



Advancing science literacy on viruses through PBL-SETS with interactive multimedia: Effectiveness and students' voices

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Abstract

This research is necessary because it explores integrated learning to enhance science literacy by engaging students with virus-related materials and prepares students to face future pandemics. This study aims to analyze the effectiveness of multimedia-assisted PBL-SETS in improving students' science literacy about viruses. This study is a quasi-experiment using a one-group pretest-posttest design. The subjects of this study were 40 tenth-grade students at a high school in East Java. This research used a descriptive quantitative methodology that utilised a pre-experimental pretest-posttest design with one group of forty students of class X at a high school in East Java. The PISA 2025 framework was used to develop science literacy tests, while questionnaires assessed students' responses to interactive media. Quantitative and qualitative descriptive analyses were used to analyze the data. The results of the study show that: (1) students' science literacy skills, which were initially 97.5% in the low/very low category, became 47% in the good/very good category; (2) the level of improvement in students' science literacy skills was in the moderate category ($N\text{-Gain} = 0.628$); and (3) students' responses to learning were in the good and very good categories. It was concluded that the use of PBL-SETS, supported by interactive multimedia, was effective in improving students' science literacy in the subject of viruses. Further research is recommended in the form of a quasi-experimental study with a larger, more diverse sample and by integrating local wisdom into the development of interactive multimedia.

Abstrak. Penelitian ini penting karena mengeksplorasi pembelajaran terpadu untuk melatih literasi sains pada materi virus yang lebih menyenangkan dan mempersiapkan siswa untuk menghadapi pandemi di masa depan. Penelitian ini bertujuan untuk menganalisis efektivitas PBL-SETS berbantuan multimedia interaktif untuk meningkatkan literasi sains siswa pada materi virus. Penelitian ini termasuk quasi-eksperimen dengan menggunakan one-group pretest-posttest design. Subjek penelitian adalah 40 siswa kelas X di sebuah SMA di Jawa Timur. Kerangka kerja PISA 2025 digunakan untuk mengembangkan instrumen tes literasi sains, sedangkan kuesioner menilai tanggapan siswa terhadap media interaktif. Analisis deskriptif kuantitatif dan kualitatif digunakan untuk menganalisis data yang didapat. Hasil penelitian menunjukkan bahwa: (1) kemampuan literasi sains siswa yang awalnya 97,5% dalam kategori rendah/sangat rendah menjadi 47% dalam kategori baik/sangat baik; (2) level peningkatan kemampuan literasi sains siswa dalam kategori sedang ($N\text{-Gain} = 0.628$); dan (3) respons siswa terhadap pembelajaran dalam kategori baik dan sangat baik. Diperoleh simpulan bahwa penerapan PBL-SETS berbantuan multimedia interaktif adalah efektif untuk meningkatkan kemampuan literasi sains siswa pada materi virus. Direkomendasikan untuk melakukan penelitian lebih lanjut dalam bentuk studi quasi-eksperimental dengan sampel yang lebih besar dan beragam, serta dengan mengintegrasikan kebijaksanaan lokal ke dalam pengembangan multimedia interaktif.

A. Introduction

Nowadays, science literacy is not merely the accumulation of scientific knowledge learned in class, but it also includes the important competency of applying scientific principles and concepts in solving problems in everyday life (Kusumaningtyas et al., 2025; Shilla et al., 2025), including issues related to viruses. The reference states that the main goals of science education include teaching skills (Broderick, 2023), which can answer global challenges through improving learning processes that are holistic, inclusive, adaptive, and able to respond to developments and technological advances that are always dynamic (Sokolova et al., 2025). This problem underscores the urgency of developing science literacy, a crucial skill for success in today's rapidly changing world (Luzyawati et al., 2025). The results of the study show that students who can read and write about science will have enormous potential in contributing to scientific, social, technical, and technological advances (Apriliyani et al., 2023), and tend to be able to understand facts, ideas, and procedures from basic science (Elhai, 2023). However, in reality, many students find it challenging to explore science literacy and address various global problems (Putri et al., 2025). Therefore, we need to implement strategies, methods, approaches, and other forms of innovation to enhance science literacy through diverse learning methods. This effort aims to make teaching and learning activities more flexible, meaningful, and fun in exploring and learning abstract and phenomenal concepts, including viral content.

This research activity is essential for students to study viral materials, given the potential for future pandemics. In addition, this activity is considered necessary for a more adaptable and engaging approach in understanding viral information, given its abstract nature and its significance as a precursor. Problem-Based Learning Models, specifically the Science, Environment, Technology, and Society (PBL-SETS) approach, aided by interactive multimedia, can facilitate students' understanding of viruses by connecting them to real-life events and enhancing the authenticity of materials through visualisation. (Nasihah et al., 2024), and work well for students (Saragih et al., 2025). Based on international scale evaluations such as the Programme for International Student Assessment (PISA), students' science literacy is still below the global average in many countries, including Indonesia (OECD, 2023). Based on these references, new technologies and innovative methods to improve science literacy can help countries grow more competitive and cooperative globally.

Exposing virus-related content is considered very important for preventing and anticipating potential pandemics. The results of the study show that the PBL method (Hasanah & Sari, 2023; Hidayanti & Wulandari, 2023; Meidiana & Pertiwi, 2024) and the SETS approach (Niate & Paidi, 2025; Atmojo &

Wardana, 2025; Warlinda et al., 2022) have been confirmed to assist students in making it easier for them to learn and for educators in teaching. This fact is supported by research results that indicate that interactive multimedia can potentially increase students' scientific literacy (Asrizal et al., 2025; Sandra et al., 2024; Shofawati et al., 2023). Therefore, PBL-SETS innovations that utilise technology-based learning media make teaching fun and interactive, potentially increasing students' access to learning resources.

Several previous studies have shown that the SETS and PBL approaches can be linked to several methods to improve students' critical thinking skills (Devy et al., 2020; Mayasari & Ramdiah, 2023), problem-solving skills (Mulyani & Heliawati, 2025; Rizki & Adlini, 2022; Safitri et al., 2025), creative thinking skills (Kariimah et al., 2022; Kusuma et al., 2024), and student comprehension (Xiang & Han, 2023). In addition, the use of interactive multimedia has also been shown to contribute positively to motivation (Barut & Dursun, 2022), communication (Saragih et al., 2025), character (Septiani et al., 2020), science literacy (Shofawati et al., 2023), learning independence (Niate & Paidi, 2025), and cognitive learning outcomes (Sari et al., 2024). However, little research has examined interactive multimedia-assisted PBL-SETS on viral materials, especially regarding how to facilitate learning and how participants respond.

This research aims to reduce the gap by empirically investigating the effectiveness of PBL-SETS, supported by interactive multimedia, in learning about viruses. Implementing PBL-SETS, assisted by interactive multimedia, can potentially improve the theoretical framework and practical application in the development of science education today. In addition, these research activities are also expected to provide a strong scientific basis for practical research activities in technology-based science learning and real-world situations.

The objective of this research is to analyze how effective interactive multimedia is in assisting the implementation of PBL-SETS. This study also presents student responses related to interactive multimedia-assisted PBL-SETS, which can help students develop science literacy, and participants' perceptions of them as new, flexible, easy, easy to read, and readily available. This goal aligns with efforts worldwide to improve scientific literacy, as outlined in the Indonesian education roadmap for 2025–2045, to ensure adherence to national and international education standards.

Previous studies have shown the effectiveness of PBL and SETS separately (Acut & Antonio, 2023), and that interactive multimedia improves learning processes and outcomes (Roy et al., 2025; Mayer, 2024). However, no study has integrated all three

simultaneously, especially in abstract and contextual virus material. Previous studies have not explicitly examined how PBL-SETS, when supported by interactive multimedia, can be used to train students' science literacy. Therefore, the novelty of this study lies in integrating PBL-SETS with interactive multimedia to enhance students' science literacy. This study not only confirms its effectiveness in improving science literacy but also expands the empirical evidence supporting the use of interactive media to implement PBL-SETS in real-world, situation-based science learning. Thus, this study addresses the need to develop science learning that is adaptive to the demands of 21st-century science literacy and provides a conceptual and practical foundation for integrating innovative technology-based learning models in the classroom.

B. Material and method

This study is quantitative and uses a one-group pretest-posttest design (O1 X O2) in the pre-experimental phase. In this design, one group of participants took a pretest (O1) to assess their initial science literacy about viruses. PBL-SETS, assisted by interactive multimedia (X), was implemented, and the students were finally asked to take a posttest (O2) to assess changes in their science literacy. Through this design, researchers can assess the effectiveness of learning in measuring the level of improvement in science literacy and students' responses to the learning. The subjects of this study were 10th-grade students at an Islamic high school in Tulungagung, Indonesia. The research sample was obtained through purposive sampling, guided by several considerations (students had never studied viral material, had never participated in PBL-SETS or interactive multimedia, and recommendations from biology teachers regarding academic readiness and class characteristics), resulting in a sample of 40 students. Given that this study did not use a control class, no analysis of equality between groups was conducted, and the effectiveness of learning was focused on changes in pretest and posttest scores in the same group, as well as student responses to learning.

Before the research was implemented, all learning tools (teaching modules, interactive multimedia, and student worksheets) and PBL-SETS integrated with interactive multimedia were validated by science learning experts. The results were 93.3% for the teaching module, 96.7% for interactive multimedia, and 94.8% for the student worksheet, so that all learning tools were declared "very valid" (range 81%–100%) and feasible to be implemented in learning (Nasihah et al., 2024). In addition, the instrument's

validity and reliability of science literacy were 81% (very valid) and 0.63 (high reliability), making it suitable for use in this study.

The teaching material is based on the topic "Virus", which includes characteristics, replication mechanisms, the role of viruses in life, and efforts to prevent diseases caused by viruses. The PBL-SETS learning intervention with interactive multimedia was conducted in four sessions, each focusing on a major subtopic of viral material, and all sessions used devices validated as "superior" (81-100% eligibility).

The instrument to obtain data on science literacy in this study was developed based on the framework of the Programme for International Student Assessment (PISA) 2025, which includes 3 (three) main competencies or abilities (OECD, 2022): (a) the ability to explain scientific phenomena (SL1); (b) the ability to design scientific investigations, evaluate scientific investigations, interpret data, and critically evaluate scientific evidence (SL2); and (c) the ability to research, evaluate, and use information (SL3). Furthermore, to assess students' perception and experience of the use of interactive multimedia, a response questionnaire was used with 5 (five) indicators, namely (a) novelty of science literacy and fun learning; (b) interactive multimedia flexibility learning; (c) ease of understanding and adding insights; (d) design and readability; and (e) accessibility, filled in after the learning is complete, consisting of a statement with two response options ("Yes" is worth 1 (one) and "No" is worth 0). Screenshots of interactive multimedia to develop students' scientific literacy are presented in Figure 1.

For data analysis, learning effectiveness was measured by increasing students' science literacy scores using the N-Gain formula. Furthermore, the N-Gain interpretation was classified as low ($g < 0.30$), moderate ($0.30 \leq g \leq 0.70$), and high ($g > 0.70$). A learning is categorised as adequate if the average N-Gain is at least in the moderate category (>0.3) (Hake, 1998). Furthermore, to compare pretest and posttest scores to determine the percentage success rate in learning. Score categorisations range from 90 to 100 (excellent), 80 to 89 (good), 70 to 79 (adequate), 60 to 69 (low), and below 60 (very low) (Borich & Blanchette, 2022). In addition, students' responses to interactive multimedia were measured quantitatively by assessing the percentage of affirmative ("Yes") responses on the survey, with an acceptable standard of effectiveness set at at least 61%. Categorisation of student response percentage intervals (P): $81\% \leq P \leq 100\%$ "Excellent"; $61\% \leq P \leq 80\%$ "Good"; $41\% \leq P \leq 60\%$ "That's enough"; $21\% \leq P \leq 40\%$ "Less than"; and $0\% \leq P \leq 20\%$ "Not much" (Jafar et al., 2020).

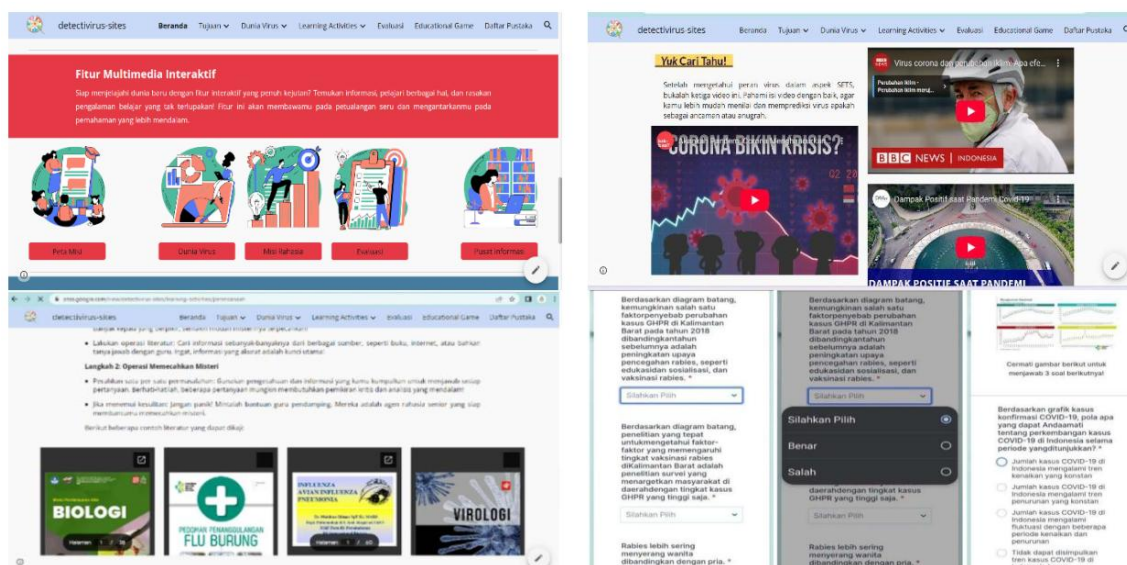


Figure 1 Interactive multimedia to develop students' scientific literacy (in Indonesian)

C. Results and discussion

The presentation of results and discussion focused on the study's objectives: the effectiveness of PBL-SETS, assisted by interactive multimedia in improving science literacy, based on pretest and posttest data, as well as student responses to the implementation of learning and interactive multimedia. The results of the analysis of students' pretest and posttest science literacy scores are presented in Tables 1 and 2.

Based on Table 1, the pretest results indicate that students' initial science literacy skills remain

generally low, with 82.5% in the very low category, 15% in the low category, and 2.5% in the moderate category. In contrast, the posttest results show that 22.5% of students are in the very good category and 25% are in the good category. Although there are still 32.5% of students in the low/very low category, Table 1 indicates that the application of PBL-SETS assisted by interactive multimedia can help students improve their science literacy skills at school. This is reinforced by the N-Gain results for students' science literacy indicators, as presented in Table 2.

Table 1 Distribution of individual student completeness percentage in pretest and posttest

Score Interval	Assessment criteria	Percentage (%)	
		Pretest	Posttest
90–100	Very good	0.0	22.5
80–89	Good	0.0	25.0
70–79	Moderate	2.5	20.0
60–69	Low	15.0	30.0
≥60	Very low	82.5	2.5

Table 2 Comparison of average pretest, posttest, and N-Gain of students' science literacy ability

Indicator	Average		Difference	N-Gain	N-Gain criterion
	Pre test	Post test			
SL 1	45.5	83.0	37.5	0.688	Moderate
SL 2	51.0	84.5	33.5	0.684	Moderate
SL 3	29.5	65.5	36.0	0.511	Moderate
Average	42.0	77.7	35.7	0.628	Moderate

Note: SL 1 = the capacity to explain scientific phenomena; SL 2 = compiling and evaluating the investigation design and interpreting scientific data or evidence; SL 3 = research, evaluation, and use of information.

Based on Table 2, the pre-test results show that students' initial science literacy skills in explaining scientific phenomena, organizing and evaluating investigative designs, interpreting scientific data or evidence, and researching, evaluating, and using information are still low. Conversely, after implementing PBL-SET using interactive multimedia,

post-test scores for the three science literacy indicators were higher than pre-test scores. This finding is reinforced by the N-Gain analysis (Table 1), which shows that the improvement in science literacy indicators before and after implementing PBL-SET, with interactive multimedia support, is moderate.

Table 3 Student response questionnaire results on learning

Aspects	Positive response	
	%	Category
The novelty of science literacy and fun learning	77.5	Good
Interactive multimedia flexibility learning	87.5	Very good
Ease of understanding and adding insight	86.3	Very good
Design and readability	80.0	Very good
Accessibility	85.0	Very good

The improvement in students' ability to explain scientific phenomena indicates that integrating PBL-SETS with interactive multimedia strengthens students' conceptual understanding of viruses. Virus material is very relevant to students' lives during the COVID-19 pandemic (Nasihah et al., 2024), impacting students' social and educational aspects (Alghamdi, 2021). Similar pandemics may emerge as problems in the future (Abdelouahed et al., 2025; Rudroff, 2025), and this authentic problem is one of the hallmarks of PBL. References from research results that affirm that PBL plays an essential role in developing an in-depth understanding (Al-Otaibi, 2025) through the presentation of authentic and contextual problems (Djou et al., 2022). The reference also affirms that interactive multimedia support contributes to visualising abstract concepts (Ainyn & Dwiningsih, 2022), such as viruses that are difficult to observe directly, thus requiring clearer representation tools. Therefore, the success of this improvement confirms the relevance of the SETS approach that connects the dimensions of science, technology, environment, and society to provide contextual meaning in modern biology learning.

The application of PBL-SETS, assisted by interactive multimedia, can also improve students' ability to compile and evaluate investigative designs and interpret scientific data. These results are consistent with research reporting that PBL is effective in training students to develop critical thinking skills (Dina et al., 2024; Istiana et al., 2024; Sagita, 2021), problem-solving (Asyhari & Sifa'i, 2021; Hidayati & Wagiran, 2020; Treepob et al., 2023), and higher-level thinking skills (Safitri et al., 2025). The findings of the study state that the success of science literacy teaching depends on adequate guidance and support from teachers (Walag et al., 2022) and the use of interactive learning media (Shofawati et al., 2023). Therefore, the increase in these indicators reflects the effectiveness of PBL-SETS and multimedia in facilitating science literacy.

The application of PBL-SETS, assisted by interactive multimedia, can also improve students' ability to identify, understand, and use information in the moderate category. The main challenge is the low initial score, suggesting that the capacity to identify, understand, and use information still needs improvement. These results align with the OECD's findings in PISA, which state that students in various countries still have difficulty integrating and

evaluating complex scientific information (Ahmad et al., 2023; Tat & Tat, 2023). Using interactive multimedia in PBL-SETS can enhance this by providing access to a wider range of diverse, interactive information sources. Although the effectiveness of PBL-SETS was evident in all three indicators, the results show the need for follow-up strategies that emphasize information literacy skills as the basis for comprehensive science literacy. Digital literacy still needs to be strengthened so that students can sort out valid information. However, the intervention's success in improving students' science literacy is supported by students' positive responses to the learning process, as shown in Table 3.

Based on Table 3, students responded positively to the novelty of science literacy and its learning and very positively to the flexibility of multimedia, ease of understanding, added insight, design, readability, and accessibility. These results show increased engagement and comfort with learning when PBL-SETS is enriched with interactive multimedia, consistent with evidence that problem-based approaches improve engagement and authentic learning. High scores in flexibility and accessibility reflect interactive media's ability to support adaptive learning and cross-contextual knowledge transfer. These findings confirm that interactive and visual digital content can increase engagement (Muir et al., 2022) and learners' motivation to learn (Guaña et al., 2024).

Although many aspects indicate a superior category, the "only" good novelty value (77.5%) suggests that the media's initial appeal must be sustained across various project tasks and challenges to prevent the novelty effect from quickly fading—an issue relevant to motivation in PBL implementation. In addition, although multimedia aids the formation of mental representations of viral concepts, optimising outcomes depends on applying multimedia design principles (e.g., segmentation, proximity) and on supporting pedagogical scaffolding to guide students' investigation and evaluation of information.

Interactive multimedia-assisted PBL-SETS has been shown to contribute to more effective student achievement in schools (Kldiashvili et al., 2025). Based on the results of previous research that supports the claim that problem-based learning with technology can help people think more creatively (Nulhakim et al., 2020), develop a capacity for critical thinking (Abdulah et al., 2021), higher-level thinking (Haritzah et al.,

2024), and motivation (Far'i et al., 2023). The PBL-SETS model also helps students progress from the middle category to the higher category (Devy et al., 2020), reinforcing the finding that PBL can improve differences in learning outcomes in the classroom (Susaningsih et al., 2023). These results confirm the importance of integrating new concepts and innovations in science education to help everyone strengthen their science literacy knowledge.

This study has several limitations, including a single-group design without a control group, which limits the strength of generalization and causal inference. The limited sample size from a single school with specific characteristics allows for contextual influences that are not fully controlled. In addition, the relatively short duration of the intervention does not allow for observation of the long-term impact on concept retention and student health preparedness. However, interactive multimedia-assisted PBL-SETS effectively improve science literacy and learning experiences (including reflection on flexibility, accessibility, and comprehension) but require strengthening through scaffolding and operational feedback. Visualisation of the analysis of student response questionnaires about learning during PBL-SETS and interactive multimedia.

D. Conclusion

The application of PBL-SETS, assisted by interactive multimedia, has been shown to improve science literacy. This finding is based on an increase in students' science literacy in the moderate category and on their positive responses to the learning process. Students learn in a meaningful, interesting, and enjoyable way, especially abstract and contextual material on viruses. Further research is recommended using a quasi-experimental design with larger sample sizes and greater diversity. To increase the relevance of learning, it is recommended that efforts be made to develop interactive multimedia that integrates local wisdom.

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