

Development of Google Sites-Based Learning Media Integrated with a Metacognitive PDCA Strategy for Reaction Rate Learning

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Abstract: This study aimed to develop Google Sites-based learning media integrated with the Strategy Metacognitive-PDCA (SM-PDCA), comprising Preparing, Doing, Checking, and Assessing & Following-Up, and to evaluate its validity, practicality, and potential to support students' cognitive learning outcomes in reaction rate learning. The study employed Type 1 developmental research using the ADDIE model. A pilot test involved 32 eleventh-grade students, while the implementation phase involved 36 students using a pre-experimental one-group pretest-posttest design. Data were collected using validation sheets, a student response questionnaire, and a cognitive learning outcome test that had undergone expert and empirical validation and showed a reliability coefficient of 0.866. The media and subject matter expert validation scores were 92% and 96%, respectively, while student responses reached 88%, indicating excellent validity and practicality. Students' mean cognitive score increased from 55.86 on the pretest to 91.31 on the posttest, with an N-gain of 0.81. These findings suggest that integrating SM-PDCA into Google Sites provides a valid and practical learning environment with potential to support improved cognitive learning outcomes in reaction rate learning.

Keywords: Cognitive learning outcomes; Google sites; Reaction rate; SM-PDCA

Introduction

Chemistry learning requires students to connect observable phenomena with explanations at the particle level and with symbolic representations such as equations, graphs, and mathematical relationships. This demand is particularly evident in reaction rate learning, which involves conceptual understanding, interpretation of experimental data, collision theory, mathematical relationships, and factors affecting reaction rates. Reaction rate learning requires students to connect macroscopic, submicroscopic, and symbolic representations in order to develop a more comprehensive understanding of chemical phenomena (Meutia et al., 2021). The topic is also characterized by abstract processes, calculations, graphs, and particle-level interactions that are not always directly observable, which may create difficulties for students in

understanding the underlying concepts (Rahmi et al., 2023). The integration of multiple representations can also support students' metacognitive processes by helping them relate different forms of chemical knowledge during learning (Locatelli & Davidowitz, 2021).

These characteristics indicate the need for learning media that can organize different forms of information and provide students with opportunities to engage actively with learning materials. Digital and website-based learning media provide an environment in which text, images, videos, worksheets, exercises, and assessment activities can be integrated within a single platform (Josué et al., 2023). Google Sites is one platform that can support such an environment because it allows different learning resources to be organized and accessed through various devices (Bangun et al., 2022). Previous research has shown that Google Sites-assisted

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learning devices can meet validity, practicality, and effectiveness criteria in science learning (Waraga et al., 2023). In chemistry education, Google Sites has also been developed to incorporate multilevel chemical representations, demonstrating its potential to present chemical content in a more structured and visually supported learning environment (Danin & Kamaludin, 2023).

More recent developments further demonstrate the potential of Google Sites and website-based media to support chemistry learning. Google Sites-based learning media developed for chemistry have obtained high validation scores from material and media experts and have shown potential to support students' learning interest (Laili et al., 2025). Website-based chemistry learning has also been developed to provide multimedia content, interactive activities, and structured learning resources for abstract chemistry concepts (Nahadi et al., 2025). These findings suggest that web-based learning environments can provide flexible access to diverse learning resources while supporting more structured learning experiences.

However, providing digital learning resources alone does not necessarily ensure that students actively regulate their own learning (Norman & Furnes, 2016). The educational value of digital tools may also depend on how they are integrated with pedagogical approaches and learning activities (Wohlfart et al., 2023). Reaction rate learning requires students not only to access information but also to recognize what they understand, identify difficulties, monitor their learning progress, and determine appropriate actions when their understanding remains incomplete. Metacognitive learning is relevant to these processes because it involves students' awareness and regulation of their own learning through planning, monitoring, and evaluation (Flavell, 1979). In reaction rate learning, metacognition-based learning materials have been developed to facilitate these processes and have shown potential to improve students' conceptual understanding (Nurmiati et al., 2025).

Technology enhanced learning environments can further support metacognitive regulation when metacognitive prompts are incorporated to guide students' monitoring and evaluation processes (Hsu et al., 2017). The relevance of metacognitive regulation has also been demonstrated in chemistry learning, where metacognitive training integrated into online learning was associated with improved student performance. A structured approach to facilitating metacognitive regulation is provided by the Strategy Metacognitive-PDCA (SM-PDCA), which consists of four stages: Preparing, Doing, Checking, and Assessing & Following-Up (Parlan et al., 2018). In the Preparing stage, students review learning materials, identify

relevant prior knowledge, establish learning goals, and determine learning strategies. The Doing stage engages students in active learning activities such as discussion, questioning, completing assignments, and constructing their understanding. During Checking, students monitor their learning progress, evaluate the effectiveness of their learning strategies, identify difficulties, and consider alternative solutions. The Assessing & Following-Up stage allows students to evaluate whether the learning objectives have been achieved and determine appropriate subsequent learning activities. These stages form a cyclical process that provides opportunities for students to organize, monitor, and evaluate their learning, which are fundamental processes in metacognitive regulation (Panadero, 2017).

The characteristics of Google Sites provide opportunities for these SM-PDCA stages to be systematically organized within a digital learning environment. Learning objectives, instructional materials, visual resources, worksheets, self-checking activities, assessments, and reflection tasks can be incorporated into an integrated learning sequence. Previous research has demonstrated that Google Sites can be combined with structured instructional approaches rather than functioning merely as a repository of digital materials. For example, Google Sites has been integrated with the 8E Learning Cycle in chemistry learning, with website content organized according to the stages of the instructional model (Pratiwi et al., 2025). Google Sites-based chemistry media have also been organized using Discovery Learning activities (Laili et al., 2025). These findings indicate that the instructional value of Google Sites depends not only on its technological features but also on how pedagogical activities are structured within the platform.

Similar integration between web-based media and pedagogical frameworks has been reported in chemistry education. Website-based chemistry media have been integrated with flipped classroom learning to support learning motivation and achievement (Rahman et al., 2021). Interactive chemistry websites have also been developed by embedding STEM and socio-scientific issue approaches within the learning environment (Khodizah et al., 2025). These studies demonstrate that website-based media can serve as environments for implementing pedagogically structured learning rather than merely delivering digital content.

Nevertheless, these previous developments differ from the focus of the present study. Google Sites-based chemistry media have been integrated with instructional approaches such as the 8E Learning Cycle and Discovery Learning (Laili et al., 2025; Pratiwi et al., 2025). Meanwhile, digital media developed specifically for

reaction rate learning have focused on multiple representations and virtual laboratory activities (Meutia et al., 2021; Rahmi et al., 2023), metacognition-based learning materials have been developed separately for the same topic (Nurmiati et al., 2025). Therefore, the research gap does not lie in the absence of Google Sites-based chemistry learning, digital reaction rate media, or metacognitive learning materials. Rather, the gap lies in the explicit integration of the SM-PDCA metacognitive cycle into the structure and learning activities of Google Sites specifically for reaction rate learning.

Accordingly, the novelty of this study lies in embedding the SM-PDCA stages of Preparing, Doing, Checking, and Assessing & Following-Up directly into Google Sites-based reaction rate learning. In the developed media, the Preparing and Doing stages are supported through organized learning objectives, reaction rate materials, visual resources, and student worksheets. The Checking stage is facilitated through self-checking activities, while the Assessing & Following-Up stage is supported through evaluation and reflection activities that allow students to reconsider their understanding and identify further learning needs. Thus, Google Sites is positioned not merely as a platform for delivering digital content but as a learning environment in which chemistry content and metacognitive regulation are organized within the same instructional sequence. Therefore, this study aimed to develop Google Sites-based learning media integrated with the SM-PDCA strategy and to evaluate its validity, practicality, and potential to support the cognitive learning outcomes of eleventh-grade students in reaction rate learning.

Method

This study employed Type 1 developmental research as proposed by Richey & Klein (2005). To operationalize the Type 1 developmental research framework, this study adopted the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009).

The Analysis stage focused on identifying learning needs and problems related to reaction rate learning. The Design stage involved preparing the structure of the media, learning activities, storyboard, and research instruments. During the Development stage, the Google Sites-based learning media was developed, validated by experts, revised, and subjected to a limited pilot test to examine its readability and practicality. The revised media was subsequently used in the Implementation stage, in which students completed a pretest, participated in learning using the SM-PDCA-integrated Google Sites, and completed a posttest. Evaluation was

conducted formatively throughout the development process to support product refinement. The overall research procedure is presented in Figure 1.

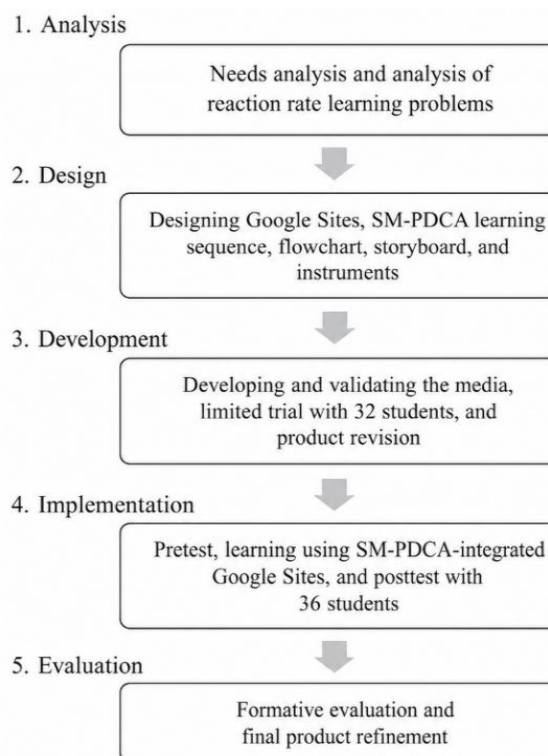


Figure 1. Research and development procedure

Research Subjects

The research subjects consisted of two groups of eleventh-grade students at a public senior high school in Jombang Regency, East Java. A pilot test involving 32 students was conducted during the Development stage to obtain data on the readability and practicality of the developed media. The Implementation stage involved 36 students who used the revised Google Sites-based learning media integrated with the SM-PDCA strategy. Students in the implementation group completed a pretest before learning and a posttest after completing the learning activities.

Research Instruments

The research instruments consisted of treatment instruments and measurement instruments. The treatment instruments included instructional modules, student worksheets, and Google Sites-based learning media. Before implementation, all treatment instruments were validated by five validators, consisting of two chemistry lecturers and three chemistry teachers, to ensure their suitability and alignment with the learning objectives.

The measurement instrument used in this study was a cognitive learning outcome test. As stated by Arikunto (2012), a test is a formal instrument for

collecting information because it is bound by specific rules and procedures. Therefore, a test was used to measure students' cognitive learning outcomes (Shek & Zhu, 2018). The test consisted of 30 items and was verified through expert judgment and empirical testing to ensure its validity and reliability before being used for data collection.

The practicality of the developed media was assessed using a student response questionnaire administered during the pilot test. The questionnaire evaluated students' perceptions of the developed media in terms of ease of use, clarity of instructions, visual presentation, and usefulness of the learning media. Students' responses were measured using a Likert scale, and the practicality score was calculated using the percentage formula.

Data Analysis

The validity data obtained from expert validators were analyzed using percentage scores. The percentage results were then categorized based on the criteria presented in Table 1.

Table 1. Media validity criteria

Percentage (%)	Criteria
81–100	Excellent
61–80	Good
41–60	Fair
21–40	Poor
0–20	Very Poor

(Ananda & Fadhli, 2018)

The percentage scores from the validity and readability tests were interpreted to determine the suitability of the developed product. The product was considered suitable if it obtained a percentage score of $\geq 61\%$. The product suitability criteria are presented in Table 2.

Table 2. Product suitability criteria

Percentage (%)	Criteria
81–100	Highly suitable
61–80	Suitable
41–60	Fairly suitable
21–40	Less suitable
0–20	Unsuitable

Data on students' learning outcome improvement were analyzed using the normalized gain, or N-gain. The N-gain categories followed Hake (1998), namely high ($g \geq 0.70$), moderate ($0.30 \leq g < 0.70$), and low ($g < 0.30$). The effectiveness categories based on N-gain percentage included ineffective ($<40\%$), less effective ($40\text{--}55\%$), moderately effective ($56\text{--}75\%$), and effective ($\geq 76\%$) (Tyas et al., 2023).

Result and Discussion

This research and development study produced Google Sites-based learning media developed through the five stages of the ADDIE model: analysis, design, development, implementation, and evaluation. The results of each stage are presented to describe the development process and the feasibility of the resulting product.

Analysis

The analysis stage began with a needs analysis to identify learning problems in the reaction rate topic (Lestari, 2023). Data were obtained through interviews with chemistry teachers and students, as well as through an analysis of reaction rate material.

The analysis of teacher interview results indicated that reaction rate instruction had been conducted using the discovery learning model, supported by student worksheets, experimental data tables, and PowerPoint presentations. However, the instructional materials used had not fully supported students' conceptual understanding, particularly in relation to the factors affecting reaction rates, reaction order, rate equations, and problem-solving involving calculations. These findings indicate the need for learning media that can present reaction rate concepts in a more systematic, visual, and structured manner while guiding students' learning processes through metacognitive stages.

Design

Based on the results of the analysis stage, the product was designed as Google Sites-based learning media. The activities in this stage included preparing the learning materials and content, creating flowcharts and storyboards, and developing the initial product design. Visual design elements were created using Canva to improve readability, visual appeal, and overall layout consistency.

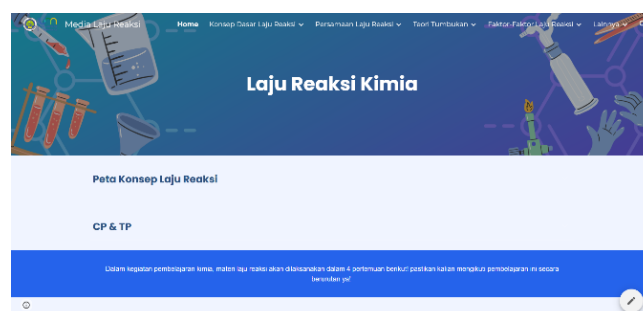


Figure 2. Home page layout of Google Sites-based learning media

The website structure consisted of a home page, learning objectives, reaction rate material, supporting

illustrations, student worksheets, evaluation tasks, and reflective activities. The learning activities in the media were organized according to the SM-PDCA stages: Preparing, Doing, Checking, and Assessing & Following-Up, so that students could follow the learning process in a more structured and reflective manner.

Figure 2 shows the home page of the Google Sites-based learning media on the reaction rate topic. This page includes the title of the media, the main topic heading, and a navigation menu that directs students to several learning sections, such as basic concepts of reaction rate, reaction rate equations, collision theory, factors affecting reaction rate, and other supporting menus.

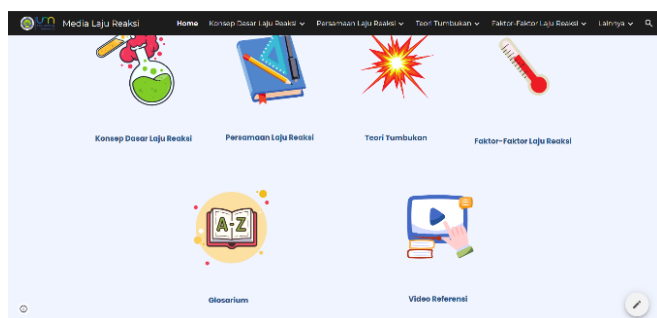


Figure 3. Main menu display of Google Sites-based learning media

Figure 3 illustrates the structure of the main menu in the learning media. Each icon represents a section of the material that students can access directly, making the learning navigation simpler, more focused, and user-friendly. This menu design was intended to help students follow the step-by-step learning flow of reaction rate material in accordance with the media design.

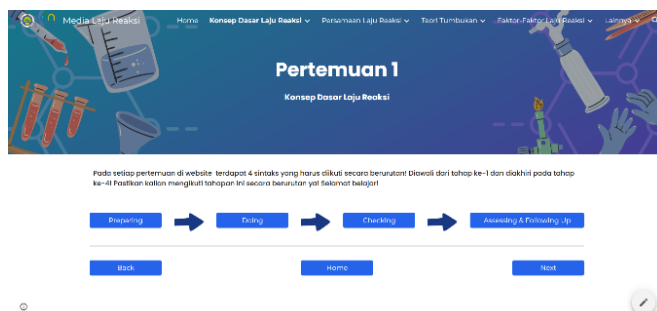


Figure 4. Integration of SM-PDCA stages in Google Sites-based learning media

Figure 4 illustrates the integration of the SM-PDCA stages within the developed Google Sites-based learning media. The learning environment was structured into four sequential stages: Preparing, Doing, Checking, and Assessing & Following-Up. This structure demonstrates that Google Sites was not merely used as a digital

repository for learning materials but was designed as an interactive learning environment that guided students through a metacognitive learning process.

In the Preparing stage, students were directed to recognize the learning objectives and activate their prior knowledge before engaging with the reaction rate materials. The Doing stage facilitated students' exploration of concepts through learning resources and activities. The Checking stage provided opportunities for students to monitor their understanding, while the Assessing & Following-Up stage encouraged reflection and further learning decisions.

Development

The developed media was validated by media experts, subject matter experts, and language experts using a validation sheet for Google Sites-based learning media on the reaction rate topic. The validation was conducted by five validators, consisting of two lecturers from Universitas Negeri Malang and three chemistry teachers from public senior high schools in Jombang.

Media Expert Validation

Media expert validation was conducted to evaluate the validity and suitability of the Google Sites-based learning media in terms of physical appearance, images and videos, and ease of use. The results of the media expert validation are presented in Table 3.

Table 3. Results of media expert validation

Indicator	Percentage (%)	Criteria
Physical appearance	93	Excellent
Images and videos	92	Excellent
Ease of use	92	Excellent
Average score	92	Excellent

Based on the media expert assessment presented in Table 3, the Google Sites-based learning media obtained an average score of 92%, which was categorized as excellent. This result indicates that the developed media met the media feasibility criteria, particularly in terms of physical appearance, the quality of images and videos, and ease of use. Therefore, the Google Sites-based learning media was considered suitable for use in reaction rate learning. This finding is consistent with previous studies reporting high feasibility scores for digital learning media in science education. Lafifa & Rosana (2023) reported a media validation score of 92% for STEM-PBL-based science learning media, indicating that digital learning products with scores above 90% can be categorized as highly feasible. Similarly, Hakim et al. (2023) reported a high media validation score for Google Sites-based learning worksheets, demonstrating the potential of Google Sites to support the development of feasible digital learning media.

Subject Matter Expert Validation

Subject matter expert validation was conducted to determine the suitability of the content presented in the Google Sites-based learning media. The assessed aspects included content/material, presentation, and language. The results of the subject matter expert validation are presented in Table 4.

Table 4. Results of subject matter expert validation

Indicator	Percentage (%)	Criteria
Content/material	95	Excellent
Presentation	94	Excellent
Language	99	Excellent
Average score	96	Excellent

Based on the subject matter expert validation presented in Table 4, the Google Sites-based learning media obtained an average score of 96%, which was categorized as excellent. The results indicate that the developed media met the feasibility criteria in terms of content accuracy, presentation, and language. Among the assessed aspects, language obtained the highest score 99%, indicating that the instructions, explanations, and terminology used in the media were considered clear and appropriate for students. Meanwhile, the content/material and presentation aspects also obtained excellent scores, demonstrating that the learning materials were aligned with the reaction rate concepts and were presented systematically. These findings are consistent with previous studies showing that digital chemistry learning media developed through systematic instructional design processes can achieve high validity ratings from experts. In chemistry learning, the quality of learning media is particularly important because it should support the presentation of chemical concepts through appropriate representations and clear explanations (Agang et al., 2021).

A limited pilot test was conducted with 32 students from Class XI-3. At this stage, students were asked to access and use the Google Sites-based learning media. After using the media, students completed a response questionnaire to evaluate the readability and practicality of the developed media. The results of the student response questionnaire showed that the Google Sites-based learning media obtained an average score of 88%, which was categorized as excellent. This result indicates that the media was easy to use, visually attractive, and presented in language that was easy for students to understand. Similar findings have been reported in previous studies, where Google Sites-based learning media received positive responses from students because the platform allows learning materials to be accessed easily and organized systematically (Dewi, 2020; Japrizal & Irfan, 2021).

In addition to quantitative data, students also provided feedback and suggestions regarding the media. This feedback was used as the basis for final revisions before the media was implemented in the field trial. Based on student feedback, revisions were made to several parts of the media, including clarifying usage instructions, simplifying certain material explanations, improving the visual presentation, and adding emphasis to the learning reflection section. These revisions were made to ensure that the learning media was easier to use and better aligned with students' learning needs.

Implementation

Prior to its use in the implementation stage, the cognitive test was examined through expert judgment and empirical testing. Expert validation resulted in a validity score of 98.0%, indicating that the test items demonstrated appropriate content validity and alignment with the learning objectives. The empirical testing showed a Cronbach's alpha reliability coefficient of 0.866, indicating high internal consistency and confirming that the test was reliable for measuring students' cognitive learning outcomes on reaction rate material (Nunnally & Bernstein, 1994).

An implementation test was conducted with 36 students from Class XI-4 to examine improvements in students' cognitive learning outcomes after using the Google Sites-based learning media integrated with the Strategy Metacognitive-PDCA (SM-PDCA), consisting of Preparing, Doing, Checking, and Assessing & Following-Up. Students' initial ability was measured using a pretest, while learning outcomes after the learning activities were measured using a posttest.

Table 5. Results of students' cognitive learning outcomes

Test	X	Passed	Failed
Pretest	55.86	1	35
Posttest	91.31	34	2

Table 5 presents the comparison of students' cognitive learning outcomes before and after the implementation of the Google Sites-based learning media integrated with the SM-PDCA strategy. The mean score increased from 55.86 in the pretest to 91.31 in the posttest. In addition, the number of students achieving the mastery criterion increased from 1 student in the pretest to 34 students in the posttest.

Table 6. Improvement analysis of students' cognitive learning outcomes

Indicator	Value	Category
N-gain	0.81	High
Effectiveness Level	81%	Effective

The improvement analysis presented in Table 6 showed an N-gain score of 0.81, categorized as high, with an effectiveness level of 81%. These findings indicate that the implementation of Google Sites-based learning media integrated with SM-PDCA was associated with an improvement in students' cognitive learning outcomes.

The improvement in students' cognitive outcomes may be related to the structured learning process provided by the integration of Google Sites and SM-PDCA. Unlike digital media that primarily function as content repositories, the developed media organized learning activities through sequential metacognitive stages. The Preparing stage encouraged students to identify learning objectives and activate prior knowledge, while the Doing stage facilitated students' engagement with learning materials, worksheets, and conceptual activities. These processes are consistent with the principles of self-regulated learning, in which students actively plan, monitor, and evaluate their own learning processes (Panadero, 2017; Zimmerman, 2002).

Compared to previous Google Sites-based chemistry media, the present study differs in the pedagogical structure embedded within the platform. Laili et al. (2025) and Pratiwi et al. (2025) organized their Google Sites content around Discovery Learning and the 8E Learning Cycle, respectively, focusing primarily on structuring the sequence of learning activities. Danin & Kamaludin (2023) emphasized multilevel chemical representation within Google Sites to support conceptual understanding of chemical bonds. In contrast, the present study integrated the SM-PDCA metacognitive cycle directly into the website structure, positioning Google Sites not only as a medium for organizing learning activities or representations but also as an environment that explicitly guides students to plan, monitor, and evaluate their own learning process at each stage of reaction rate learning. This distinction may provide a possible explanation for the observed improvement in students' learning outcomes, as students were not only exposed to structured content but were also prompted to regulate their understanding throughout the learning sequence.

The Checking stage provided opportunities for students to monitor their understanding through self-assessment activities. This stage is particularly relevant to reaction rate learning because students may experience difficulties in connecting macroscopic observations, particle-level explanations, and symbolic representations (Meutia et al., 2021; Rahmi et al., 2023). Through monitoring activities, students could recognize gaps in their understanding and reconsider their conceptions. This process is consistent with metacognitive learning, in which students are guided to monitor and regulate their own understanding. In

computer-based learning environments, metacognitive prompts have been shown to enhance students' self-regulated learning activities and learning outcomes (Guo, 2022). Similarly, explicit metacognitive instruction has been reported to benefit students' science learning by supporting the regulation of learning processes (Black & Wiliam, 2018; Zepeda et al., 2015).

Furthermore, the Assessing & Following-Up stage encouraged students to reflect on their learning achievements and determine further learning actions. This reflective process provided students with opportunities to evaluate their understanding and decide whether further learning activities were needed. Such activities are consistent with self-regulated learning, which has been associated with academic achievement in online learning environments (Theobald, 2021).

The findings of this study suggest that the improvement in students' cognitive learning outcomes was not only associated with the use of Google Sites as a digital learning medium but also with the integration of the SM-PDCA strategy, which provided a structured process for students to plan, monitor, and evaluate their learning. This finding is consistent with previous research showing that Google Sites-based learning environments can support students' learning outcomes when digital platforms are integrated with structured learning activities and instructional designs (Hidayat et al., 2023; Hikmawati et al., 2024).

Evaluation

Evaluation in this study was conducted continuously at each stage of the ADDIE development model to ensure the quality of the Google Sites-based learning media integrated with the Strategy Metacognitive-PDCA (SM-PDCA), consisting of Preparing, Doing, Checking, and Assessing & Following-Up. During the Analysis and Design stages, evaluation focused on reviewing the alignment between learning needs, website structure, learning activities, and the SM-PDCA stages.

During the Development stage, expert validation feedback was used to revise the media before the pilot test. The revisions included improvements to the visual layout, content accuracy, usage instructions, material explanations, and reflection activities. During the Implementation stage, student responses obtained from the pilot test were considered as additional feedback for refining the media before its wider use. Thus, evaluation functioned as a formative process that supported revision and refinement of the media throughout the development stages (Branch, 2009).

Conclusion

This study developed Google Sites-based learning media integrated with the Strategy Metacognitive-PDCA (SM-PDCA), consisting of Preparing, Doing, Checking, and Assessing & Following-Up, for reaction rate learning. The developed media demonstrated excellent validity based on media expert and subject matter expert assessments and was considered practical based on student responses. Furthermore, the implementation results showed an improvement in students' cognitive learning outcomes, indicated by an increase in the mean score from pretest to posttest and a high N-gain value. The findings suggest that integrating SM-PDCA into Google Sites provides a structured digital learning environment that not only presents chemistry learning resources but also supports students in planning, monitoring, and evaluating their learning processes. Thus, the contribution of this study lies in demonstrating the potential of digital learning media to provide greater instructional value when combined with systematic metacognitive strategies rather than functioning only as a platform for delivering content. This study was limited to one implementation group; therefore, further research involving larger samples, comparison groups, and different learning contexts is recommended to generalize these findings and examine the consistency of the media's impact on students' chemistry learning outcomes.

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Author Contributions

Conceptualization, methodology, investigation, data curation, formal analysis, resources, and writing—original draft preparation, A.E.D.; validation, supervision, and writing—review and editing, P.P.; supervision, project administration, and review and editing, R.J. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

References

- Agang, M. F., Tangi, H. C., & Komisia, F. (2021). Integrasi Level Makroskopik, Submikroskopik, dan Simbolik Melalui Pengembangan Video Pembelajaran pada Materi Kelarutan dan Hasil Kali Kelarutan (KSP). *Jurnal Beta Kimia*, 1(1), 29–36. <https://doi.org/10.201185/jbk.v1i1.5131>
- Ananda, R., & Fadhli, M. (2018). Teori dan Praktik dalam Pendidikan. In CV. *Widya Puspita* (Vol. 5, Nomor 3). Retrieved from <http://repository.uinsu.ac.id/3586/1/7>
- Arikunto, S. (2012). *Dasar-dasar evaluasi pendidikan*. Jakarta: Bumi Aksara.
- Bangun, R. H., Sitompul, J., & Fibriasari, H. (2022). Google Sites as Learning Media in the Material Development of Advanced Reading Comprehension. *International Journal of Research and Review*, 9(7), 519–525. <https://doi.org/10.52403/ijrr.20220756>
- Black, P., & Wiliam, D. (2018). Classroom Assessment and Pedagogy. *Assessment in Education: Principles, Policy & Practice*, 25(6), 551–575. <https://doi.org/10.1080/0969594X.2018.1441807>
- Branch, R. M. (2009). *Prologue BT - Instructional Design: The ADDIE Approach* (R. M. Branch (ed.); page. 1–20). Springer US. https://doi.org/10.1007/978-0-387-09506-6_1
- Danin, V. J., & Kamaludin, A. (2023). Development of Google Sites Based Learning Media on Chemical Bonds with Multilevel Chemical Representation. *Jurnal Penelitian Pendidikan IPA*, 9(9), 6727–6733. <https://doi.org/10.29303/jppipa.v9i9.1552>
- Dewi, N. C. (2020). Pengembangan E-Learning Berbasis Google Site untuk Meningkatkan Prestasi Belajar Siswa. *Jurnal Ilmiah Teknologi Pendidikan*, 10(1), 2010–2016. <https://doi.org/10.33369/diadik.v10i1.18149>
- Flavell, J. H. (1979). Metacognition and Cognitive Monitoring: A New Area of Cognitive-Developmental Inquiry. *American Psychologist*, 34(10), 906–911. <https://doi.org/10.1037/0003-066X.34.10.906>
- Guo, L. (2022). Using Metacognitive Prompts to Enhance Self-Regulated Learning and Learning Outcomes: A Meta-Analysis of Experimental Studies in Computer-Based Learning Environments. *Journal of Computer Assisted Learning*, 38(3), 811–832. <https://doi.org/10.1111/jcal.12650>
- 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>
- Hakim, D. R., Pertiwi, K. R., & Hakim, D. R. (2023). Development of Innovative Student Worksheet Using Google Sites for Reproductive System Material. *Jurnal Penelitian Pendidikan IPA*, 9(9), 7484–7490. <https://doi.org/10.29303/jppipa.v9i9.4429>

- Hidayat, H., Hidayat, O. S., & Widiasih, W. (2023). Development of Google Sites-Based Learning Resources to Improve Mastery of Concepts and Process Skills in Electrical Circuit Materials. *Jurnal Penelitian Pendidikan IPA*, 9(6), 4624–4631. <https://doi.org/10.29303/jppipa.v9i6.3612>
- Hikmawati, H., Suastra, I. W., Suma, K., Sudiarnika, A. A. I. A. R., & Susanti, D. (2024). Analysis of The Practicality of Google Sites-Based Teaching Materials to Improve Student Learning Outcomes. *Jurnal Ilmiah Profesi Pendidikan*, 9(2), 1160–1167. <https://doi.org/10.29303/jipp.v9i2.2194>
- Hsu, Y.-S., Wang, C.-Y., & Zhang, W.-X. (2017). Supporting Technology-Enhanced Inquiry Through Metacognitive and Cognitive Prompts: Sequential Analysis of Metacognitive Actions in Response to Mixed Prompts. *Computers in Human Behavior*, 72, 701–712. <https://doi.org/10.1016/j.chb.2016.10.004>
- Japrizal, J., & Irfan, D. (2021). Pengaruh Penggunaan Media Pembelajaran Berbasis Google Site Terhadap Hasil Belajar Siswa pada Masa COVID-19 di SMK Negeri 6 Bungo. *Jurnal Vokasi Informatika*, 1(3), 38–44. <https://doi.org/10.24036/javit.v1i3.33>
- Josué, A., Bedoya-Flores, M., Mosquera-Quinonez, E., Mesías-Simisterra, Á., & Bautista-Sánchez, J. (2023). Educational Platforms: Digital Tools for the teaching-learning process in Education. *Ibero-American Journal of Education & Society Research*, 3(1), 259–263. <https://doi.org/10.56183/iberoeds.v3i1.626>
- Khodziah, A. T., Prasetyo, Y. D., Sholahuddin, A., Iriani, R., Leny, L., & Tan, L. T. (2025). Development of an Interactive STEM-SSI Website on Organic Chemistry to Enhance Critical Thinking Skills and Scientific Literacy. *JlPI (Jurnal IPA dan Pembelajaran IPA)*, 9(4), 1375–1388. <https://doi.org/10.24815/jipi.v9i4.98>
- Lafifa, F., & Rosana, D. (2023). Development and Validation of Animation-Based Science Learning Media in the STEM-PBL Model to Improve Students Critical Thinking and Digital Literacy. *Jurnal Penelitian Pendidikan IPA*, 9(9), 7445–7453. <https://doi.org/10.29303/jppipa.v9i9.4448>
- Laili, A. M., Widarti, H. R., Puspita, A. P. I., Anantayani, A., Amrullah, N. K., & Aini, R. G. (2025). Development Of Google Sites-Based Learning Media To Increase Student Learning Interest. *IJCER (International Journal of Chemistry Education Research)*, 9(2), 165–175. <https://doi.org/10.20885/ijcer.vol9.iss2.art6>
- Lestari, D. R. M. H. U. H. D. (2023). Application of the Addie Model in Designing Digital Teaching Materials. *Jurnal Pendidikan dan Pengajaran Guru Sekolah Dasar (JPPGuseda)*, 6(1), 105–109. <https://doi.org/10.55215/jppguseda.v6i1.7525>
- Locatelli, S. W., & Davidowitz, B. (2021). Using Metavisualization to Revise an Explanatory Model Regarding a Chemical Reaction between Ions. *Chemistry Education Research and Practice*, 22, 382–395. <https://doi.org/10.1039/D0RP00339E>
- Meutia, F., Nurdin, N., & Winarni, S. (2021). Development of e-Student Worksheets Based on Multiple Representations of Factors Affecting Reaction Rates. *Jurnal Penelitian Pendidikan IPA*, 7(2), 129–136. <https://doi.org/10.29303/jppipa.v7i2.533>
- Nahadi, N., Widarti, H. R., Shidiq, A. S., Siswaningsih, W., Nurhadi, A. R., Rahmawati, T., Nais, M. K., Anggraeni, R. D., Rifa, H. A., Chotimah, R. C., Ayuni, A. D., Aphelia, L. C., & Oktaviani, T. (2025). Development of Website-Based Creative Content as Learning Media on Molecular Geometry. *Jurnal Penelitian Pendidikan IPA*, 11(4), 900–908. <https://doi.org/10.29303/jppipa.v11i4.10116>
- Norman, E., & Furnes, B. (2016). The Relationship between Metacognitive Experiences and Learning: Is There a Difference between Digital and Non-Digital Study Media? *Computers in Human Behavior*, 54, 301–309. <https://doi.org/10.1016/j.chb.2015.07.043>
- Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric Theory* (3rd ed.). McGraw-Hill.
- Nurmiati, E., Wahyono, S. B., Rhomadan, M. R., Khairah, N., & Tafrienda, U. N. (2025). Development of Metacognition-Based LKPD to Improve Conceptual Understanding in Reaction Rate Material. *Jurnal Penelitian Pendidikan IPA*, 11(4), 533–541. <https://doi.org/10.29303/jppipa.v11i4.10464>
- Panadero, E. (2017). A Review of Self-Regulated Learning: Six Models and Four Directions for Research. *Frontiers in Psychology*, 8, 422. <https://doi.org/10.3389/fpsyg.2017.00422>
- Parlan, P., Ibnu, S., Rahayu, S., & Suharti, S. (2018). Effects of the Metacognitive Learning Strategy on the Quality of Prospective Chemistry Teacher's Scientific Explanations. *International Journal of Instruction*, 11(4), 673–688. <https://doi.org/10.12973/iji.2018.11442a>
- Pratiwi, N. A., Zamhari, M., & Ridzaniyanto, P. (2025). Google Sites as a Tool for Chemistry: Exploring the 8E Learning Cycle Approach. *IJCER (International Journal of Chemistry Education Research)*, 9(1), 61–73. <https://doi.org/10.20885/ijcer.vol9.iss1.art7>
- Rahman, A. S. N., Anwar, M., & Wijaya, M. (2021). Pengembangan Media RatuChemWeb dalam Model Pembelajaran Flipped Classroom untuk Meningkatkan Motivasi dan Hasil Belajar Peserta Didik. *Chemistry Education Review (CER)*, 5(1), 37. <https://doi.org/10.26858/cer.v5i1.26356>
- Rahmi, C., Zakiyah, H., Dewi, D. K., & Jayanti, E. (2023).

- Development of Reaction Rate Lab Virtual Media in Basic Chemistry Practicum. *Jurnal Penelitian Pendidikan IPA*, 9(4), 2125–2134. <https://doi.org/10.29303/jppipa.v9i4.2126>
- Richey, R. C., & Klein, J. D. (2005). Developmental Research Methods: Creating Knowledge from Instructional Design and Development Practice. *Journal of Computing in Higher Education*, 16(2), 23–38. <https://doi.org/10.1007/BF02961473>
- Shek, D. T., & Zhu, X. N. V.-4. (2018). Pretest-Posttest Designs. *The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation*. <https://doi.org/10.4135/9781506326139.n538>
- Theobald, M. (2021). Self-Regulated Learning and Academic Achievement in Online Learning Environments: A Meta-Analysis. *Computers & Education*, 163, 104086. <https://doi.org/10.1016/j.compedu.2020.104086>
- Tyas, F. K., Dasna, I. W., Wijaya, A. R., & Setyowati, I. (2023). Problem-Based Learning versus STAD Learning Model for Improving Students' Argumentation Skills in Thermochemistry. *Jurnal Pendidikan MIPA*, 24(1), 298–308. <https://doi.org/10.23960/jpmipa/v24i1.pp298-308>
- Waraga, S. S., Abdjul, T., & Odja, A. H. (2023). Development of Google Sites-Assisted Learning Devices on Vibrations and Waves Material. *Jurnal Penelitian Pendidikan IPA*, 9(8), 6101–6110. <https://doi.org/10.29303/jppipa.v9i8.4275>
- Wohlfart, O., Wagner, A. L., & Wagner, I. (2023). Digital Tools in Secondary Chemistry Education - Added Value or Modern Gimmicks? *Frontiers in Education*, 8. <https://doi.org/10.3389/feduc.2023.1197296>
- Zepeda, C. D., Richey, J. E., Ronevich, P., & Nokes-Malach, T. J. (2019). Direct Instruction of Metacognition Benefits Adolescent Science Learning. *Learning and Instruction*, 62, 51–60. <https://doi.org/10.1016/j.learninstruc.2019.01.002>
- Zimmerman, B. J. (2002). Becoming a Self-Regulated Learner: An Overview. *Theory Into Practice*, 41(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2