the quality of education.

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