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V-SITES: DEVELOPING A WEB-BASED BIOLOGY LEARNING MEDIA TO ENHANCE CONCEPTUAL UNDERSTANDING OF VIRUS IN SENIOR HIGH SCHOOL

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ABSTRACT

This study aimed to develop Google Sites–based biology learning media on the topic of virus for Grade X students in alignment with the implementation of the Merdeka Curriculum. The research employed a Research and Development (R&D) approach using the ADDIE instructional design model. The participants consisted of 40 students from a senior high school in Tanjungpinang. Data were collected through expert validation of content and media design, questionnaires to examine teacher and student responses, and pretest–posttest assessments to evaluate learning outcomes. Expert validation results indicated a very high level of validity, with scores of 97.37% for media design and 94.04% for content feasibility. The reliability of the research instrument was also confirmed, yielding a Cronbach's alpha coefficient of 0.97, indicating excellent internal consistency. The resulting product, named V-Sites, was structured into learning units consistent with the Merdeka Curriculum and designed to support independent learning by integrating instructional materials, learning activities, and assessment components within a single digital platform. The findings indicated that V-Sites achieved a very high level of validity based on expert evaluation and received positive responses from students. In addition, student learning outcomes improved significantly, as reflected by an N-Gain score of 0.76 (high category). These results demonstrate that Google Sites–based learning media are effective and appropriate as a digital alternative for teaching virus material in Grade X biology.

Keywords: Development; Learning Media; Google Sites; Merdeka Curriculum; Virus

INTRODUCTION

The implementation of the Merdeka Curriculum emphasizes empowering teachers to design meaningful, in-depth, flexible, and learner-centered educational experiences that address students' essential needs (Wahyudin *et al*., 2024). From a constructivist perspective, learning is understood as an active process in which students construct knowledge through interaction with their environment and reflection on their learning experiences. In this framework, students function as autonomous agents responsible for regulating their own learning, while teachers assume the role of facilitators who create adaptive and supportive learning environments (Abidin & Pradiana, 2025; Ndari & Mahmudah, 2023). The Merdeka Curriculum is characterized by its emphasis on instructional flexibility, the strengthening of the Pancasila Student Profile, and a focus on essential content, thereby providing opportunities to implement student-centered learning strategies (Fatmawati *et al*., 2024). Consequently, its implementation requires

appropriate instructional media and learning designs that can foster learner autonomy and competency development, including in senior high school biology education.

Biology instruction at the senior high school level presents distinctive challenges, as it encompasses conceptual, abstract, and hierarchically structured content that requires students to integrate multiple levels of biological organization and comprehend mechanisms that are not directly observable (Hoskinson *et al*., 2024). Such characteristics demand higher-order cognitive processing and well-supported instructional approaches. When biology learning is predominantly delivered through linear information transmission without adequate visual or representational support, misconceptions may persist and subsequently become barriers to deeper conceptual understanding in later learning stages. This condition highlights the risk of fragmented knowledge construction and reinforces the need for pedagogical interventions. Therefore, instructional strategies that deliberately promote conceptual change through meaningful and contextually relevant learning experiences are essential to facilitate accurate and coherent understanding (Aleknavičiūtė *et al*., 2023).

Preliminary observations conducted at a senior high school in Tanjungpinang revealed that 58.82% of Grade X students experienced difficulties in understanding virus-related topics, particularly virus structure and replication mechanisms. These challenges were largely attributed to instructional practices that relied heavily on textbooks and printed materials, with limited integration of visual representations and digital learning media. As a result, students encountered obstacles in conceptualizing abstract biological processes involving complex and unobservable mechanisms (Marzuki & Diknasari, 2022; Triana, 2023) . The absence of adequate visual and interactive support hindered students' ability to construct coherent mental models of virus structure and replication stages. This condition has negatively affected students' academic performance, leading to suboptimal learning outcomes and achievement levels that do not fully meet the expected mastery criteria. Such findings underscore the urgency of developing instructional innovations capable of supporting deeper conceptual understanding in biology learning.

Virus constitutes a challenging topic in senior high school biology due to its microscopic scale, abstract characteristics, and dynamic processes that cannot be directly observed. Consequently, understanding virus-related concepts requires strong visualization skills and advanced reasoning abilities. Instruction that relies predominantly on textual and descriptive explanations often increases the risk of misconceptions and fragmented conceptual understanding (Diala *et al*., 2025;). Moreover, virus instruction is frequently delivered in isolation from authentic real-world contexts. This lack of meaningful contextualization tends to reduce students' cognitive engagement and limits their capacity to connect biological concepts with everyday phenomena and contemporary issues (Gungor *et al*., 2023). As a result, learning experiences may remain superficial rather than fostering deep and transferable understanding.

To address the inherent complexity of biological content and the limitations of conventional instructional approaches, digital learning media have increasingly

been recognized as a viable solution for enhancing students' conceptual understanding. Alshammary dan Alhalafawy (2023) argue that digital learning media enable information to be presented through multiple forms of representation, including textual, visual, and multimedia elements, thereby facilitating a more comprehensive understanding of abstract concepts. From a cognitive perspective, the integration of verbal explanations with visual representations can support deeper information processing and the construction of coherent mental models, particularly for microscopic biological phenomena such as viruses that cannot be directly observed (Mayer, 2009). Web-based learning environments also allow modular navigation and self-paced access to learning materials, enabling students to revisit complex concepts and regulate their learning processes, which can support conceptual change and reduce misconceptions in biology learning. A needs analysis conducted at the school indicated that 96.1% of students expressed a preference for digital learning media, while 29.29% specifically required website-based platforms. These findings demonstrate a strong demand for technology-supported instructional resources. Well-designed teaching materials should be aligned with students' learning characteristics and with instructional approaches that effectively support the achievement of learning objectives (Sarkity & Pratama, 2025).

Considering the pedagogical potential of digital media, Google Sites has emerged as a strategic platform for developing web-based learning resources capable of addressing these instructional needs. Google Sites, developed by Google, is designed to facilitate website creation through an intuitive interface and user-friendly layout, enabling easy navigation and accessibility for both teachers and students (Fauziyah & Martiningsih, 2025; Lativa *et al*., 2024) . The platform allows educators to customize instructional content according to specific learning objectives and student needs. Its capacity to integrate diverse content formats such as instructional videos, interactive quizzes, and virtual simulations within a unified interface represents a significant advantage in supporting meaningful learning experiences (Anh & Truong, 2023; Setianingsih *et al*., 2024). Moreover, its intuitive design and accessibility make Google Sites particularly suitable for educators seeking to develop adaptable learning materials that align with students' learning characteristics (Wahyuningsih & Lidyasari, 2025).

Google Sites has been widely developed and consistently recognized as an appropriate web-based learning medium, particularly in terms of expert-validated quality, practical implementation, and positive student responses (Lativa *et al*., 2024; Mukhoyyaroh *et al*., 2022; Saputra *et al*., 2023). However, most development studies position Google Sites primarily as a general platform for delivering instructional materials and assignments, without embedding pedagogical designs specifically aligned with the abstract and microscopic nature of biological content, such as virus topics.

Research by Ahadiah *et al*, (2024) demonstrates that integrating Google Sites with project-based learning approaches can significantly enhance students' creativity and self-regulated learning. Nevertheless, existing studies on Google Sites–based learning media have primarily focused on

usability and instructional design aspects, with limited empirical evidence regarding their alignment with the Merdeka Curriculum and their effectiveness in improving students' conceptual understanding of specific biology topics. In particular, few studies have examined how Google Sites–based learning media can support independent learning and differentiation principles while quantitatively improving students' understanding of virus concepts at the senior high school level. Therefore, this study aims to develop Google Sites–based biology learning media aligned with the Merdeka Curriculum and to evaluate its validity, practicality, and effectiveness in improving students' understanding of virus concepts.

METHODS

This study employed a Research and Development (R&D) approach to develop Google Sites–based biology learning media. The participants consisted of one intact class of Grade X students (n = 40) from a senior high school in Tanjungpinang. The sample was selected using purposive sampling, considering that the selected class represented the target users of the developed learning media and had access to the digital facilities required for implementing Google Sites–based learning. Students who participated in all learning activities and completed the pretest–posttest assessments were included in the study.

The development process was guided by the ADDIE model, which consists of five sequential phases: Analysis, Design, Development, Implementation, and Evaluation. This model served as a structured instructional framework to ensure systematic media development. (Branch, 2009).

1. **Analysis**

   The analysis phase aimed to identify instructional needs related to virus content for Grade X students within the framework of the Merdeka Curriculum. This phase involved examining the expected learning outcomes, students' characteristics, and the existing school learning conditions, with particular attention to the predominance of printed materials as the primary learning resources. Data were obtained through preliminary observations and analysis of relevant curriculum documents. The findings from this phase indicated a clear need for digital learning media capable of visually representing virus-related concepts while simultaneously supporting students' independent learning.

2. **Design**

   The design phase focused on formulating the structure and core components of the Google Sites–based V-Sites learning media. This stage involved organizing virus-related content, designing the media navigation system, integrating multimedia elements, and planning learning activities along with assessment components. The media design was aligned with the principles of the Merdeka Curriculum, particularly its emphasis on student-centered learning. In addition, validation instruments were developed for content and media experts to evaluate the relevance and quality of the developed media. The instrument blueprints used in this study are presented sequentially in Tables 1, 2, and 3

Table 1. Blueprint of the Content Validation Instrument

No.	Aspects	Indicators	Item Number
1.	Instructional Design	Clarity of learning objectives	1
		Alignment of learning objectives with Learning Outcomes	2
		Alignment between content and learning objectives	3
		Logical sequencing of content	4
		Content is easy to follow	5
		Relevance between media use and content	6
		Media facilitates independent learning	7
		Contextual relevance	8
2.	Content Quality	Content Relevance to Learning Objectives	9
		Novelty of the presented material	10
		Consistency between concepts and media presentation	11
		Currency of the material	12
		Clarity of content presentation	13
		Appropriateness of content scope in relation to learning objectives	14
		Appropriateness of examples used in the material	15
3.	Language and Communication	Appropriateness of images in relation to the material	16
		Appropriateness of videos in relation to the material	17
		Language clarity and comprehensibility	18
		Sentences comply with standard language conventions	19
		Sentences are free from ambiguity	20
		Use of communicative language style	21
		Consistency in the use of terms and vocabulary	22

Table 2. Blueprint of the Media Validation Instrument

No.	Aspects	Indicators	Item Numbers
1.	Usability	Menu options within the learning media are easy to understand	1
		Readability of text within the media	2
		Responsiveness of menu features	3
		Ease of accessing the media	4
		Website address is easy to remember	5
		Content presented in the media is informative	6
2.	Navigation System	Appropriateness of navigation button layout	7
		Navigation buttons function properly	8
		Navigation buttons align with user needs	9
		Availability of alternative menu options within the media	10
3.	Visual Communication	Language used in the media is appropriate	11
		Interface design is easy to understand	12
		Interface design is visually appealing	13
		Contrast between background and text	14
		Clarity of images presented	15
		Quality and relevance of videos presented	16

Table 3. Blueprint of the Practicality Instrument

No.	Aspects	Indicators	Item Number
1.	Content	Presentation of material in the media is easy to understand	1
		Interface display is easy to understand	2
		Appropriateness of images presented in the media	3
		Appropriateness of videos presented in the media	4
2.	Interactivity	Ease of accessing the media	5
		Navigation buttons are easy to use	6
		Media functions operate properly	7
3.	Usefulness	Readability of written content in the media	8
		Color contrast between background and text	9
		Media enhances students' learning motivation	10
		Media stimulates students' curiosity	11
		Media promotes independent learning	12

3. Development

In this phase, the initial design was transformed into the V-Sites learning media using Google Sites as the development platform. The resulting product incorporated structured instructional content, relevant images, embedded videos, interactive learning activities, and quizzes designed to support students' understanding of the topic

4. Implementation

The implementation phase involved the use of the developed V-Sites learning media in the biology learning process for Grade X students. The implementation was conducted during the virus topic instruction over two classroom meetings. Students accessed the V-Sites platform using their personal smartphones or available school

computers through an internet connection. The platform functioned as the primary learning resource that integrated learning materials, multimedia content, interactive activities, and assessment tasks.

During the implementation process, the teacher acted as a facilitator who guided students in navigating the V-Sites platform, provided explanations when necessary, and facilitated discussions related to the learning activities. Students were also allowed to access the platform outside the classroom to support independent learning and review the learning materials. The implementation phase consisted of two stages:

a. Practicality Testing

Practicality was assessed through evaluations conducted by both teachers and students. Teachers examined the usability, clarity, and suitability of the media features, while students evaluated ease of access, multimedia functionality, and the media's effectiveness in supporting independent learning. The collected responses were analyzed using a Likert scale.

b. Effectiveness Testing

The effectiveness of the learning media was measured through a posttest administered after students used the V-Sites media. The improvement in students' conceptual understanding was calculated using the N-gain formula.

5. Evaluation

The evaluation phase comprised both formative and summative components. Formative evaluation was conducted at each stage of the ADDIE process through validator feedback and limited field trials. In contrast, summative evaluation was carried out at the final stage to determine the overall validity, practicality, and effectiveness of the product. Final revisions of the V-Sites learning media were implemented based on the comprehensive results of this evaluation.

The feasibility of the V-Sites learning media was calculated using the formula proposed by Riduwan (2018):

$$K = \frac{F}{N.\,I.\,R} \times 100\%$$

Where:
K = Feasibility percentage
F = Total score obtained from respondents
N = Maximum possible score
I = Number of items in the assessment instrument
R = Number of respondents

The percentages obtained from the validity and practicality tests were interpreted according to the criteria proposed by Sugiyono (2019), as presented in Table 5.

The effectiveness of the V-Sites learning media was calculated using the N-Gain formula to measure the improvement in students' learning outcomes by comparing pretest and posttest scores. This approach provides a more objective measure of instructional effectiveness. The resulting N-Gain values were categorized into high, medium, and low levels based on the criteria established by Hake (1998), as presented in Table 4.

Table 4. Interpretation of N-Gain Scores

No.	N-Gain Score	Improvement Category
1	$\langle g \rangle \geq 0{,}7$	High
2	$0{,}3 \leq \langle g \rangle < 0{,}7$	Medium
3	$\langle g \rangle < 0{,}3$	Low

RESULTS AND DISCUSSIONS

1. Analysis

The analysis phase constituted a systematic effort to identify discrepancies between existing instructional conditions and the ideal standards expected in terms of

Table 5. Criteria for Validity and Practicality

Criteria		Score	Percentage (%)
Validity	Practicality		
Very Valid	Very Practical	4	76-100
Valid	Practical	3	51-75
Invalid	Impractical	2	26-50
Highly Invalid	Highly Impractical	1	0-25

curriculum demands, student characteristics, and subject content (Branch, 2009; Dede *et al*., 2025). Findings derived from teacher interviews and student questionnaires conducted at a senior high school in Tanjungpinang revealed persistent conceptual difficulties in biology instruction, particularly on the topic of virus. These challenges stem largely from the abstract, microscopic, and hierarchically structured nature of the content (Silvana & Trimulyono, 2023).

Classroom practices were found to rely heavily on printed materials and verbal explanations, providing insufficient representational support for students' conceptual understanding. When virus-related content is presented linearly through text without dynamic visual reinforcement, students tend to struggle, thereby increasing the likelihood of misconceptions. This finding aligns with previous studies identifying virus as one of the biology topics most susceptible to misunderstanding, primarily due to inadequate visual representations in instruction (Gafur *et al*., 2024).

The analysis further revealed a misalignment between the aspirations of the Merdeka Curriculum and current classroom practices. Although the curriculum emphasizes student-centered learning, strengthened conceptual understanding, and the integration of digital technologies to promote independent learning (Sihotang & Harahap, 2025). These principles have not been optimally realized due to limited utilization of digital learning media. Pedagogically designed web-based media have been shown to effectively support self-directed learning and enhance conceptual understanding (Faza & Lestari, 2025).

2. Design

The media design in this study extended beyond visual presentation, placing strong emphasis on an instructional structure that facilitates the attainment of Learning Outcomes (CP) and Learning Objectives (TP). Accordingly, V-Sites was organized using a modular learning sequence consisting of clearly defined objectives, structured instructional materials, learning activities, assessment components, and references. This organization enables students to engage in guided yet autonomous learning.

This design approach reflects the principle of instructional alignment, which highlights the coherent integration of learning objectives, instructional activities, and assessment strategies to support meaningful learning processes (Younas *et al*., 2025; Zhao *et al*., 2023) .

The virus content within V-Sites was arranged progressively, beginning with foundational concepts and advancing toward more complex topics, including virus structure, replication processes, and their roles in life systems. Such structured and visually supported organization has been shown to enhance conceptual understanding in biology learning (Dede *et*

al., 2025). In addition, the design prioritized user interaction and learning experience in a web-based environment. Intuitive navigation features such as quick-access menus, return buttons, and keyword search functions were incorporated to facilitate students' self-regulated learning (Iswardani *et al*., 2025; Maryani *et al*., 2022). V-Sites also integrates scientific activities grounded in contextual issues, such as Covid-19, to foster higher-order thinking skills. The interface of V-Sites is presented in Figure 2.

3. Development

Prior to classroom implementation, V-Sites underwent a feasibility assessment to determine its appropriateness for instructional use. This process involved expert validation from both content and media perspectives, focusing on the alignment of materials with learning objectives, clarity of presentation, design quality, and usability. Expert validation represents a critical component in development research, functioning as a quality control mechanism to ensure that the product is not only technically sound but also pedagogically appropriate and responsive to students' characteristics (Maryani *et al*., 2022).

a. Content Validity Results

The results of the content validation indicated that V-Sites achieved a very high level of validity, as presented in Table 6. This finding reflects strong alignment among instructional design, content organization, and the intended biology learning objectives related to virus topics.

Table 6. Results of Content Validation

Aspects	Validator Assesment (%)		Average (%)	Criteria
	I	II		
Instructional Design	96.42	92.85	94.63	Very Valid
Content Quality	93.75	93.75	93.75	Very Valid
Language and Communication	87.5	100	93.75	Very Valid
Average (%)	92.55	95.53	94.04	Very Valid

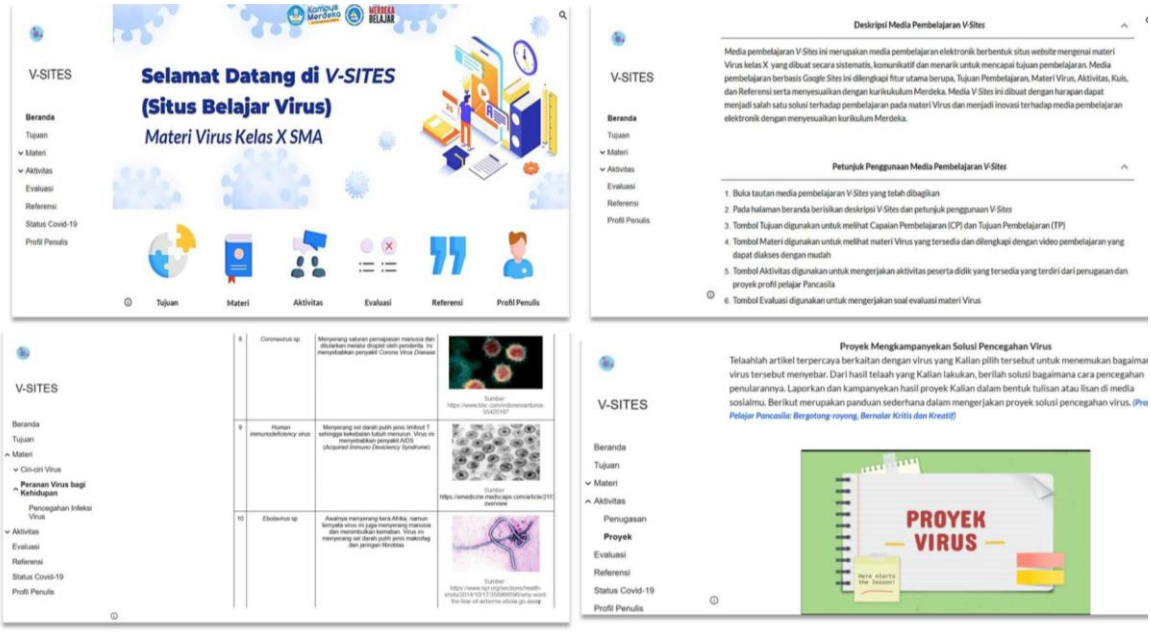


Figure 1. Website Interface of the V-Sites Learning Media

The materials were systematically structured and outcome-oriented, enabling students to follow conceptual progression in a gradual and coherent manner—an essential aspect when addressing abstract biological concepts. Well-structured instructional design is known to play a crucial role in guiding learning and reducing cognitive load, particularly in biology education, which demands deep conceptual processing (Koć-Januchta *et al*., 2022; Wu *et al*., 2022).

Furthermore, the quality of the instructional content and language was evaluated as highly appropriate. The materials were presented accurately, contextually, and communicatively, in accordance with students' cognitive characteristics (Setianingsih *et al*., 2024). The discussion of virus concepts extended beyond definitional explanations by connecting structural features with their relevance to real-life contexts, thereby promoting meaningful learning. Clear and precise language further enhanced readability and minimized the risk of misconceptions, which is particularly important in digital biology instruction (Elmabaredy & Gencel, 2024).

b. Media Validation Results

The media validation results indicate that V-Sites achieved a very high level of validity in terms of usability, navigation, and visual communication design, as presented in Table 7. High usability suggests that the media is easily accessible, user-friendly, and operable without requiring complex technical adjustments. The intuitive and consistent navigation system enables students to move efficiently across different learning sections. This finding was also supported by students' responses during the implementation stage. Several students reported that the V-Sites platform was easy to navigate and helped them access learning materials more independently. Teachers also observed that students were able to follow the learning sequence on the platform with minimal guidance, indicating that the structured navigation and integrated learning activities supported students' independent learning during the lesson. These findings align with established principles of digital learning usability, which identify ease of interaction as a key determinant of web-based instructional effectiveness (Ahadiah *et al*., 2024; Pardo-Baldoví *et al*., 2023).

Moreover, the visual communication quality of V-Sites was evaluated as highly appropriate. Effective layout organization, appropriate color schemes, readable typography, and the integration of visual and audiovisual elements contributed to clearer representations of abstract biological concepts. Visual design grounded in multimedia learning principles supports the construction of accurate mental models while minimizing cognitive load (Kassa *et al*., 2024). In addition, visual clarity and design consistency enhance students' focus and engagement, which are

Table 7. Results of Media Expert Evaluation

Aspects	Validator Assesment (%)		Percentage (%)	Criteria
	I	II		
Usability	95	100	97.5	Very Valid
Navigation System	100	100	100	Very Valid
Visual Communication	96.42	92.85	94.63	Very Valid
Average (%)	97.14	97.61	97.37	Very Valid

essential components of effective biology learning in digital environments (Musa *et al*., 2025; Zhumash & Zhumagulova, 2025).

4. Implementation

The implementation phase was conducted to examine the practicality of the V-Sites learning media by involving teachers and students as direct users in classroom-based biology instruction. The teacher practicality assessment focused on operational ease, clarity of instructional flow, and the alignment of V-Sites features with the instructional requirements of virus-related content. The findings indicate that the media can be effectively utilized in classroom settings. These results suggest that the instructional design, navigation system, and content presentation are consistent with established principles of usability and accessibility, which play a crucial role in fostering acceptance and effective use of digital learning media in schools (Solihin *et al*., 2025; Suraida *et al*., 2025).

From the students' perspective, practicality testing demonstrated that V-Sites was perceived as user-friendly and supportive of independent learning. Students were able to access learning materials, activities, and exercises within an organized and integrated environment, thereby minimizing unnecessary complexity in media usage. These findings reinforce the notion that effective digital learning media should not only be visually engaging but also cognitively supportive and conducive to students' self-directed learning (Lindra et al., 2025; Putri *et al*., 2024; Wansit *et al*., 2024). The results of the practicality assessment are presented in Table 8.

Table 8. Results of Practicality Assessment by Teachers and Students

Aspects	Percentage (%)	Criteria
Practicality (Teacher Evaluation)	98.33	Very Practical
Practicality (Student Evaluation)	94.3	Very Practical
Average	96.31	Very Practical

The N-Gain analysis revealed a high level of improvement in students' learning outcomes, indicating that V-Sites effectively enhanced students' conceptual understanding, as presented in Table 9. The high N-Gain value can be attributed to the media design, which presents virus-related content in a visual, structured, and contextualized format. This approach enables students to construct clearer mental representations of abstract concepts.

Table 9. N-Gain Test Result

Learning Outcomes Average		*N-Gain*	Category	Interpretation
Pre-test	*Post-test*			
52.37	89.37	0.7689	High	Highly Effective

Furthermore, the integration of textual explanations, visual elements, and interactive activities within a single platform supports more efficient information processing while reducing cognitive load during the learning process (Astarina *et al*., 2024). The accessibility of the media, which allows students to learn independently and progress at their own pace, also contributed to improved learning outcomes. This finding is consistent with previous research demonstrating that interactive digital learning media positively influence students' conceptual achievement (Munthe *et al*., 2025; Reskiyati *et al*., 2023).

5. Evaluation

The overall evaluation results indicate that V-Sites meets the established criteria for validity, practicality, and effectiveness as a digital learning medium. Beyond serving as the final phase of the development process, the evaluation functioned as a quality assurance mechanism confirming the media's capacity to support concept-oriented biology learning and independent study (Nasution & Astuti, 2024), in alignment with the principles of the Merdeka Curriculum. These findings further highlight that the development of digital media on open platforms such as Google Sites offers flexibility for adaptation to other biology topics, provided that contextual factors, technological readiness, and students' learning needs are carefully considered (Putriana & Nursaid, 2025; Ramadani, 2025; Zulkifli *et al*., 2025).

Although the findings indicate that the V-Sites learning media contributed to the improvement of students' conceptual understanding of viruses, it is important to consider that several non-media factors may also have influenced the observed learning outcomes. For instance, students' motivation may have increased due to the novelty of using a digital learning platform, which can stimulate curiosity and engagement during the learning process. In addition, the teacher's role as a facilitator in guiding students through the learning activities may have supported students' comprehension of the material. The availability of learning materials that could be accessed outside the classroom might also have encouraged additional study time. Therefore, while the results demonstrate the potential effectiveness of the developed media, these contextual factors should be considered when interpreting the improvement in learning outcomes.

CONCLUSION

Based on the results of the ADDIE-based research and development process, the Google Sites–based biology learning media (V-Sites) for Grade X virus content has been demonstrated to be valid, practical, and effective in supporting the implementation of the Merdeka Curriculum. The media exhibits strong alignment with intended learning outcomes, students' characteristics, and biology learning principles that emphasize conceptual understanding. Its high level of practicality reflects ease of use, clear navigation, and support for both guided and independent learning. Moreover, the effectiveness testing yielded a high N-Gain score, indicating a significant improvement in students' learning outcomes. Therefore, V-Sites can be considered an appropriate adaptive and contextual digital learning alternative for enhancing meaningful biology instruction at the senior high school level.

Future studies are recommended to further examine the effectiveness of Google Sites–based learning media through experimental designs involving control groups to obtain more rigorous evidence of its impact on students' learning outcomes. Longitudinal studies may also be conducted to investigate the sustainability of students' conceptual understanding over time. In addition, future research could explore the implementation of the developed media in different school contexts and analyze specific media components to identify which features most effectively support students' conceptual understanding and independent learning.

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REFERENCES

Abidin, Z., & Pradiana, M. (2025). Chatbot-autoreply for virus topics to strengthen the profile of pancasila students with critical thinking and creativity. *Biosfer*, *18*(1), 243–254. https://doi.org/10.21009/biosferjpb.49290

Ahadiah, R., Juhanda, A., Hendrawati, H., & Nuranti, G. (2024). The influence of PjBL based on 21CLD self-regulation dimension using google sites to creativity and self-regulation. *Jurnal Mangifera Edu*, *9*(1), 32–45. https://doi.org/10.31943/mangiferaedu.v9i1.202

Aleknavičiūtė, V., Lehtinen, E., & Södervik, I. (2023). Thirty years of conceptual change research in biology – A review and meta-analysis of intervention studies. *Educational Research Review*, *41*, 100556.https://doi.org/10.1016/j.edurev.2023.100556

Alshammary, F. M., & Alhalafawy, W. S. (2023). Digital Platforms and the Improvement of Learning Outcomes: Evidence Extracted from Meta-Analysis. *Sustainability*, *15*(2), 1305. https://doi.org/10.3390/su15021305

Anh, T. T. N., & Truong, N. N. (2023). Mobile E-Portfolios on Google Sites: A Tool for Enhancing Project-Based Learning. *International Journal of Interactive Mobile Technologies*, *17*(11). https://doi.org/https://doi.org/10.3991/ijim.v17i11.39673

Astarina, R., Yerizon, Bentri, A., & Zainil, M. (2024). Development of Interactive Learning Media Assisted by Google Sites in Building Materials for Elementary Schools Grade V. *Jurnal Penelitian Pendidikan IPA*, *10*(SpecialIssue), 226–233.https://doi.org/10.29303/jppipa.v10iSpecialIssue.8555

Branch, R. M. (2009). *Instructional Design: The ADDIE Approach*. Springer US. https://doi.org/10.1007/978-0-387-09506-6

Dede, V. A., Buku, M. N. I., & Seran, L. (2025). Pengembangan dan Validasi Media Booklet Materi Virus sebagai Sumber Belajar bagi Peserta Didik SMA:(Development and Validation of Virus Material Booklet Media as a Learning Resource for High School Students). *BIODIK*, *11*(1), 218–231. https://doi.org/https://doi.org/10.22437/biodik.v11i1.42276

Diala, C. G., Anaba, S. C., Adu, G. M., Ohaekwe, C. C., Ajayi, O. A., & Obakhena, T. O. (2025). Diagnostic Analysis of Student Misconceptions on Viral and Bacterial Concepts in Introductory Biology Courses. *Path of Science*, *11*(9), 7001. https://doi.org/10.22178/pos.122-58

Elmabaredy, A., & Gencel, N. (2024). Exploring the integration of self-regulated learning into digital platforms to improve students' achievement and performance. *Discover Education*, *3*(1), 262. https://doi.org/10.1007/s44217-024-00233-4

Fatmawati, B., Marzuki, M., Roshayanti, F., & Suprapto, P. K. (2024).

Fostering students' problem-solving skills through biology learning model integrated with Kurikulum Merdeka. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *10*(2), 392–403. https://doi.org/10.22219/jpbi.v10i2.32857

Fauziyah, N., & Martiningsih, R. R. (2025). Effectiveness of Mathematics Learning using the Google Sites Application at Junior High School. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *9*(1), 297. https://doi.org/10.31764/jtam.v9i1.28167

Faza, A., & Lestari, I. A. (2025). Self-Regulated Learning in the Digital Age: A Systematic Review of Strategies, Technologies, Benefits, and Challenges. *The International Review of Research in Open and Distributed Learning*, *26*(2), 23–58. https://doi.org/10.19173/irrodl.v26i2.8119

Gafur, I. A., Yustina, Suryawati, E., & Hadriana. (2024). *Exploring Challenges in Understanding Abstract Biological Concepts: A Visual Literacy Perspective* (pp. 234–245). https://doi.org/10.2991/978-238476-216-3_25

Gungor, B. A., Saracoglu, S., & Metin, M. (2023). Perspective of Teachers to Context-Based Learning and Its Use in Science Education. *Canadian Journal of Science, Mathematics and Technology Education*, *23*(1), 27–47. https://doi.org/10.1007/s42330-023-00266-1

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/ 10.1119/1.18809

Hoskinson, J. S., Davison, D. R., Sanders, H., Jiménez-Marín, B., & Michod, R. E. (2024). Translating research on evolutionary transitions into the teaching of biological complexity. II. A NGSS-aligned framework for teaching the hierarchy of life. *Evolution: Education and Outreach*, *17*(1), 16. https://doi.org/10.1186/s12052-024-00209-w

Iswardani, A., Jatmiko, B., Hariyono, E., & Rey Dafa Ahmadi, M. (2025). The Effectiveness of G-Sites-Based Learning to Improve Students' Critical Thinking Skills. *Journal of Digit alization in Physics Education*, *1*(2).https://doi.org/10.26740/jdpe.1.2.41960

Kassa, M. M., Azene, M. K., Mengstie, S. M., & Ferede, M. W. (2024). Effect of using multimedia and dynamic classroom integrated instruction on grade 11 students' biology academic achievement. *Heliyon*, *10*(18), e37315.https://doi.org/10.1016/j.heliyon.2024.e37315

Koć-Januchta, M. M., Schönborn, K. J., Roehrig, C., Chaudhri, V. K., Tibell, L. A. E., & Heller, H. C. (2022). "Connecting concepts helps put main ideas together": cognitive load and usability in learning biology with an AI-enriched textbook. *International Journal of Educational Technology in Higher Education*, *19*(1), 11. https://doi.org/10.1186/s41239-021-00317-3

Lativa, V., Sari, M. S., & Setiowati, F. K. (2024). Effectiveness of e-module based on Google Sites in plant diversity courses on creative thinking skills of biology students.

BIO-INOVED: Jurnal Biologi-Inovasi Pendidikan, *6*(1), 73–79. https://doi.org/https://doi.org/10.20527/bino.v6i1.17663

Lindra, A. T., Budiningsih, C. A., & Ismaniati, C. (2025). Development of Google Sites-based learning media to enhance student motivation. *Inovasi Kurikulum*, *22*(2), 933–950. https://doi.org/10.17509/jik.v22i2.81886

Manches, A., & Ainsworth, S. (2022). Learning about viruses: Representing COVID-19. *Frontiers in Education*, *6*, 736744. https://doi.org/https://doi.org/10.3389/feduc.2021.736744

Maryani, M., Nisak, M. S., & Supriadi, B. (2022). Implementasi media pembelajaran berbasis web Google Sites untuk meningkatkan kemampuan memecahkan masalah siswa SMA pokok bahasan gelombang bunyi. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2136–2144. https://doi.org/https://doi.org/10.29303/jppipa.v8i4.2037

Marzuki, M., & Diknasari, M. (2022). Misconceptions: An Analysis of Certainty of Response Index (CRI) on Photosynthesis Materials for Junior High School Students. *Biosfer: Jurnal Tadris Biologi*, *13*(1), 49–55. https://doi.org/10.24042/biosfer.v13i1.12480

Mayer, R. E. (2009). *Multimedia learning (2nd ed.)*. Cambridge University Press.

Mukhoyyaroh, Q., Miharja, J., Baldah, B., & Yuniarti, A. (2022). Development of p3d learning strategy using google sites to support 21st-century skills. *Biosfer: Jurnal Tadris Biologi*, *13*(2), 135–147. https://doi.org/https://doi.org/10.24042/biosfer.v13i2.14164

Munthe, E., Sriadhi, S., & Junaidi, A. (2025). Empowering Science Education with Google Sites: Development and Evaluation of Differentiated Learning Media for Middle School Using the ADDIE Model. *FINGER : Jurnal Ilmiah Teknologi Pendidikan*, *4*(2), 116–125.https://doi.org/10.58723/finger.v4i2.428

Musa, f., Mohammad, S. K., Mohammad, b., & israel, k. O. (2025). Effect of Multimedia-Based Instructional Strategy on Achievement in Genetics Concepts among Secondary School Biology Students in Niger State, Nigeria. *Federal University Gusau Faculty of Education Journal*, *2*(2), 59–65. https://doi.org/10.64348/zije.2025120

Nasution, F. N. J., & Astuti, T. (2024). Website-Based Learning Media Using Google Sites to Improve Student Learning Outcomes in Natural and Social Sciences Subjects on Biodiversity Material. *Jurnal Penelitian Pendidikan IPA*, *10*(10), 7904–7913. https://doi.org/10.29303/jppipa.v10i10.7967

Ndari, W., & Mahmudah, F. N. (2023). Implementation of the Merdeka Curriculum and its challenges. *European Journal of Education and Pedagogy*, *4*(3), 111–116. https://doi.org/https://doi.org/10.24018/ejedu.2023.4.3.648

Pardo-Baldoví, M. I., San Martín-Alonso, Á., & Peirats-Chacón, J. (2023). The smart classroom: Learning challenges in the digital ecosystem. *Education Sciences*, *13*(7), 662.

https://doi.org/https://doi.org/10.3390/educsci13070662

Putri, I. I., Rahmat, A., Riandi, R., & Riza, L. S. (2024). Utilizing learning media in biology: A step towards interactive media development. *Journal of Natural Science and Integration*, *7*(2), 292–302. https://doi.org/https://doi.org/10.24014/jnsi.v7i2.29493

Putriana, T., & Nursaid, N. (2025). Design and Evaluation of Google Sites–Based Learning Media to Teach Biographical Text Identification. *AL-ISHLAH: Jurnal Pendidikan*, *17*(3). https://doi.org/10.35445/alishlah.v17i3.8001

Ramadani, D. (2025). The validity and practicality of physics learning media on measurement topic using google sites. *Physics Learning and Education*,*3*(2).https://doi.org/https://doi.org/10.24036/ple.v3i2.238

Reskiyati, R., Abdjul, T., & Supartin, S. (2023). Development of Google Sites Assisted Learning Media on Vibration, Waves and Sound Material. *E3S Web of Conferences*, *400*,01017.https://doi.org/https://doi.org/10.1051/e3sconf/202340001017

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

Saputra, R., Diandita, Y. N., & Zulfiati, H. M. (2023). Pengembangan media pembelajaran berbasis web Google Sites pada pembelajaran IPS sekolah dasar. *Didaktik: Jurnal Ilmiah PGSD STKIP Subang*, *9*(2), 3327–3338. https://doi.org/https://doi.org/10.36989/didaktik.v9i2.962

Sarkity, D., & Pratama, Y. (2025). Empowering Future Educators Through Team-Based Projects: A Pathway to SDG 4 in Teaching Material Development. *INSANIA : Jurnal Pemikiran Alternatif Kependidikan*, *30*(1), 1–23. https://doi.org/10.24090/insania.v30i1.10836

Setianingsih, D., Siswono, T. Y. E., & Yumiati. (2024). Pengembangan Media Pembelajaran Berbasis Web (Google Sites) untuk Meningkatkan Keterampilan Berpikir Kritis dan Literasi Digital Siswa Kelas V Sekolah Dasar. *ELSE (Elementary School Education Journal): Jurnal Pendidikan Dan Pembelajaran Sekolah Dasar*, *8*(2). https://doi.org/10.30651/else.v8i2.23179

Sihotang, R. F., & Harahap, H. J. P. (2025). Penerapan Kurikulum Merdeka Terhadap Media Digital Dalam Inovasi Pembelajaran. *Journal of Education Transportation and Business*, *2*(1), 335–339. https://doi.org/ 10.57235/jetbus.v2i1.6447

Silvana, I., & Trimulyono, G. (2023). *Profil Miskonsepsi Siswa pada Materi Virus Menggunakan Four-Tier Multiple Choice Diagnostic Test* (Vol. 12, Number 2). https://doi.org/https://doi.org/10.26740/bioedu.v12n2.p432-439

Solihin, S., Apriliani, A. S. N., & Nabila Nur Jannah, A. (2025). ROCED: Robot card biology education as a media for biology learning. *JPBIO (Jurnal Pendidikan Biologi)*, *10*(1), 35–49. https://doi.org/ 10.31932/jpbio.v10i1.4227

Sugiyono. (2019). *Metode Penelitian Kuantitatif Kualitatif dan RND* (Ke 2). Alfa Beta.

Suraida, Saputra, J., Salahuddin, Syefrinando, B., & Susanti, T.

(2025). E-Encyclopedia for Biology Education: Design, Development, and Evaluation of an Innovative Learning Resource. *International Journal of Education and Teaching Zone*,*4*(2),223–242. https://doi.org/https:// doi.org/10.57092/ijetz.v4i2.442

Susanti, D., Kusumastuti, M. N., & Machmudin, D. (2025). Development of visual representation skills assessment for animal biosystematic subject. *Assimilation: Indonesian Journal of Biology Education*, *8*(2), 173–186. https://doi.org/https ://doi.org/10.17509/aijbe.v8i2.85892

Triana, B. M. (2023). Potret miskonsepsi siswa SMA pada materi komponen penyusun dan interaksi dalam ekosistem. *Jurnal Bioeduin*, *13*(2), 49–57. https://doi.org /https://doi. org/10.15575/bioeduin.v13i2.18766

Wahyudin, D., Subkhan, E., Malik, A., Hakim, M. A., Sudiapermana, E., LeliAlhapip, M., Nur Rofika Ayu Shinta Amalia, L. S., Ali, N. B. V, & Krisna, F. N. (2024). *Kajian akademik kurikulum merdeka*. Kemendikbud.

Wahyuningsih, S., & Lidyasari, A. T. L. (2025). Google Sites Interactive Multimedia to Improve Information Literacy of Elementary School Students. *International Journal of Elementary Education*, *9*(2), 360–369. https://doi.org/ 10.23887/ijee.v9i2.94047

Wansit, A. P., Anisa, F., Agustin, P., & Sabrina, S. N. (2024). Penerapan Kurikulum Merdeka Terhadap Media Digital Dalam Inovasi Pembelajaran. *Karimah Tauhid*, *3*(3), 3244–3252.

Wu, Q., Petsangsri, S., & Morris, J. (2022). Students' technology, cognitive, and content knowledge (TSCCK) instructional model effect on cognitive load and learning achievement. *Education Sciences*, *12*(12),916.https://doi.org/https://doi .org/10.3390/educsci12120916

Younas, M., El-Dakhs, D. A. S., & Jiang, Y. (2025). Knowledge construction in blended learning and its impact on students' academic motivation and learning outcomes. *Frontiers in Education*, *10*. https://doi.org/ 10.3389/feduc.2025.1626609

Zhao, L., Zhao, B., & Li, C. (2023). Alignment analysis of teaching–learning-assessment within the classroom: how teachers implement project-based learning under the curriculum standards. *Disciplinary and Interdisciplinary Science Education Research*, *5*(1), 13. https://doi.org/https://doi.org/10.118 6/s43031-023-00078-1

Zhumash, Zh., & Zhumagulova, K. A. (2025). The effectiveness of integrated use of computer programs and video films in teaching school biology. *Bulletin of the natural and geographical sciences series*, *83*(1). https://doi.org/https://doi.org/10.518 89/3005-6217.2025.83.1.006

Zulkifli, Z., Rini, F., & Ramadhanti, D. (2025). Development of a Learning Management System Using Google Sites in Chemistry Lessons. *Journal of Computer-Based Instructional Media*,*3*(2),129-148.https://doi.org/ 10.58712/jcim. v3i2.152