ISSN: 3026-4596
Journal of Computer-based Instructional Media, Vol. 3, No. 2, pp. 129-148, 2025

Development of a Learning Management System Using Google Sites in Chemistry Lessons

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Received: 27 July 2025; *Revised:* 09 October 2025; *Accepted:* 16 October 2025

https://doi.org/10.58712/jcim.v3i2.152

Abstract: Low student learning outcomes in Chemistry at SMAN 1 V Koto Kampung Dalam, Padang Pariaman Regency, are caused by teachers' limitations in utilizing interactive digital learning media. Learning is still dominated by conventional methods, while students need attractive visual and digital media to understand abstract Chemistry concepts. This study aims to develop and test the validity, practicality, and effectiveness of a Google Sites-based Learning Management System in Chemistry learning. The method used is Research and Development (R&D) with the ADDIE model, which includes the stages of Analysis, Design, Development, Implementation, and Evaluation. The research subjects consisted of 30 grade XI students selected through random sampling from a total population of 92 students. The research instruments included an expert validation sheet, a teacher and student practicality questionnaire, and a learning outcome test (pre-test–post-test). The results showed that the Google Sites-based learning management system was rated "Highly Valid" by subject matter and media experts and "Highly Practical" according to teacher and student responses. The effectiveness test using the Wilcoxon Signed-Rank Test produced a significant value of 0.000 (<0.05) and an N-Gain score of 0.83 in the "Effective" category. Future work is recommended to integrate this learning management system with learning analytics and mobile learning features to expand its effectiveness in sustainable digital learning.

Keywords: Learning Management System; Google Sites; Chemistry; ADDIE Model

1. Introduction

The development of information and communication technology has changed the global education paradigm towards a more digital, open, and collaborative learning system (Huff et al., 2025). This transformation requires students to have digital literacy, critical thinking skills, and independent learning skills as key competencies for the 21st century (Kizim et al., 2025). However, the implementation of digital learning in Indonesia still faces considerable challenges, especially at the secondary school level, due to limitations in infrastructure, teachers' ability to manage digital media, and students' readiness to participate in structured online learning.

Learning Management Systems are one of the strategic solutions for managing technology-based learning processes (Mtebe et al., 2025). Through learning management systems, teachers can compile materials, assignments, and assessments in one integrated system so that teaching and learning activities become more systematic and efficient (Özbek et al., 2025). However, many schools still use learning management systems in a limited way, only as a medium for assigning tasks, and have not optimized them as interactive learning tools that can increase student engagement and learning outcomes (Tomas et al., 2025). In Europe, the integration of digital learning systems combined with a collaborative approach has been shown to improve students' conceptual understanding (Woldeyes et al., 2024). On the other hand, studies in Asia confirm that successful adoption is highly dependent on teacher readiness and institutional support (Buljan & Rajamani, 2024). These differences highlight the implementation gap in Indonesian secondary schools, which are still limited by infrastructure and digital pedagogical capacity (Lu et al., 2024).

Several studies show that the effective use of learning management systems can increase motivation, learning outcomes, and the quality of interaction between teachers and students (Adi et al., 2024). Several previous studies also confirm that learning management systems developed according to user needs can improve the effectiveness of science learning, including chemistry, which requires a high level of conceptual understanding and abstract thinking skills (Ondrada et al., 2024). One potential platform for development is Google Sites because it is easy to use, easily accessible, and allows the integration of various digital learning resources without requiring complex programming skills (Turnbull et al., 2024).

Previous studies have focused more on developing learning management systems for higher education or general subjects (Nawaz et al., 2025). Only a few studies have systematically developed and tested a Google Sites-based Learning Management System for chemistry learning in high schools using the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model (Oktiarina et al., 2025). This condition indicates the need for a structured learning system that is easy for teachers to implement and capable of improving students' understanding of Chemistry material (Tannenbaum et al., 2025). Based on this, this study aims to develop a Google Sites-based Learning Management System that is feasible, practical, and effective for use in chemistry learning at SMAN 1 V Koto Kampung Dalam, Padang Pariaman Regency (Alam et al., 2024). This study is expected to contribute to the development of digital learning media in secondary schools and serve as a reference for teachers and other researchers in creating Chemistry learning that is more interesting, interactive, and oriented towards student learning outcomes (Sakellari et al., 2025).

2. Methods

2.1 Type and model of research

This study uses the Research and Development (R&D) method, which aims to produce a learning product in the form of a Google Sites-based Learning Management System for Chemistry lessons (Innocente et al., 2023). The development model used is Analysis, Design, Development, Implementation, and Evaluation (ADDIE) (Wegler et al., 2025). The stages of the development model are illustrated in Figure 1, which describes the five main stages in the product development process.

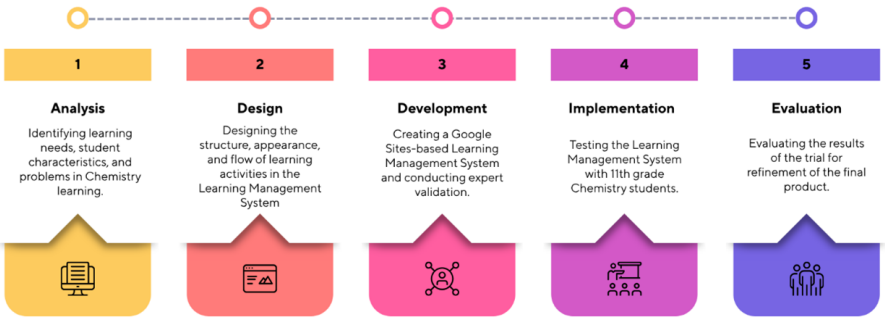


Figure 1. ADDIE model stages in learning management system development

2.2 Research subject

The research was conducted at SMAN 1 V Koto Kampung Dalam, Padang Pariaman Regency, West Sumatra Province. The research subjects consisted of 30 students in grade XI MIPA, who were selected using random sampling techniques from a population of 92 students. In addition to students, the research also involved two subject matter experts from the field of chemistry education and two media experts from the field of learning technology to validate the developed product. The location and subjects were selected based on the consideration that the school had implemented digital-based learning, but the use of the learning management system was still limited, which was in line with the research objective of improving the effectiveness of chemistry learning through the development of Google Sites-based media.

2.3 Data collection instruments and techniques

In this study, instruments were systematically designed to measure the validity, practicality, and effectiveness of developing a Google Sites-based Learning Management System for chemistry learning. The instruments used include: (1) observation sheets, (2) questionnaires, (3) learning outcome test instruments, and (4) research instrument validation sheets. Each instrument was used with different data collection techniques according to the type of information desired (Turnbull et al., 2024).

Table 1. Questionnaire grid for material validity

No	Indicator	Question number
1	Content suitability	1–4
2	Language and sentences	5–16

Table 2. Media validity questionnaire grid

No	Indicator	Question number
1	Media display	1–9
2	Ease of use	10–13
3	The benefits of media	14–16

Table 3. Teacher practicality instrument grid

No	Indicator	Question number
1	Display quality	1–8
2	Ease of navigation	9–13
3	Presentation of material	14–16
4	Implementation	17–24

Table 4. Student practicality instrument grid

No	Indicator	Question number
1	Learning	1–7
2	Use of Media	8–15
3	Benefits	16–18

The validation process is carried out in stages to ensure that the research instruments meet theoretical and empirical standards. The validation results form the basis for assessing the reliability of the data to be collected.

2.4 Data analysis techniques

Data analysis was conducted using descriptive quantitative methods to assess the quality of the Google Sites-based learning management system in terms of validity, practicality, and effectiveness. Data was obtained from expert validation, respondent feedback, and student learning outcomes. This approach was used because development research emphasizes product quality evaluation rather than inferential hypothesis testing (Lee et al., 2024).

2.4.1 Validity analysis

Validity analysis aims to assess the extent to which the learning management system meets the eligibility criteria based on the results of assessments by subject matter experts and media experts. The assessment was conducted using a four-point Likert scale. Validity analysis aims to assess the extent to which the learning management system meets the eligibility criteria based on the results of assessments by subject matter experts and media experts. The assessment was conducted using a four-point Likert scale (Liu et al., 2025).

Table 5. Likert scale response assessment

No	Answer options	Weight
1	Strongly agree	3
2	Agree	2
3	Disagree	1
4	Strongly disagree	0

Table 6. Validity criteria

Score (%)	Category
1–25	Not Valid
>25–50	Less Valid
>50–75	Valid
>75–100	Highly Valid

A product is declared suitable for use if it obtains a "Valid" or "Highly Valid" rating, which means that its content, appearance, and language are in accordance with the principles of learning media development.

2.4.2 Practical analysis

Practical analysis is used to assess the ease and usefulness of the learning management system based on feedback from teachers and students.

Table 7. Practicality categories

Score (%)	Category
1–25	Not Practical
>25–50	Less Practical
>50–75	Practical
>75–100	Very Practical

A Learning Management System is considered practical if it receives a rating of "Practical" or "Very Practical," indicating that the system is easy to use, engaging, and relevant for use in learning activities.

2.4.3 Effectiveness analysis

Effectiveness analysis was used to assess the extent to which the use of a Google Sites-based learning management system improved student learning outcomes. Data were obtained through pretest and post test results using statistical tests and the N-Gain approach.

2.4.3.1 Normality test

The normality test uses Shapiro–Wilk with a significance level of 0.05 to determine the distribution of data. If Sig. $> 0.05 \rightarrow$ The data is normally distributed. Meanwhile, if Sig. $\leq 0.05 \rightarrow$ The data is not normally distributed (Rishko et al., 2025).

2.4.3.2 Hypothesis test (Paired t-test)

This test is used to determine significant differences between pretest and post test scores.

H_0: There is no significant difference between pretest and post test scores.
H_1: There is a significant difference between pretest and post test scores.

2.4.3.3 N-Gain Score

This effectiveness analysis provides empirical evidence that a Google Sites-based Learning Management System can significantly improve student learning outcomes compared to conventional learning, while also demonstrating the quality of media application in the Chemistry learning process.

Table 8. Effectiveness criteria

Score (%)	Category
<40	Ineffective
40–55	Less effective
56	Fairly effective
>76	Effective

3. Results

3.1 System overview

This study produced a development product in the form of a Google Sites-based Learning Management System used as a learning medium for Chemistry on the topic of Acid-Base Titration for 11th grade students at SMAN 1 V Koto Kampung Dalam. The development process was carried out using the ADDIE model, which consists of the stages of Analyse, Design, Develop, Implement, and Evaluate, resulting in a product that is theoretically and empirically feasible. The main objective of this research is to determine the validity, practicality, and effectiveness of the Google Sites-based Learning Management System in improving student learning outcomes. Therefore, all research results are presented based on the ADDIE model stages to describe in detail the product development and evaluation process.

3.2 Results based on ADDIE development stages

3.2.1 Analyse

The analysis stage was conducted to identify learning needs and the initial conditions of students and the learning environment. Based on interviews with chemistry teachers and the distribution of questionnaires to 11th grade students, it was found that the chemistry learning process in schools is still teacher-cantered, focusing on lectures and conventional exercises (Nagel et al., 2025). Teachers face difficulties in explaining abstract concepts such as acid-base reactions and molarity calculations, while students find the material difficult to understand without the help of interactive visual media (Yin & H.-M., 2023). In addition, the pretest results showed an average score of 59.13%, below the Minimum Competency Test Criteria (KKTP) of 76% (AlSharafat et al., 2023). This data confirms that most students do not yet understand titration material conceptually or procedurally (Das et al., 2025). This condition indicates the need for more interesting learning media that can facilitate active interaction between students and teachers (Halim et al., 2024).

3.2.2 Design

At the design stage, the results of the needs analysis are transformed into a systematic and structured product design. The Learning Management System design covers aspects of content, navigation, visual display, and evaluation instruments for product testing. The Learning Management System design structure includes five main menus, namely: The Home page serves as the main entrance, displaying an introduction to learning, motivational videos, and guidelines for using the Learning Management System; The Attendance page provides a Google Form-based attendance system that is integrated with automatic recap; The Materials Page contains text, videos, and interactive exercises on Acid-Base Titration; The Discussion Forum Page is used as an online interaction space between students and teachers; The Teacher Contact Page contains teacher profiles and academic communication guidelines.

3.2.3 Development

The development stage is the direct embodiment of the product design that was prepared in the design phase. At this stage, the Learning Management System was built on the Google Sites platform, following the storyboard and navigation architecture that had been formulated. To provide a concrete picture of the final product, the following is documentation of the Google Sites-based Learning Management System display according to the research output.

3.2.3.1 Home page

The Home page serves as an entrance that organizes the initial learning experience in a friendly and interactive manner. The title "Grade XI Chemistry" is displayed alongside attractive illustrations to create a positive learning atmosphere. The main navigation menu is located at the top so that users can immediately find the core features without additional cognitive load. On the same page, there are three large icons for quick navigation to "Lesson Material," "Grades and Progress," and "Teacher Profile and Contact." This strategy shortens the click distance to key features and reinforces a systematic learning flow. The page also includes a motivational quote: "Learning chemistry is not just about formulas and reactions but understanding the changes in the world from the atomic scale to life" to foster a sense of meaning from the outset.

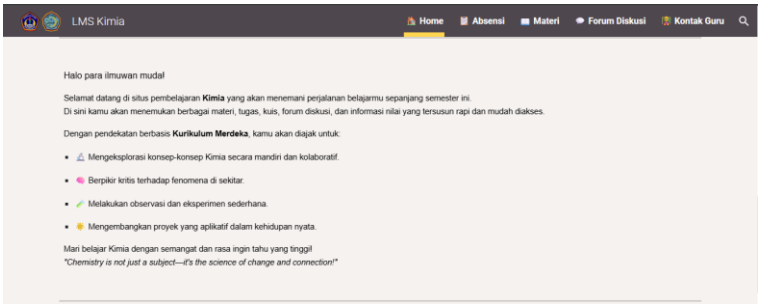
Figure 2.
(a) Main display of the home page, and
(b) Quick navigation on the home page

(a)

(b)

Quick navigation provides direct and efficient access so that students do not need to manually browse through menus. In this section, the learning approach is explicitly explained with reference to the Merdeka Curriculum. The emphasis on critical thinking skills and the encouragement of independent experimentation is presented to align expectations for learning behaviour throughout the use of the Learning Management System. Explanation of the approach of placing pedagogical scaffolding at the forefront: students are given an overview of how to interact with the material, when to use videos, how to make use of exercises, and why discussion forums are important for clarifying concepts.

Figure 3. Explanation of the learning approach on the home page



At the bottom of the page, an introductory video titled "What is Chemistry Really?" is embedded to spark curiosity and bridge the relevance of chemistry to everyday life. The placement of the video at the end of the page scroll aims to encourage content orientation first, then reinforce it through audiovisual media.

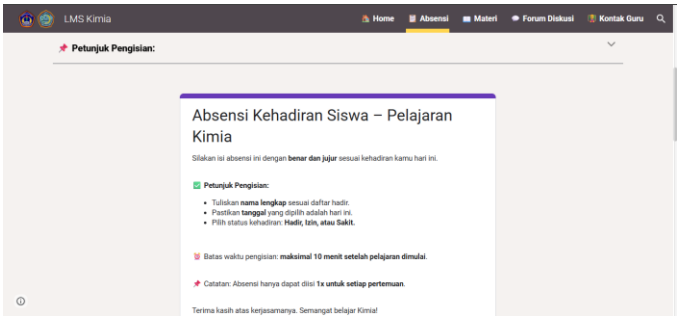
Figure 4. Introductory video display on the home page

3.2.3.2 Attendance page

The Attendance page is designed to manage attendance efficiently and in a documented manner. The title "Student Attendance - Chemistry" is followed by a welcome message and page functions so that students understand the purpose and urgency of filling it out.

Figure 5. (a) Attendance page introduction display, and (b) Attendance form display

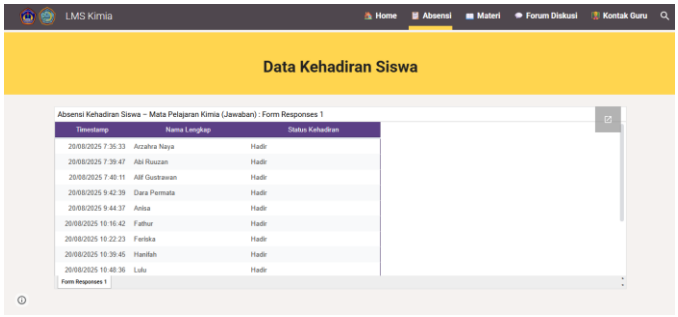
(a)



(b)

The filling instructions are presented in clear and procedural language: filling in the full name, selecting the attendance status (Present, Permission, Sick), a maximum filling time limit of ten minutes after the lesson starts, and a requirement to fill it in once per meeting.

Figure 6. Attendance form display

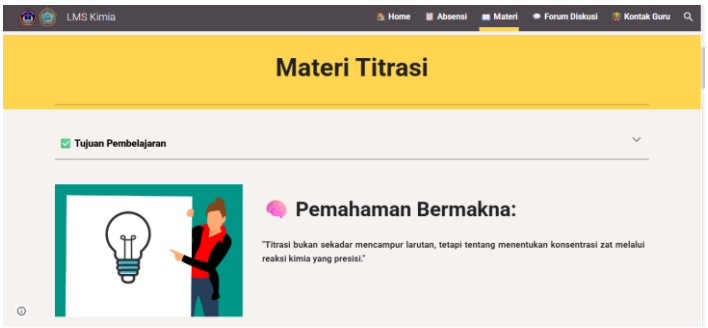


3.2.3.3 Materials page

The Material Page is designed as a gateway to learning content. It features a welcome banner and expandable sections for "General Description," "Chemistry Learning Outcomes – Phase F (Grade XI)," and "Expected Pancasila Student Profile." This structure helps students build a cognitive map of learning objectives and the relevance of the material before entering the topic.

Figure 7. (a) Main display of the material page, and (b) Titration material

(a)

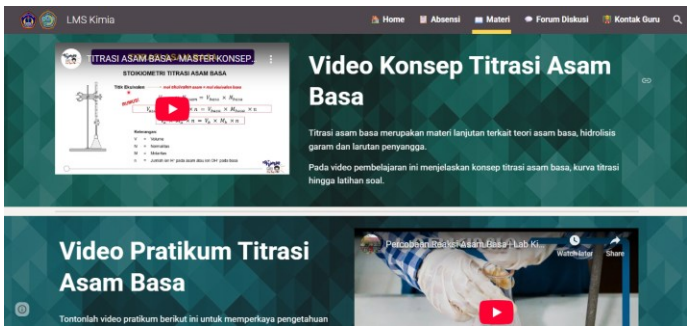


(b)

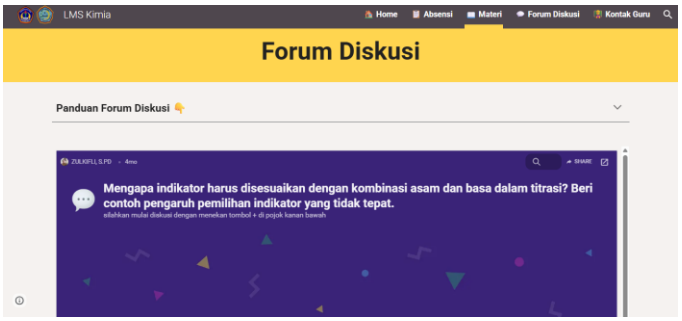
When students select the Titration topic, the Learning Management System displays a special page that begins with the learning objectives and a "Meaningful Understanding" statement: "Titration is not just about mixing solutions but about determining the concentration of a substance through a precise chemical reaction." This element focuses attention on the conceptual essence, not just the calculation algorithm. To support understanding of abstract concepts, two videos are integrated: (a) a video on Acid-Base Titration that reviews basic theory, titration curves, and exercises; and (b) a video on Acid-Base Titration Practicum that visually demonstrates laboratory procedures. The concept-practicum video duo bridges

the macroscopic, microscopic, and symbolic realms of chemistry so that representations reinforce each other.

Figure 8.
(a) Learning video, and (b) Material discussion forum



(a)



(b)

The discussion room on the material page facilitates two-way communication between students and teachers. Students can ask questions, post problems, or request further explanation on difficult sections. Teachers monitor and provide clarification so that guidance remains personal yet efficient. The existence of the forum confirms that the media is not passive; it invites interaction, feedback, and collaboration in line with the needs identified in the analysis stage.

Figure 9.
Material evaluation

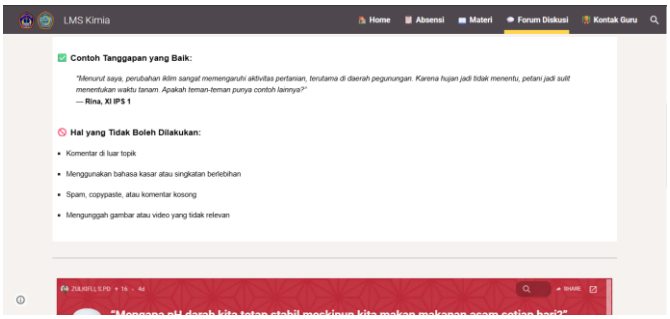
The Evaluation page serves as a tool for measuring understanding. An attractive banner is combined with explicit instructions: read the questions carefully, use the formulas in the calculation questions, and answer honestly. The evaluation is in the form of multiple-choice questions to collect quantitative data, which is then analysed in the effectiveness section.

3.2.3.4 Discussion forum page

The Discussion Forum page serves as a hub for collaborative interaction across topics. At the beginning, there is a guide on "How to Participate in Discussions" to maintain the quality of interaction, including reading topics carefully, responding politely, and using appropriate language. This guide reduces friction in participation and standardizes discussion ethics.

Figure 10.
(a) Main display of the discussion forum page, and (b) Discussion forum guidelines and rules

(a)



(b)

Examples of good responses and a list of prohibitions (e.g., use of profanity or irrelevant posts) are included to provide explicit modelling. Modelling helps novice learners begin contributing without confusion about format, while also creating a healthy discussion culture.

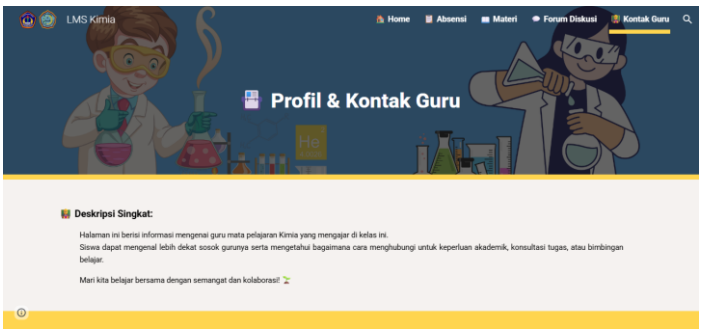
Figure 11.
Example of discussion topics in the forum

Topics are designed to stimulate scientific reasoning. Questions such as "Why does our blood pH remain stable even though we eat acidic foods every day?" force students to activate the concept of buffer solutions and relate it to everyday biological phenomena. This type of topic shifts the discussion from mere reproduction of information to concept-based argumentation.

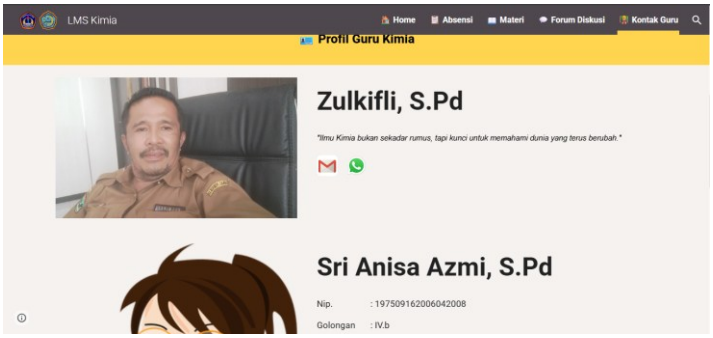
3.2.3.5 Teacher contact page

The Teacher Contact Page facilitates communication and guidance outside of learning sessions. This page helps students recognize their chemistry teachers and understand the official communication channels for academic purposes.

Figure 12.
(a) Main view of the teacher contact page, and (b) Chemistry teacher profile



(a)



(b)

The profile displays important information such as name, employee ID number, classification, institution, photo, and personal quote. Contact information such as email and WhatsApp are provided for direct communication channels.

Figure 13.
Notes on communicating with teachers

The "Notes" section provides communication etiquette: make an appointment in advance, use polite and clear language, and understand that responses are given during school hours. These guidelines instill professional communication literacy while maintaining teacher time efficiency.

3.2.4 Implementation

The implementation stage is a field trial of products that have been declared feasible by subject matter experts and media experts, conducted at State Senior High School 1 V Koto Kampung Dalam on August 7, 2025, involving 30 grade XI students. Before use, the researcher provided guidance on accessing and utilizing the Google Sites-based Learning Management System features, which included material pages, discussion forums, evaluation procedures, navigation methods, and participation ethics. During this period, students studied text content, infographics, and videos, completed exercises and worksheets, and interacted in forums to clarify concepts. Data collection was carried out sequentially through a pretest at the beginning of implementation, followed by a post test after the learning series was completed, and the

distribution of practicality questionnaires to teachers and students to assess comprehensibility, ease of navigation, attractiveness of appearance, and usefulness.

3.2.5 Evaluation

The evaluation stage comprehensively assesses the quality of the Google Sites-based Learning Management System in terms of media, material, and practicality of use by teachers and students (S. Ma, 2024). The assessment was carried out by media experts, material experts, and test instrument experts to obtain an objective picture of the product's suitability (Zhu et al., 2024). In the field, researchers conducted practicality tests through questionnaires to teachers and students and analysed learning outcomes using pre-tests and post-tests according to the research design (Fu & Li, 2022). The evaluation results show that the product meets the criteria of validity, practicality, and effectiveness for chemistry learning at State Senior High School 1 V Koto Kampung Dalam in 2025 and serves as the basis for revisions so that the media can be used sustainably and replicated in similar contexts (Filipescu et al., 2024).

3.3 Validity, practicality, and effectiveness results

3.3.1 Media validation

Validation by experts from the Information Technology Study Program ensures the feasibility in terms of appearance, ease of use, and usefulness of the Google Sites-based Learning Management System. The instrument used is an assessment questionnaire, and the results are used as the basis for refinement before field testing. The average score of 87% in the highly valid category indicates that the interface design and core functions meet the standards of feasibility according to experts and are suitable for use in field tests.

Table 9. Media validity results

No	Assessment Aspect	Validator 1	Validator 2	Validator 3	Average	Category
1	Media Display	75	97	92	88	Very Valid
2	Ease of Use of Media	75	94	94	88	Very Valid
3	Media Benefits	75	92	92	86	Very Valid
Average					**87**	**Highly Valid**

3.3.2 Material validation

Validation by experts in the field of Chemistry assessed the accuracy of the content in accordance with the curriculum and the language of the material on the Google Sites-based Learning Management System. On average, 92% confirmed that the content was accurate, aligned with the curriculum, and communicative, with minor adjustments needed to terms.

Table 10. Material validity results

No	Assessment aspect	Percent	Category
1	Content Suitability	94	Highly valid
2	Language and Sentence Presentation	90	Very valid
Average		**92**	**Highly valid**

3.3.3 Teacher practicality

The practicality assessment by chemistry teachers reflects the ease of applying the media in real classroom learning. The average of 93.14% indicates that the media supports teaching methods that are easy to operate and reliable for use in the classroom.

Table 11. Results of teacher practicality responses

No	Assessment aspect	Percent	Category
1	Display Quality	92	Very Practical
2	Ease of Navigation	88	Very Practical
3	Presentation of Material	100	Very Practical
4	Implementation	92.86	Very Practical
Average		**93.14**	**Very Practical**

3.3.4 Student practicality

Practicality test by 30 grade XI students assessed the experience of using the media in learning. Average 87% indicates that the media is easy to use, useful for interactive learning, and requires reinforcement of contextual examples for some students

Table 12. Results of student practicality responses

No	Practical aspect	Percent	Category
1	Lessons	84	Very Practical
2	Use of Media	88	Very Practical
3	Benefits	88	Very Practical
Average		**87**	**Very Practical**

3.3.5 Effectiveness

Effectiveness is reviewed through a comparison of pretest and post test scores using hypothesis testing normality tests and N-Gain analysis.

3.3.5.1 Normality test

The normality test is the first step to ensure that the collected data is normally distributed. In this study, with a relatively small sample size (N=30), the Shapiro-Wilk test is considered more relevant and accurate.

Table 13. Normal test results

	Kolmogorov–Smirnov			Shapiro–Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Pretest	.158	30	.053	.937	30	.074
Post test	.167	30	.033	.923	30	.033

The results show that the pretest data is normally distributed because the significance value is $0.074 > 0.05$, while the post-test data is not normal because $0.033 < 0.05$. Because the normality requirement was not met in the post-test, the difference test did not use a paired t-test but instead used the Wilcoxon Signed-Ranks Test, which does not require normality for paired data (Chuma et al., 2023). In this way, the researcher was still able to assess whether there was a significant change in scores after using the Google Sites-based Learning Management System.

3.3.5.2 Hypothesis testing

The null hypothesis H0 states that there is no difference in the mean scores between the pretest and post-test. The alternative hypothesis H1 states that there is a difference in the mean scores between the pretest and post-test. Because the post test data are not normal, the Wilcoxon Signed-Ranks Test for paired data is used for testing. The significance level is set at $\alpha = 0.05$. Decisions are made using the rule $p < 0.05$ to reject H0 and $p \geq 0.05$ to fail to reject H0. The interpretation is directed at whether there is an improvement in learning outcomes after intervention through the Learning Management System.

Table 14. Hypothesis test results

Test statistic	Post test - Pretest
Wilcoxon Signed-Ranks Test Z	−4.805
Asymp. Sig. (2-tailed)	.000

Significance value .000 < 0.05 confirms that there is a significant improvement in learning outcomes after using the Google Sites-based Learning Management System.

3.3.5.3 N-Gain

N-Gain analysis is used to measure the relative increase in learning outcomes. More detailed N-Gain analysis results can be seen in the following table.

Table 15. N-Gain Results

No	Pretest	Posttest	N-Gain
1	60	95	0.88
2	65	95	0.86
3	40	80	0.67
4	60	90	0.75
5	50	85	0.70
6	55	85	0.67
7	70	95	0.83
8	55	90	0.78
9	65	100	1.00
10	45	85	0.73
11	70	95	0.83
12	45	80	0.64
13	55	90	0.78
14	70	95	0.83
15	40	85	0.75
16	65	80	0.43
17	75	90	0.60
18	50	85	0.70
19	60	95	0.88
20	70	100	1.00
21	60	90	0.75
22	60	85	0.63
23	75	100	1.00
Average	**40**	**90**	**0.83**

The average N-Gain of 0.83 or 83% meets the effectiveness criteria because N-Gain is greater than 0.76. Thus, the Google Sites-based Learning Management System falls into the effective category and contributes significantly to improving students' understanding and learning outcomes compared to before the intervention.

4. Discussion

This study aims to develop a feasible, practical, and effective Google Sites-based Learning Management System for teaching the topic of Acid-Base Titration in Chemistry at State Senior High School 1 V Koto Kampung Dalam (Bonura et al., 2023). The operational objectives include verifying the validity of the media and material, assessing practicality according to teachers and students, and testing effectiveness in improving learning outcomes by comparing pretest and post-test scores (Saad El Imanni et al., 2023; Singh et al., 2025; Wang et al., 2020). The main findings show a strong correlation between objectives and results. Media validity is in the highly valid category with an average of 87% (Kocsis et al., 2025). The validity of the material was in the highly valid category with an average of 92% (Flauzino et al., 2025). Practicality according to teachers was in the highly practical category with an average of 93.14%. Practicality according to students was in the highly practical category with an average of 87% (Okunlola & Naicker, 2025). The effectiveness of learning is confirmed by a significant difference in scores and an

average N-Gain of 0.83 in the effective category, meaning that the product is not only feasible in terms of design but also has an impact on learning outcomes (Oyebola et al., 2025; Song et al., 2025).

The very high media validity results indicate that the interface design, navigation flow, and core functions have met the criteria for (Giday & Perumal, 2024). The aspects of appearance, ease of use, and usefulness are within a highly valid range. This condition confirms that the visual design and interaction structure support the needs of Chemistry learning, which requires quick access to materials, exercises, and evaluations in a single connected ecosystem. The high validity of the material shows that the content is accurate, curriculum-appropriate, and communicative for students (Kocsis et al., 2025). The arrangement of learning objectives, meaningful understanding statements, conceptual material, videos, and exercises builds a bridge between declarative and procedural knowledge on the topic of Acid-Base Titration (Seringa et al., 2025). Language consistency helps reduce ambiguity in terminology, thereby strengthening conceptual understanding (Knöchelmann et al., 2025). The practicality according to teachers in the very practical category shows that the Learning Management System facilitates planning, implementation, and evaluation. The highest score in material presentation indicates that the learning path from orientation to practice to evaluation has supported the teaching flow in the classroom. This provides a basis that the media is ready to be replicated in the next meeting without significant technical burdens (Adolwa et al., 2025).

Practicality, according to students in the very practical category, indicates ease of use, attractiveness, and benefits for interactive learning. Engagement is seen through the consumption of concept videos and practical videos, the completion of structured exercises, and the use of discussion forums to clarify concepts (Khami et al., 2025; Russell et al., 2025). This pattern is in line with the needs of learners at the analysis stage, which requires visual media and interaction space to overcome difficulties with abstract concepts.

The effectiveness of learning was verified through two main indicators: (Hu et al., 2024). A paired difference test using the Wilcoxon Signed-Ranks Test produced a significance value of less than 0.05, which means that there was an increase in learning outcomes after the intervention (Esper, 2024). The average N-Gain of 0.83 falls into the effective category, indicating a significant relative improvement in conceptual understanding (Villarrubia Zúñiga et al., 2024). The combination of text, images, infographics, concept videos, practical videos, exercises, and discussion forums appears to successfully bridge macroscopic, microscopic, and symbolic representations in Chemistry (Hoskins et al., 2025; J. Ma et al., 2025; Thepwongsa et al., 2024).

A minor contradiction is seen in the variation of individual achievements, with some students falling within the moderate N-Gain range (Sakellari et al., 2025). This variation is related to differences in initial readiness, independent learning strategies, or intensity of participation in forums (Aldino et al., 2025). The non-normal post test data also showed a clustering of high scores after a reasonable intervention when many learners approached the maximum score (Eitel et al., 2024). This variation does not alter the general conclusion but indicates the need for differentiated support (Talens, 2025).

The practical implications for schools and teachers are to maintain an effective set of components, namely a motivating introduction, multimodal materials, gradual exercises, responsive discussion forums, and clear evaluations (Guzmán-Rincón et al., 2025; Pansri et al., 2024). Short training programs for teachers to design material pages, exercises, and evaluations on Google Sites will accelerate replication (Dogaru et al., 2025; Neil et al., 2025). The addition of concise guidelines for students and session plan sheets for teachers has the potential to increase time efficiency and consistency in the implementation of (Narendra Reddy et al., 2025; Yazıcıoğlu & Akgüngör, 2025). Limitations of this study include the moderate sample size, single-school context, and relatively short implementation period. The paired-group design did not eliminate all possible external influences. Further research should expand the location and topic, extend

the intervention period, add a comparison group, and assess the long-term impact on science process skills to strengthen the generalization of findings.

5. Conclusion

This study establishes the basis for developing a Google Sites-based Learning Management System for teaching chemistry on the topic of acid-base titration at the secondary school level. The main objective is to produce a suitable, practical, and effective medium through the stages of Analysis, Design, Development, Implementation, and Evaluation so that the product is in line with the curriculum and operational in the classroom context. The results show consistency between objectives and achievements. Media validity is in the highly valid category with an average of 87%. Material validity is in the highly valid category with an average of 92%. Practicality according to teachers is in the highly practical category with an average of 93.14%, and practicality according to students is in the highly practical category with an average of 87%. Effectiveness was confirmed through nonparametric paired tests with a p-value < 0.05 and an average N-Gain of 0.83 in the effective category, so that the integration of text, images, infographics, videos, practical videos, structured exercises, and discussion forums was proven to improve conceptual understanding. Future Work focuses on strengthening causal design through control group or cluster randomized designs at multiple sites with larger samples to increase generalization. Instrument quality needs to be improved through content validity testing, interrater reliability, and confirmatory factor analysis for more precise and stable measurements. Integration of learning analytics to link engagement and learning time with achievement is necessary. Expansion to other chemistry topics and longitudinal studies to assess knowledge retention and transfer will strengthen the evidence of long-term effectiveness.

Author's Declaration

Author contribution

Zulkifli: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing original draft, Visualization, Project administration. **Faiza Rini**: Supervision, Conceptualization, Methodology, Validation, Resources, Writing review & editing, Supervision. **Rini Novita**: Supervision, Validation, Investigation, Data curation, Writing review & editing.

Funding statement

This research did not receive specific funding from any institution, whether public, commercial, or non-profit.

Acknowledgement

The authors would like to express their appreciation to the media experts and Chemistry Education experts for their validation and constructive input on the research products and instruments. We would also like to thank the Principal, Chemistry teachers, educational staff, and students of SMAN 1 V Koto Kampung Dalam, Padang Pariaman Regency, for their permission, facilities, participation, and feedback during the development, implementation, and evaluation processes. The authors are solely responsible for the content and shortcomings of this article.

Conflict of interest

The authors declare that there are no conflicts of interest related to this publication.

Ethical clearance

The involvement of teachers and students complied with the Code of Ethics for Educational Research and the Declaration of Helsinki. Research permission was obtained from SMAN 1 V Koto Kampung Dalam (Permit No. 200.14.5.4/998.b/SMAN1.Kamdal/2005), and all parties provided their consent for the use of anonymized data. The procedures were conducted without disrupting the learning process, ensuring confidentiality of identity, applying informed consent for voluntary participation, and protecting the rights of all participants.

Data availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

AI Statement

The grammar of this article has been corrected with the help of ChatGPT. The author confirms that all revisions are consistent with the topic and research data, and an English language specialist has validated the data and its formulation. This manuscript does not contain any sentences generated by artificial intelligence.

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