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E-Module Assisted by Augmented Reality with a Discovery Learning Model on Virus Material to Increase Scientific Literacy and Learning Independence for Class X High School Students

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Abstract: This study aimed to assess the feasibility, practicality, and effectiveness of an e-module assisted by augmented reality with a discovery learning model on virus material to increase scientific literacy and learning independence for class X high school students. The study employed the ADDIE development model by Dick and Carey, employing a quasi-experimental, nonequivalent pretest-posttest control group design. The study involved 60 grade X students from SMA Negeri 1 Pengasih, with class X1 as the control group and X2 as the experimental group selected through cluster random sampling. Various instruments were utilized, including questionnaires from media and material experts, assessments by biology teachers, student responses, as well as tests on learning independence and science literacy. Data analysis encompassed descriptive and inferential statistics. The findings indicated the e-module's suitability, with media experts rating it at 98.37% and material experts at 99%. The practicality evaluation by biology teachers yielded a score of 95.32%, while student responses reached 96.96%. The N-Gain test demonstrated a substantial increase, and the One-Way MANOVA test indicated statistical significance ($p < 0.05$). This e-module has demonstrated its viability, practicality, and efficacy in enhancing scientific literacy and learning independence concerning virus material.

Keywords: Augmented Reality; Discovery Learning; E-module; Learning Independence; Science Literacy; Virus

Introduction

The advancement of science and technology in the 21st century has a significant impact on education, even in Indonesia. Technology and information compel the education sector to adjust, enhancing the effectiveness of learning activities. Rahayu et al. (2022) according educators need to leverage digital and communication technology to bolster learning. Apart from integrating technology into education, teachers must also cultivate various skills to assist students in adapting to the current era (Sutrisna, 2021).

Vital skills for students in the 21st century include comprehending, communicating, and applying scientific knowledge to address challenges (Mardhiyah et al., 2021). Odah et al. (2023) according to students should cultivate fundamental literacy, proficiency, and character traits. Scientific literacy encompasses crucial abilities. It involves thinking methodically and comprehending to resolve issues in the environment (Aristeidou et al., 2020). Valladares (2021) affirmed that scientific literacy empowers students to grasp concepts and put them into practice in daily life.

Many educators and educational institutions remain unaware of the significance of scientific literacy

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for students. The findings of PISA 2022 indicate that high school students in Indonesia still exhibit relatively low levels of scientific literacy (OECD, 2023). A study conducted at SMA Negeri 1 Pengasih revealed that only 32.9% of Class X students demonstrated low-level scientific literacy skills. This deficiency in scientific literacy is attributed to insufficient critical thinking abilities and a lack of interest in reading (Sumanik et al., 2021). Zulanwari et al. (2023) further noted that the introduction of new material poses challenges for students in answering questions. Enhancing students' scientific literacy skills can be achieved through the implementation of suitable models, methodologies, teaching resources, and assessment instruments (Novita et al., 2021). It is essential for students to cultivate their independent learning skills, with teachers serving solely as guides rather than constant supervisors (Rahayu et al., 2021).

Learning independence has a significant influence on science literacy outcomes. A survey conducted at SMA Negeri 1 Pengasih showed that the learning independence of grade X students only reached 48%, which is categorized as low. Students with low levels of learning independence tend to be less confident and dependent on others in completing their assignments (Ambiyar et al., 2020). To create an effective learning process, appropriate models, methods, and teaching materials are needed, as well as the use of information and communication technology that is in accordance with 21st century developments (Zahwa et al., 2022; Yuliana et al., 2021). Ambiyar et al. (2020) also emphasized that students' learning independence can be evaluated through the way they complete tasks in the learning process. Students who have high learning independence tend to complete tasks quickly and accurately, while those with low learning independence tend to be less confident and more dependent on others (Janson, 2024).

Interviews with biology teachers at SMA Negeri 1 Pengasih revealed that teachers predominantly utilize black-and-white printed textbooks and text-heavy PowerPoint presentations to deliver course material. However, these traditional teaching methods have proven ineffective in helping students meet learning objectives, particularly in the context of virus-related topics. The lack of innovative approaches by teachers to align teaching materials with contemporary advancements, coupled with time constraints, results in heavy reliance on standard textbooks. This reliance, in turn, restricts students' access to comprehensive information, thereby hindering the optimization of their skills. The limited access to information poses challenges in delivering course material, especially within the expansive and intricate domain of biology, which often involves abstract concepts that are challenging to demonstrate directly (Lewar, 2023).

Students found the virus material challenging to comprehend, with up to 73.3% attributing this difficulty to the inability to directly observe the material and inadequate teaching resources. This aligns with Febrina et al. (2023), who highlighted the complexity of understanding virus-related content among students. The lack of comprehension has a direct impact on learning outcomes that fall short of the Minimum Completion Criteria (KKM). Educators and students alike seek instructional materials that offer visual representations, flexibility, promote self-directed learning, and enhance scientific literacy. While smartphones have the potential to engage students in learning, their full educational utility remains untapped (Kholiq, 2020). This corresponds to the universal ownership of smartphones, with educational institutions possessing the necessary facilities and infrastructure to support smartphone-based learning activities. Leveraging technology includes developing applications to create modules enriched with diverse learning tasks.

Muktiani et al. (2022) emphasized that an effective e-module incorporate interactive features. Interactivity entails a dynamic exchange between educators and learners facilitated by a blend of text, visuals, graphics, audio, animations, videos, and digital interactions within the module. Such e-modules are essential tools for educators in disseminating educational content. Allo et al. (2022) highlighted that an optimal learning experience should be engaging, stimulating, motivational, and offer opportunities for students to enhance their skills and capabilities. The e-devised in this research stems from interviews with educators and an analysis of student requirements, revealing a desire among educators to leverage mobile devices to enhance students scientific literacy and foster independent learning.

Augmented reality-enhanced e-modules enhance learning engagement, fostering students' autonomy and enthusiasm for education. These modules are versatile for both in-class and out-of-class use, empowering students to pursue knowledge autonomously (Basit & Suhartini, 2023). Module design should incorporate effective educational frameworks like discovery learning to boost student engagement (Ariana et al., 2020; Sahnaz, 2023; Hastuti et al., 2023). Implementing the discovery learning approach not only ensures students receive information but also engages them in activities like identifying scientific issues, comprehending scientific phenomena, analyzing data, and assessing scientific evidence (Ariana et al., 2020; Kholiq, 2020). Augmented reality-supported e-modules utilizing the discovery learning model for teaching virus-related topics offer interactive experiences with virtual elements, facilitating a playful grasp of theoretical concepts (Kamiana et al., 2019; Kaharuddin et al., 2023). These e-modules cater to diverse learning styles within the self-directed curriculum, fostering autonomy and enhancing scientific literacy.

Based on the explanation above, several problems were found. Therefore, it is necessary to develop teaching material in the form of an by e-module assisted by augmented reality with a discovery learning model on virus material to increase scientific literacy and learning independence for class X high school students.

Method

This study employed a quasi-experimental approach utilizing a non-equivalent pretest-posttest control group design. The research methodology adopted was research and development (R&D) following the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) by Dick & Carey (Sugiyono, 2023). The study participants comprised 30 students from grade XI of SMA Negeri 1 Sewon and 60 students from grade X of SMA Negeri 1 Pengasih. Additionally, the participants encompassed 2 expert lecturers specializing in media and materials, along with 2 biology teachers. Sampling involved cluster random sampling through a study group draw. The outcome of this research is an e-integrated with augmented reality, employing a discovery learning approach on virus-related content to enhance the scientific literacy and learning independence of grade X SMA students. The development stages of the e-align with the ADDIE model, encompassing:

Analysis Phase

The first phase of this research involves conducting problem analysis in schools to address issues through alternative solutions. This phase includes various methods like 1) interviewing biology teachers to identify challenges in biology learning, 2) assessing student requirements for educational materials supporting learning and 21st-century skills, and 3) performing an initial study to evaluate scientific literacy skills and learning independence by completing scientific literacy tools and independence questionnaires.

Design Phase

The design stage involves gathering various references to be used as illustrations in creating the e-module. During this phase, the foundational structure of the e-is established through the development of a flowchart and storyboard. Additionally, the systematic organization of content, creation of student worksheets (LKPD), and design of evaluation tools to gauge the efficacy of the e-in enhancing scientific literacy and fostering independent learning are carried out.

Development Phase

The development phase involves transforming the compiled basic framework into an application product known as an e-module. Subsequently, the developed e-undergoes validation by media and material experts to assess its feasibility. This validation process is conducted by qualified experts in various assessment aspects. Apart from experts, practitioners such as biology teachers from SMA Negeri 1 Pengasih and SMA Negeri 1 Sewon, along with students from SMA Negeri 1 Sewon, participate in a small-scale trial to evaluate the e-module's practicality. During this phase, feedback, recommendations, and insights are gathered from experts, practitioners, and students to enhance the usability of the e-for the upcoming large-scale testing phase.

Implementation Phase

The implementation phase, also known as the large-scale or field trial phase, aims to assess the efficacy of the developed e-in enhancing scientific literacy and student learning independence in authentic settings, specifically during biology lessons on virus-related topics. This phase employs a quasi-experimental approach utilizing a non-equivalent pretest-posttest control group design. The field trial involved 60 tenth-grade students at SMA Negeri 1 Pengasih, selected using cluster random sampling for both the control and experimental groups. During this phase, an analysis was conducted by administering pretests and posttests during the learning activities to compare the average levels of scientific literacy and student learning independence.

Evaluation Phase

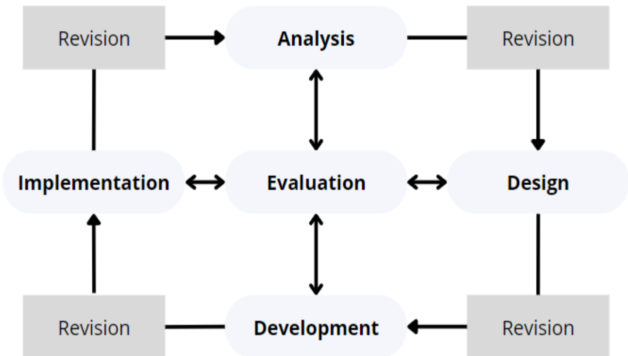

Figure 1. ADDIE Development Model Flow

The evaluation of the e-is based on the outcomes derived from the implementation stage and the four preceding stages. This evaluation serves as a follow-up to the implementation stage results, involving a sequence of data analysis procedures and rectification of e-shortcomings. The outcomes of this phase confirm that the developed e-has been assessed for viability, usability, and efficacy as an educational tool to enhance scientific literacy and independent learning in virus-related subjects, enabling its integration into educational institutions.

Research Tools

In the initial phases of research, development, and evaluation, various instruments are utilized. These include test and non-test instruments. The test instrument is designed to assess students' scientific literacy skills regarding virus material both before and after instruction. Non-test instruments encompass an e-assessment questionnaire evaluated by media and material experts, an assessment questionnaire by biology teacher practitioners and student feedback, a questionnaire gauging students' learning independence pre- and post-instruction, and a questionnaire on learning implementation.

Technique for Data Analysis

The data analysis method employed to evaluate product feasibility incorporates both quantitative and qualitative approaches. Media and material experts conducted the feasibility analysis, utilizing a Likert scale with four response options: very good/practical (4), good (3), less good (2), and very less good (1). The mean score per aspect was subsequently transformed into a 100-point value using the subsequent formula:

$$Score = \frac{Mean\ score}{Highest\ score} \times 100\% \quad (1)$$

Table 1. Product Feasibility Criteria (Riduwan, 2018)

Score (%)	Criteria
81-100	Very worthy
61-80	Worth it
41-60	Enough
21-40	Not worthy
≤ 20	Very inadequate

Data analysis was conducted on the practicality results, utilizing quantitative and qualitative methods to evaluate the product's practicality. The product's practicality analysis was performed using a Likert scale with 4 answer choices, evaluated by biology teachers and students using prepared instruments. The quantitative data obtained will be transformed into qualitative data using a specific formula.

$$Score = \frac{Mean\ score}{Highest\ score} \times 100\% \quad (2)$$

Table 2. Product Practicality Criteria (Riduwan, 2018)

Score (%)	Criteria
81-100	Very practical
61-80	Practical
41-60	Enought
21-40	Less practical
≤ 20	Very impractical

The product effectiveness analysis was conducted based on pretest and posttest results of scientific literacy and learning independence in trial classes. SPSS 25 software was utilized for descriptive statistics, including N-gain score, and inferential statistical analysis such as multivariate or one-way manova. N-gain was used to assess the improvement in students' pretest and posttest scores for scientific literacy and learning independence skills. Scientific literacy results were evaluated using the Gutman scale, assigning a score of 1 for correct answers and 0 for incorrect ones. Learning independence results were analyzed using a Likert scale with four options: strongly agree (4), agree (3), disagree (2), and strongly disagree (1). The assessment of student responses, both pretest and posttest, aimed to gauge the effectiveness of the e-assisted by augmented reality with the discovery learning model on virus material in enhancing scientific literacy and learning independence among high school students in class X.

Table 3. Partial Eta Squared Criteria (Stevens, 2016)

Partial Eta Squared	Criteria
$x > 0.138$	Height
$0.60 < x < 0.138$	Currently
$0.01 < x < 0.60$	Low

Result and Discussion

The creation of an e-assisted by augmented reality using a discovery learning approach on virus content to enhance the scientific literacy and learning autonomy of tenth-grade high school students is conducted following the ADDIE model, encompassing analysis, design, development, implementation, and evaluation.

Analysis Phase

The analysis carried out at this initial stage involves conducting interviews with biology teachers and analyzing teaching material needs. The aim of this stage is to assess teaching material needs, student characteristics, and learning materials.

Analysis of Educational Materials Requirements

The outcomes of interviews with biology educators at SMA Negeri 1 Pengasih revealed that enhancing scientific literacy and students' autonomy in learning is crucial in the autonomous curriculum to foster the acquisition of 21st-century competencies. The educators proposed the creation of an e-assisted by augmented reality utilizing a discovery learning approach to enhance learning, particularly on the topic of viruses. This e-includes 2D and 3D visuals, videos, and animations to engage students and enhance comprehension.

Teachers still rely on traditional black-and-white textbooks and text-heavy PowerPoint presentations for learning activities. However, these methods, including lectures, discussions, and summarizing with the 5M model, have proven ineffective in meeting learning objectives. Traditional textbooks focus on rote memorization and do not foster 21st-century skills. Printed teaching materials have limitations such as unclear images, susceptibility to damage, and high paper and ink consumption. In contrast, digital teaching materials are viewed as more practical as they can be accessed on smartphones, promote independent learning, and are more engaging. E-modules offer flexibility, enabling access anytime and anywhere, and align with technological advancements in education. The shift from printed modules to e-modules is deemed better suited to the demands of 21st-century learning.

A preliminary assessment conducted at SMA Negeri 1 Pengasih revealed that the scientific literacy proficiency of grade X students was suboptimal. The proficiency levels in explaining scientific phenomena or issues scientifically were 31.7% (low category), while designing and evaluating scientific investigations stood at 32.2% (low category). Additionally, interpreting scientific evidence and data was at 35.0% (moderate category). Findings from the questionnaire on learning independence indicated that the ability to not rely on others was at 41% (low category), self-initiative at 32% (very low category), self-discipline at 60% (moderate category), and self-responsibility at 41% (low category). In conclusion, students' scientific literacy and learning independence skills remain inadequate, highlighting the necessity for teaching materials that can enhance both proficiencies.

Analysis of Learning Materials

The findings from interviews and student needs analysis revealed challenges faced by teachers and students in conveying and comprehending educational material. The issue lies in the inadequacy of teaching resources to effectively illustrate the content on viruses. Viruses are a key component of the final biology curriculum (CP) in Phase E, focusing on empowering students to devise solutions for issues related to biodiversity, viruses, biotechnological advancements, ecosystem dynamics, and environmental shifts. These learning objectives are further detailed and transformed into core subjects within the virus-themed curriculum. Key topics covered in this encompass the historical background, characteristics, structure, life cycle, replication process, functions, as well as prevention and treatment strategies for viral infections.

Design Phase

The e-planning process comprises four key stages: 1) developing a foundational e-framework encompassing a flowchart and storyboard, featuring sections such as introduction, instructions, indicators, concept maps, resources, AR, LKPD, summative assessment, reference list, glossary, developer profile, and discussion forum. 2) Organizing content systematically based on the curriculum, translating learning outcomes (CP) into instructional objectives (TP) to establish a coherent flow of learning objectives (ATP). 3) Creating student worksheets (LKPD) for inclusion in the e-module. 4) Crafting assessment tools to gauge the e-module's efficacy in enhancing scientific literacy and self-directed learning. Following the development of the validation instrument, it undergoes consultation and validation by expert educators. Feedback and recommendations from these experts are then incorporated to refine the instrument for suitability in research endeavors.

Development Phase

The development phase is the third stage of this research. During this phase, implementation is conducted according to the pre-designed e-module. The outcomes of the e-development with augmented reality support are illustrated in Figure 2.

Figure 2. Display of the homepage, menu page, and E-module assisted by Augmented Reality

Following the development of the product, the subsequent phase involves validation by experts utilizing assessment sheets from media and material experts to evaluate the feasibility of the developed e-module. The evaluation outcomes from media and material experts are showcased in Tables 4 and 5.

Table 4. Product Evaluation Results by Media Members

Assessment Aspect	Score	Mark	Criteria
Software engineering	4	100	Very worthy
Visual communication	3.87	96.75	Very worthy
Average		98.37	Very worthy

According to Table 4, the developed product is deemed highly suitable for educational purposes based on the evaluation by media experts. This outcome aligns with the research by Ariana et al. (2020), affirming that the discovery learning-oriented focusing on plant tissue content is deemed appropriate for educational use as assessed by media expert educators specializing in software engineering and visual communication. This electronic is recognized for its high quality, utilization of clear language following the General Guidelines for Indonesian Spelling (PUEBI), and user-friendly interface, thereby enhancing the learning experience. Additionally, the provides explicit usage instructions, fully functional buttons, and engaging presentations of images, videos, and animations. Lathifah (2021) emphasizes that educational materials are considered suitable when they are user-friendly during the learning process and feature fully operational buttons.

Table 5. Product Assessment Results by Material Experts

Assessment Aspect	Score	Mark	Criteria
Material eligibility	4	100	Very worthy
Accuracy of material	4	100	Very worthy
Didactic	3.8	95	Very worthy
Construction	4	100	Very worthy
Technical	4	100	Very worthy
Average		99	Very worthy

According to Table 5, the developed product has been deemed highly suitable for educational purposes by material experts' evaluation. Nurhidayanti et al. (2022) affirmed that employing AR with the discovery learning model is viable. Portana et al. (2021) elucidated that the content within teaching materials serves as a tool to aid educators in delivering information effectively, thereby facilitating the teaching and learning process. The evaluation conducted by media experts, consistent with the findings of Aprilia et al. (2020), indicates that e-modules enhance students' independence in learning and enhance engagement through text, images, audio, and video. Lathifah (2021) asserted that teaching materials are deemed suitable if they are user-friendly for learning purposes. The assessment from validators revealed that the developed teaching materials were rated as highly suitable or good, allowing for their utilization in small-scale student assessments.

Following the completion of the feasibility assessment, the product underwent enhancements guided by recommendations and insights from expert educators. Subsequently, the product proceeded to the practical testing phase, involving biology teacher practitioners and student feedback. The outcomes of the practical evaluation conducted by biology teachers and students are detailed in Tables 6 and 7.

Table 6. Product Assessment Results by Biology Teachers

Assessment Aspect	Score	Mark	Criteria
Software engineering	3.5	87.5	Very practical
Visual communication	4	100	Very practical
Material eligibility	3.75	93.75	Very practical
Accuracy of material	3.83	95.75	Very practical
Didactic	3.91	97.75	Very practical
Construction	3.95	98.75	Very practical
Technical	3.75	93.75	Very practical
Average		95.32	Very practical

Referring to Table 6, the developed product is deemed highly functional for use as evaluated by biology teacher practitioners. Educational resources are deemed functional when they fulfill practicality criteria, are user-friendly, and receive favorable evaluations (Harjuni et al., 2023). According to Szmeja et al. (2023), an e-module is considered practical if its features operate optimally and offer flexibility in usage. A practical e-module is one that is interactive, easily comprehensible, and includes visuals, videos, and engaging interfaces to capture students' attention and facilitate comprehension of the content (Astuti et al., 2024).

Table 7. Results of Product Assessment by Students

Assessment Aspect	Score	Mark	Criteria
Presentation	3.86	96.39	Very practical
Linguistics	3.87	96.67	Very practical
Visual communication	3.89	97.29	Very practical
Benefits	3.9	97.5	Very practical
Average		96.96	Very practical

According to Table 7, the developed product is deemed highly practical for biology education, as indicated by student feedback. These findings align with Gustiar et al. (2023), who suggest that educational resources following Indonesian spelling conventions and of high quality are suitable for implementation. Rahayu (2020) suggest that an e-module is considered practical when it incorporates engaging features and fully functional buttons. Lidayni (2022) also proposes that student response surveys serve as a valuable tool for evaluating product practicality, as they capture students' initial learning experiences.

Implementation Stages

The implementation phase commenced following the revision of the e-based on feedback from educators and students, ensuring its optimal utilization in the educational setting. The implementation took place at SMA Negeri 1 Pengasih, involving two groups: X1 as the control group (30 students) and X2 as the experimental group (30 students), employing a nonequivalent pretest-posttest control group quasi-experimental design. A pretest was administered to assess the initial levels of scientific literacy and learning independence before the intervention. The experimental group utilized the e-in two sessions (totaling 4 instructional hours), whereas the control group used printed materials following the 5M model. Subsequent to the learning process, both groups underwent a posttest to assess the final outcomes of scientific literacy and learning independence.

The product effectiveness test began with a descriptive analysis of students' scientific literacy and learning independence. The results showed that the experimental class using an augmented reality-assisted e-with a discovery learning model had a higher score than the control class that did not use the e-module. However, descriptive statistical analysis was not enough to prove the effectiveness of the product being developed. The results of descriptive statistics on students' scientific literacy can be seen in tables 8 and 9.

Table 8. Results of Descriptive Statistical Analysis of Science Literacy

	Experimental Class	Control Class
Average (%)	77	49
N-gain	0.77	0.49
Criteria	Height	Currently

Referring to Table 8, the utilization of e-modules assisted by augmented reality and employing the discovery learning model for teaching virus-related content demonstrated a noteworthy influence on the scientific literacy of students in the experimental group compared to the control group. This disparity stems from the distinct methodologies applied in the two groups. As per Sugiyono (2023), the non-equivalent control group design research framework involves a control group and an experimental group that share similar conditions but receive different interventions, thereby impacting the research outcomes. The findings indicate that the experimental group witnessed a 77% enhancement in scientific literacy, whereas the control group saw a 49% improvement. The 28% boost in scientific literacy within the experimental group can be attributed to the integration of e-modules assisted by augmented reality within the framework of the discovery learning model.

Based on Table 9, it states that the developed e-has a significant impact on the learning independence of students in the experimental class compared to the control class. This difference is caused by the use of e-modules assisted by augmented reality with the discovery learning model. The increase in learning independence in the experimental class reached 78%, while in the control class it was only 55%. This shows that there was a 23% increase in learning independence in the experimental class.

Table 9. Results of Descriptive Statistical Analysis of Learning Independence

	Experimental Class	Control Class
Average (%)	78	55
N-gain	0.78	0.55
Criteria	Height	Currently

Inferential statistical tests were conducted to assess the effectiveness of the augmented reality-assisted e-with the discovery learning model to improve students' scientific literacy and learning independence on virus material. Data on scientific literacy and learning independence were analyzed using parametric methods if they met the requirements, such as multivariate normal distribution, linearity between dependent variables, and homogeneity of the variance-covariance matrix (Stevens, 2016). The results of the prerequisite tests are presented in tables 10, 11, and 12, including:

Table 10. Results of Multivariate Normality Test Analysis

		Mahalanobis Distance	qi
Mahalanobis Distance	Pearson Correlation	1	.957**
	Sig. (2-tailed)		.000
	N	60	60
Qi	Pearson Correlation	.957**	1
	Sig. (2-tailed)	.000	
	N	60	60

Based on Table 10, it states that the correlation coefficient value is 0.957, which indicates a high correlation. The significance value of 0.00 (sig. <0.05) indicates that the data is normally distributed multivariately. Furthermore, in Table 11 the results of the linearity test between each pair of dependent variables.

Table 11. Linear Relationship Test Results

	Sig.	(p) Sig.
Deviation from Linearity	0.315	P > 0.05

Referring to Table 11, a linear relationship exists between each pair of dependent variables within every independent variable class. This relationship is identified by the deviation from linearity value. A deviation from the linearity value of 0.315 indicates a linear relationship between the two dependent variables. Furthermore, Table 12 displays the outcomes of the homogeneity test for the variance-covariance matrix, revealing a significance value of 0.152 (> 0.05), signifying homogeneity within the variance-covariance matrix.

Table 12. Results of the Homogeneity Test of the Variance-Covariance Matrix

Box's M	F	Sig.
15.649	1.448	0.152

The prerequisite test results confirm that the necessary conditions for performing hypothesis testing with parametric tests have been satisfied through the multivariate test. Consequently, hypothesis testing in this study utilized the one-way MANOVA test. This test seeks to compare the mean levels of scientific literacy and learning independence among students utilizing e-modules with augmented reality in conjunction with the discovery learning model and those who do not use e-modules concurrently.

The decision-making criteria in this study utilizing the MANOVA test rely on the Hotelling's Trace value. This is due to the study encompassing two categories of dependent variables and fulfilling the data requirements with a multivariate normal distribution and a homogeneous variance-covariance matrix. A higher Hotelling's Trace value corresponds to a more significant impact on the model.

Table 13. Results of Multivariate Test Analysis (MANOVA)

Effect	Sig.	Partial Eta Squared
Hotelling's Trace	0.000	0.673

Based on Table 13, it states that the significance value of 0.05 ($p < 0.05$) indicates that H0 is rejected and Ha is accepted, meaning that there is a significant difference in scientific literacy and learning independence between students who use e-modules assisted by augmented reality with the discovery learning model compared to students who do not use it. This difference indicates that e-modules assisted by augmented reality with the discovery learning model are effective in improving scientific literacy and learning independence. Furthermore, the effect size test was conducted to determine the effect or contribution of the e-developed on each research variable. The results of the effect size test are presented in Table 14.

Table 14. Results of the Effect Size Test of Scientific Literacy and Learning Independence

Variable	Sig.	Partial Eta Squared
Science literacy	0.000	0.530
Learning independence	0.000	0.472

According to Table 14, the partial eta squared value for the scientific literacy variable is 0.530, with a significance of 0.000 < 0.05, indicating a variance in scientific literacy between students utilizing e-modules with augmented reality under the discovery learning model and those who do not. The impact of the e-module on scientific literacy is 53%, meeting high criteria. Similarly, for the learning independence variable, a partial eta squared value of 0.427 is observed, with a significance of 0.000 < 0.05, signifying a notable distinction. The e-module's influence on learning independence is 47.2%, also meeting high criteria.

Table 15. Correlation Test Results

		Science literacy	Learning independence
Scientific literacy	Pearson Correlation	1	.431*
	Sig. (2-tailed)		.018
	N	30	30
Learning independence	Pearson Correlation	.431*	1
	Sig. (2-tailed)	.018	
	N	30	30

Based on Table 15, it states that the Pearson correlation value (r count) of scientific literacy and learning independence is obtained at 0.431. In addition, the results of the Pearson correlation (r count) of scientific literacy and learning independence obtained positive results and there is a sign (*) indicating that there is a unidirectional (positive) relationship in the two variables. This shows that increasing scientific literacy will be followed by an increase in learning independence and vice versa.

Kholiq (2020) elucidated the effectiveness of BDF AR2 in enhancing students' scientific literacy in the study of flower structure. Setia (2023) further highlighted that scientific literacy skills can be enhanced through the utilization of discovery learning-based modules in science education. The incorporation of discovery learning in the educational framework influences students' interaction with the subject matter. This approach entails providing initial stimuli to prepare students to focus on issues and equips them with the skills to identify, gather, analyze, and draw conclusions from the challenges presented. The findings of the research demonstrate that students in the experimental group displayed a keen focus on the given problems, engaging in discussions to address pertinent questions. Kulsum (2020) expounded on how the implementation of the discovery learning model in education can stimulate students' self-motivation, foster classroom collaboration, and enhance their capacity to process and interpret data to draw evidence-based conclusions, which are integral components of scientific literacy.

Kulsum et al. (2020) asserted that the discovery learning model comprises six stages. The initial stage involves providing stimulation and exposing students to discourse and images to enhance their problem-analysis skills. This phase aligns with identifying issues in the scientific literacy indicator. Subsequently, the problem identification stage necessitates students to recognize and articulate problems from the presented discourse and images, in line with predicting phenomena and formulating questions in the scientific literacy indicator. During the data collection stage, students engage in autonomously locating and gathering data using e-modules with augmented reality or other literary resources, aligning with the scientific literacy indicator of designing problem-solving.

The data processing stage involves processing information gathered during problem-solving activities conducted by students. This stage aligns with data analysis and transforming data from one format to another in the scientific literacy indicator. The validation stage focuses on guiding students to assess pertinent information derived from data, statements, or other representations acquired. This stage corresponds to the scientific literacy indicator of explaining hypotheses. The final stage entails drawing conclusions, engaging the class in deriving conclusions from discussions with the teacher's assistance. This stage aligns with the scientific literacy indicator of making decisions grounded in scientific discoveries and evidence.

The utilization of e-modules combined with augmented reality within the discovery learning framework can serve as an educational tool that highlights contextual and authentic challenges. This approach facilitates critical thinking, problem identification, and concept comprehension among students. Studies conducted by Nursaban et al. (2021) indicate that the discovery learning model is more efficient in enhancing scientific literacy compared to traditional methods. The benefits of this model encompass guiding students to collaborate in resolving issues through observation and interaction, aiding in deriving conclusions from problem analysis and data gathering, and fostering learning independence (Setia, 2023).

Augmented reality-enhanced e-modules offer various features that can enhance learning motivation, including the presentation of 3-dimensional images of viruses, discussion forums, LKPD, and summatives. Utilizing e-modules can extend students' learning time by providing knowledge and learning opportunities without constraints of space and time (Agusningtyas et al., 2024). The incorporation of 3-dimensional images and videos in e-modules can aid students in transforming abstract concepts into more tangible ones (Kelana et al., 2021). The progression of the era has resulted in advancements in science and technology, urging students to become self-reliant in the learning process through the utilization of diverse available learning resources. Leveraging learning resources can offer profound insights as a discovery process and facilitate optimal comprehension of the material by students.

The utilization of e-modules can facilitate students in self-directed learning by providing usage instructions and self-learning guides (Nurhasnah et al., 2020). These e-modules also feature LKPD containing virus-related issues pertinent to students' daily lives. Consequently, students can independently explore all information sources within the educational materials and construct their own understanding. Furthermore, the developed educational materials incorporate supplementary learning resources that enhance students' knowledge and information on the subject matter. According to Choirunnisya et al. (2021), students are deemed to have achieved independent learning when they can autonomously acquire, manage, and interconnect information.

Strong learning independence in students has an indirect impact on their scientific literacy skills, and vice versa. This is evidenced by the results of a correlation test revealing a positive Pearson correlation coefficient of 0.431 between learning independence and scientific literacy. This suggests a moderate correlation between the two variables, driven by their positive association. Students with robust learning independence demonstrate systematic thinking, enhancing the effectiveness and optimization of their scientific literacy. Conversely, students with proficient scientific literacy skills typically exhibit high levels of learning independence (Mashudi et al., 2024).

When examining the competency elements within scientific literacy indicators, such as explaining scientific phenomena or issues scientifically, designing and evaluating scientific investigations, and interpreting evidence and data scientifically, each necessitates learning independence. Mashudi et al. (2024) elucidated that enhancing students' learning independence could positively influence their scientific literacy. Enhanced scientific literacy among students can enhance their cognitive abilities in autonomously solving problems and augment the responsibility in learning imparted by educators (Suharjono, 2022).

Conclusion

The e-module assisted by augmented reality with a discovery learning model on virus material proves to be suitable for integration into biology learning activities. This conclusion is drawn from assessments conducted by media experts, material experts, biology teacher practitioners, and student responses, all of which yielded high scores and deemed the e-module very suitable and practical. Moreover, the effectiveness of the e-module in enhancing scientific literacy and fostering learning independence among class X SMA students is evident from the N-gain score test and the one-way MANOVA test, which demonstrated significant improvements.

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Retno Sandi Saputra developed the research concept, methods, design, data analysis, original draft, funding, management, responsibility, and coordination of the research activities, whereas Bernadetta Octavia oversaw, supervised, and validated the research instruments.

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References

Agusningtyas, D., Erika, F., & Qadar, R. (2024). Analysis of Teachers' Needs for Interactive e-Module to Train Critical Thinking Skills in the Merdeka Curriculum Era. *International Journal of STEM Education for Sustainability*, *4*(1), 79–96. https://doi.org/10.53889/ijses.v4i1.342

Allo, A. Y. T., & Suhendra, C. D. (2022). Development of E-Modules Using Augmented Reality in Physics Teaching At High School of Manokwari Regency. *Jurnal Penelitian Pendidikan IPA*, *7*(2), 52–59. https://doi.org/10.26740/jppipa.v7n2.p52-59

Ambiyar, A., Aziz, I., & Melisa, M. (2020). Perbedaan Kemandirian Belajar Siswa pada Masa Pandemi di SMAN 1 Lembah Melintang dan SMAN 1 Lembah Gumanti. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *4*(2), 1246–1258. https://doi.org/10.31004/cendekia.v4i2.367

Aprilia, I., & Suryadarma, I. G. P. (2020). E-Module of Mangrove Ecosystem (Emme): Development, Validation and Effectiveness in Improving Students' Self-Regulated. *Biosfer: Jurnal Pendidikan Biologi*, *13*(1), 114–129. https://doi.org/10.21009/biosferjpb.v13n1.114-129

Ariana, D., Situmorang, R. P., & Krave, A. S. (2020). Pengembangan Modul Berbasis Discovery Learning pada Materi Jaringan Tumbuhan untuk Meningkatkan Kemampuan Literasi Sains Siswa Kelas XI IPA SMA. *Jurnal Pendidikan Matematika dan IPA*, *11*(1), 34–46. https://doi.org/10.26418/jpmipa.v11i1.31381

Aristeidou, M., & Herodotou, C. (2020). Online citizen science: A systematic review of effects on learning and scientific literacy. *Citizen Science: Theory and Practice*, *5*(1), 1–12. https://doi.org/10.5334/cstp.224

Astuti, Y., Suyidno, S., Suryajaya, S., & Jamilah, N. (2024). Development of E-Modules on Puberty Materials to Train Digital Literacy of Madrasah Ibtidaiyah Learners. *SEJ (Science Education Journal)*, *8*(1), 1–18. https://doi.org /10.21070/sej.v8i1.1643

Basit, M., & Suhartini, S. (2023). Module Discovery Learning Biodiversity Material Based on Gunungkidul Beach to Increasing Interest and Independence in Learning of High School Students. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 12116–12129. https://doi.org/10.29303/jppipa.v9i12.5159

Choirunnisya, L. R., & Sudira, P. (2021). Developing an E-Module of Making Edmodo-Based Hosanna Moda System Bustier to Improve Learning Independence and Learning Achievement. *Jurnal Pendidikan Vokasi*, *11*(2), 275–293. https://doi.org/10.21831/jpv.v11i3.40196

Febrina, R., Arsih, F., Alberida, H., & Fadilah, M. (2023). Analisis Kebutuhan Modul Interaktif Materi Virus Berbasis Website Google Sites untuk Siswa SMA. *Jurnal Ilmiah Profesi Pendidikan*, *8*(4), 2131–2136. https://doi.org/ 10.29303/jipp.v8i4.1676

Gustiar, A. W., Saepurokhman, A., & Irianto, A. (2023). Analisis Kelayakan Isi dan Penggunaan Bahasa dalam Buku Teks Bahasa Indonesia Kelas IX Karya Agus Trianto, dkk. Sebagai Upaya Pemilihan Bahan ajar Bermutu. *Literat-Jurnal Pendidikan*

Bahasa dan Sastra Indonesia, *2*(1), 62–70. Retrieved from https://ejournal.unsap.ac.id/index.php/literat/article/view/693

Harjuni, M. R., Halidjah, S., & Ghasya, D. A. V. (2023). Pengembangan Suplemen Bahan Ajar Ebook Berbasis Kearifan Lokal di KALBAR Bermuatan Nilai Karakter. *Journal on Education*, *6*(1), 6048–6055. https://doi.org /10.31004/joe.v6i1.3806

Hastuti, A. S., Rakhmawati, D., & Dwijayanti, I. (2023). Keefektifan Pembelajaran Problem Based Learning dan Discovery Learning dalam Peningkatan Literasi Sains Siswa SD. *Didaktik: Jurnal Ilmiah PGSD STKIP Subang*, *9*(2), 1394–1405. https://doi.org/ 10.36989/didaktik.v9i2.858

Janson, S. (2024). *ELearning - Virtual Independent Learning: Digital Memory Training, Self-motivation, Goal Achievement, Anti-stress Concept, Mindfulness, Advanced Online Formatio, Further Education*. Best of HR – Berufebilder.

Kaharuddin, K., Pernando, Y., Marfuah, M., & Musliadi, K. H. (2023). Aplikasi Augmented Reality (AR) Sebagai Media Pembelajaran Sistem Rangka Manusia. *Journal of Information System Research (JOSH)*, *4*(4), 1168–1175. https://doi.org/10.47065/josh.v4i4.3685

Kamiana, A., Kesiman, M. W. A., & Pradnyana, G. A. (2019). Pengembangan Augmented Reality Book Sebagai Media Pembelajaran Virus Berbasis Android. *KARMAPATI (Kumpulan Artikel Mahasiswa Pendidikan Teknik Informatika)*, *8*(2), 165–171. https://doi.org/10.23887/karmapati.v8i2.18351

Kelana, J. B., & Wardani, D. S. (2021). *Model Pembelajaran IPA SD*. Edutrimedia Indonesia.

Kholiq, A. (2020). Development of B D F-AR 2 (Physics Digital Book Based Augmented Reality) to train students' scientific literacy on Global Warming Material. *Berkala Ilmiah Pendidikan Fisika*, *8*(1), 50–58. https://doi.org/10.20527/bipf.v8i1.7881

Kulsum, N. N. S., Surahman, E., & Ali, M. (2020). Implementasi Model Discovery Learning Terhadap Literasi Sains dan Hasil Belajar Peserta Didik Pada Sub Konsep Pencemaran Lingkungan. *Biodidaktika: Jurnal Biologi Dan Pembelajarannya*, *15*(2), 55–65. http://dx.doi.org/10.30870/biodidaktika.v15i2.8722

Lathifah, Y. H. (2021). Modul Sistem Pencernaan Manusia Berbasis Augmented Reality (AR) sebagai Sumber Belajar. *Neuron : Journal of Biological Education*, *1*(1), 1–14. https://doi.org/10.14421/neuron.2021.11-01

Lewar, A. K., & Suhartini, S. (2023). Pengembangan Modul Berbentuk Scrapbook pada Materi Sistem Saraf untuk Meningkatkan Hasil Belajar Siswa SMA Kelas XI. *Jurnal Pendidikan Sains Indonesia*, *11*(1), 96–112. https://doi.org/10.24815/jpsi.v11i1.26980

Lidayni, A., Arnidah, A., & Anwar, C. R. (2022). Analisis Kelayakan Isi dan Penggunaan Bahasa dalam Buku Teks Bahasa Indonesia Kelas IX SMP Karya Agus Trianto, dkk. Sebagai Upaya Pemilihan Bahan Ajar Bermutu. *Inovasi Kurikulum*, *19*(2), 263–276. https://doi.org/10.17509/jik.v19i2.45411

Mardhiyah, R. H., Aldriani, S. N. F., Chitta, F., & Zulfikar, M. R. (2021). Pentingnya Keterampilan Belajar di Abad 21 Sebagai Tuntutan dalam Pengembangan Sumber Daya Manusia. *Lectura: Jurnal Pendidikan*, *12*(1), 29–40. https://doi.org/10.31849/lectura.v12i1.5813

Mashudi, M., Raharjo, T. J., & Kusmawan, U. (2024). Development of a Science Learning Module using the Guided Discovery Method to Increase Learning Independence and Scientific Literacy Ability. *Jurnal Penelitian Pendidikan IPA*, *10*(2), 982–987. https://doi.org/10.29303/jppipa.v10i2.6244

Muktiani, N. R., Soegiyanto, Siswantoyo, Rahayu, S., & Hermawan, H. A. (2022). Augmented reality mobile app-based multimedia learning of Pencak Silat to enhance the junior high school students' learning outcomes. *Cakrawala Pendidikan*, *41*(2), 553–568. https://doi.org/10.21831/cp.v41i2.49217

Novita, M., Rusilowati, A., Susilo, S., & Marwoto, P. (2021). Meta-Analisis Literasi Sains Siswa di Indonesia. *Unnes Physics Education Journal*, *10*(3), 209–215. https://doi.org/10.15294/upej.v10i3.55667

Nurhasnah, N., Kasmita, W., Aswirna, P., & Abshary, F. I. (2020). Developing Physics E-Module Using "Construct 2" to Support Students' Independent Learning Skills. *Thabiea : Journal of Natural Science Teaching*, *3*(2), 79. https://doi.org/10.21043/thabiea.v3i2.8048

Nurhidayanti, A., Nofianti, E., Kuswanto, H., Wilujeng, I., & Suyanta, S. (2022). Analisis Kemandirian Belajar Peserta Didik SMP Melalui Implementasi LKPD Discovery Learning Berbantuan Augmented Reality. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, *10*(2), 312–328. https://doi.org/10.24815/jpsi.v10i2.23719

Nursaban, E., & Ewisahrani, E. (2021). Pengaruh Model Pembelajaran Discovery Learning dan Self Efficacy Terhadap Keterampilan Literasi Sains. *JISIP (Jurnal Ilmu Sosial dan Pendidikan)*, *5*(4), 1502–1511. https://doi.org/10.58258/jisip.v5i4.2611

Odah, A., & Yuniarti, Y. (2023). Budaya Literasi Sekolah untuk Mengembangkan Keterampilan Abad 21. *Jurnal Basicedu*, *7*(6), 4193–4203.

https://doi.org/10.31004/basicedu.v7i6.6730

OECD. (2023). PISA 2022 Result (Volume I): The State of Learning and Equity in Education. In *PISA 2022 Results (Volume I): The State of Learning and Equity in education* (Vol. 1). Retrieved from https://www.oecd-ilibrary.org/education/pisa-2022-results-volume-i_03c74bdd-en.

Portana, H. V., Fronda, J. G., Policarpio, D. G. T., Rome, C. R., & Lllames, G. A. (2021). Effectiveness and Acceptability of Instructional Materials in the Enhancement of Students' Academic Achievement. *International Journal of Advanced Engineering, Management and Science*, *7*(1), 12–15. https://doi.org/10.22161/ijaems.71.2

Rahayu, I. F., & Aini, I. N. (2021). Analisis Kemandirian Belajar Dalam Pembelajaran Matematika Pada Siswa SMP. *Jurnal Pembelajaran Matematika Inovatif*, *4*(4), 789–798. https://doi.org/10.22460/jpmi.v4i4.789-798

Rahayu, R., Iskandar, S., & Abidin, Y. (2022). Inovasi Pembelajaran Abad 21 dan Penerapannya di Indonesia. *Jurnal Basicedu*, *6*(2), 2099–2104. https://doi.org/10.31004/basicedu.v6i2.2082

Rahayu, M. S. I., & Kuswanto, H. (2020). Development of Android-Based Comics Integrated with Scientific Approach in Physics Learning. *Journal of Physics: Conference Series*, *1440*(1), 1–8. https://doi.org/10.1088/1742-6596/1440/1/012040

Riduwan. (2018). *Skala Pengukuran Variabel-Variabel Penelitian*. Alfabeta.

Sahnaz, S. (2023). *Pengembangan E-LKPD Model DL Materi Keanekaragaman Gen Berbasis Keanekaragaman Varietas Belimbimg di Agrowisata Belimbing Karangsari untuk Meningkatkan Literasi Sains dan Kemandirian Belajar Peserta Didik Kelas X SMA*. (Unpublished master thesis). Universitas Negeri Yogyakarta.

Setia, W. S. (2023). Pengembangan E-Modul berbasis Discovery Learning Untuk Meningkatkan Literasi Sains Peserta Didik. *DIADIKC: Jurnal Ilmiah Teknologi Pendidikan*, *13*(2), 325–337. https://doi.org/10.33369/diadik.v13i2.31544

Stevens, J. (2016). *Applied Multivariate Statistics for the Social Sciences*. Lawrence Elbraum Associates.

Sugiyono. (2023). *Metode Penelitian Kuantitatif Kualilatif dan R&D*. Alfabeta.

Suharjono, A. V. & Y. W. (2022). Pengembangan Pocket Book untuk Meningkatkan Kemandirian Belajar dan Literasi Sains Peserta Didik SMA. *Jurnal Pendidikan Fisika*, *09*(02), 41–65. https://dx.doi.org/10.21831/jpf.v9i2.18354

Sumanik, N. B., Nurvitasari, E., & Siregar, L. F. (2021). Analisis Kemampuan Literasi Sains Mahasiswa Calon Guru Pendidikan. *Jurnal Inovasi Pendidikan Sains*, *12*(1), 22–32. https://doi.org/10.20527/QUANTUM.V12I1.10215

Sutrisna, N. (2021). Analisis Kemampuan Literasi Sains Peserta Didik SMA di Kota Sungai Penuh. *Jurnal Inovasi Penelitian*, *1*(12), 2683–2694. https://doi.org/ 10.47492/jip.v1i12.530.

Szmeja, P., Fornés-Leal, A., Lacalle, I., Palau, C. E., Ganzha, M., Pawłowski, W., ... & Schabbink, J. (2023). ASSIST-Iot: a Modular Implementation of a Reference Architecture for the Next Generation Internet of Things. *Electronics*, *12*(4), 1–33. https://doi.org/10.3390/electronics12040854

Valladares, L. (2021). Scientific Literacy and Social Transformation. *Science & Education*, *30*(3), 557–587. https://doi.org/10.1007/s11191-021-00205-2

Yuliana, Y., & Atmojo, I. R. W. (2021). Analisis Kebutuhan Bahan Ajar Digital Interaktif untuk Pembelajaran Ilmu Pengetahuan Alam Abad 21. *Jurnal Basicedu*, *5*(6), 6034–6039. https://doi.org/10.31004/basicedu.v5i6.1733

Zahwa, F. A., & Syafi'i, I. (2022). Pemilihan Pengembangan Media Pembelajaran Berbasis Teknologi Informasi. *Equilibrium: Jurnal Penelitian Pendidikan dan Ekonomi*, *19*(1), 61–78. https://doi.org/10.25134/equi.v19i01.3963

Zulanwari, Z. A. Z., Ramdani, A., & Bahri, S. (2023). Research Analisis Kemampuan Literasi Sains Siswa SMA Terhadap Soal-Soal PISA Pada Materi Virus dan Bakteri. *Journal of Classroom Action (JCAR)*, *5*(SpecialIssue), 210–216. https://doi.org/10.29303/jcar.v5iSpecialIssue.4374