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Development of Science Learning Tools Based on Google Workspace for Education on the Topic of Biodiversity to Improve the Students 4C Skills

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Abstract: The background of this research is the low level of mastery of 4C skills among seventh-grade students in Kutai Kartanegara Regency, compounded by a tendency for conventional science instruction to be one-way and abstract. This study aims to develop, test the feasibility, practicality, and effectiveness of GWE-based science learning materials focused on the topic of biodiversity, with the goal of enhancing students' 4C skills. The research employs a Research and Development (R&D) approach using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. Field testing was conducted using a quasi-experimental design—specifically a non-equivalent control group design—at two schools: SMPN 1 Kenohan and SMPN 1 Anggana, involving 80 students selected through purposive sampling. Data were collected via expert validation sheets, tests (pre-test and post-test), observation sheets for 4C skills, and user response questionnaires. Data analysis was performed using descriptive and inferential statistics (Independent Sample t-test). The results indicate that the developed learning materials are highly feasible and theoretically valid, according to expert assessments. The materials proved to be highly practical, with student response percentages reaching 91.48% at SMPN 1 Kenohan and 91.93% at SMPN 1 Anggana. The GWE-based learning materials were found to be significantly effective in improving students' cognitive learning outcomes; this is evidenced by high N-Gain scores in the experimental groups—0.72 at SMPN 1 Kenohan and 0.73 at SMPN 1 Anggana—along with a t-test significance value of 0.000 ($p < 0.05$). Furthermore, all indicators of students' 4C skill performance fell into the "very high" category. In conclusion, the GWE-based science learning materials developed in this study are feasible, practical, and effective for enhancing students' 4C skills. It is recommended that teachers consistently integrate local environmental phenomena into digital instruction to maintain the sharpness of students' critical reasoning.

Keywords: 4C Skills; ADDIE; Biodiversity; Google workspace for education; Science learning materials

Introduction

The development of information and communication technology (ICT) has brought about fundamental changes across various sectors, including education. The Industrial Revolution 4.0 era demands that the education system innovate and produce a generation that is creative, innovative, and competitive. This shift is known as 21st-Century Learning, which emphasizes the mastery of ICT, or digital literacy. ICT

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literacy has become an essential skill for both teachers and students, given the vast amount of learning material now available and accessible via the internet (Munandar et al., 2024). In today's digital era, information technology has become an integral part of daily life, including within the educational sphere (Januarti et al., 2024; Khasanah et al., 2019). The use of technology in the learning process not only facilitates access to information but also holds the potential to enhance student engagement and creativity (Doyan et al., 2026; Muliyadi et al., 2026).

One platform widely used in education is Google Workspace for Education (GWE), which offers a variety of tools and applications that support collaboration, communication, and creativity. Basic-level use of GWE provides features such as Google Docs, Google Slides, Google Sheets, and Google Classroom, enabling students to collaborate in real-time, share ideas, and develop projects together. Rahayu (2021) states that the use of GWE can improve student learning outcomes—increasing the average evaluation score from 77.5% to 84% and raising the proportion of students who meet or exceed the Minimum Mastery Criteria (KKM) from 76% to 82.1%. Nevertheless, significant challenges remain, specifically regarding internet data quotas and network connectivity. Insani et al. (2020) also note that the ICT literacy level of junior high school students following their use of Google Suite for Education (GSE) falls into the "good" category (averaging 71.90%), with students possessing higher academic ability demonstrating even greater levels of ICT literacy.

The use of Google Classroom in education in Indonesia offers numerous benefits, including enhancing the proficiency of both teachers and students in using technology, saving time, promoting environmental sustainability, overcoming geographical barriers, fostering collaboration, enabling communication beyond time constraints, and providing secure document storage (Sudarsana et al., 2019). Furthermore, Irvan et al. (2021) noted that training for teachers on the use of Google Workspace for Education (GWE) has been conducted smoothly and effectively. Recently, training on the implementation of Project-Based Learning—utilizing Google Docs and Google Slides to create instructional materials—has been widely carried out across various regions (Palupi et al., 2022). It is expected that leveraging GWE features in the learning process will empower students to be more creative in designing and presenting their projects, while also fostering innovations relevant to their coursework, including in the field of Natural Sciences (IPA).

In Kutai Kartanegara Regency, the education sector continues to face several challenges, such as limited access to high-quality learning resources and a lack of interactive teaching methods. Meanwhile, the landscape of educational media has evolved significantly, particularly with the rise of online learning tools. The suitability of application-based learning media depends heavily on the students' specific circumstances and their environment; therefore, there is an urgent need to implement application-based instructional tools for junior high school (SMP) students. In Kutai Kartanegara Regency, junior high students encounter difficulties in learning Natural Sciences (IPA) a subject where conceptual understanding and practical application are crucial. Traditional teaching methods, however, are often ineffective in stimulating student interest and creativity. Therefore, a new, more engaging, and effective approach is needed to increase student involvement in learning projects.

However, despite the many benefits offered, challenges remain in the implementation of Google Workspace for Education (GWE) within educational settings, particularly in regions with limited technological infrastructure. In Kutai Kartanegara Regency, the integration of technology into the learning process is still in its early stages. Many teachers have yet to fully grasp how to use these tools effectively.

Method

This study represents Research and Development (R&D) adopting the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) (Branch, 2009). This design was selected due to its systematic, generic, and adaptive structure for integrating learning technology. Testing the effectiveness of the learning tools in the implementation phase applied a Quasi-Experimental approach, specifically the Non-equivalent Control Group Design (Sugiyono, 2019).

The trial subjects in this study were 80 Grade VII students in the 2025/2026 academic year, selected using the Purposive Sampling technique. The sample was distributed across two research loci: (1) SMPN 1 Kenohan (20 experimental class students, 20 control class students), and (2) SMPN 1 Anggana (20 experimental class students, 20 control class students). The experimental classes were treated using GWE-based science tools through a Project-Based Learning (PjBL) scenario, while the control classes used conventional non-GWE methods.

Data collection utilized instrument triangulation: (a) Expert Validation Sheets (measured by the Aiken's V Index), (b) Teacher and Student Response Questionnaires (Likert scale) to measure practicality, (c) Digital Performance Observation Sheets to analyze the 4C dimensions, and (d) Cognitive Test Instruments in the form of Pre-tests and Post-tests. Cognitive improvement was evaluated using Normalized Gain (N-

Gain) analysis. The significance of effectiveness between the experimental and control classes was analyzed inferentially using the parametric Independent Sample t-test at a 95% confidence level ($\alpha = 0.05$) after meeting the prerequisite normality (Shapiro-Wilk) and homogeneity (Levene's Test) tests.

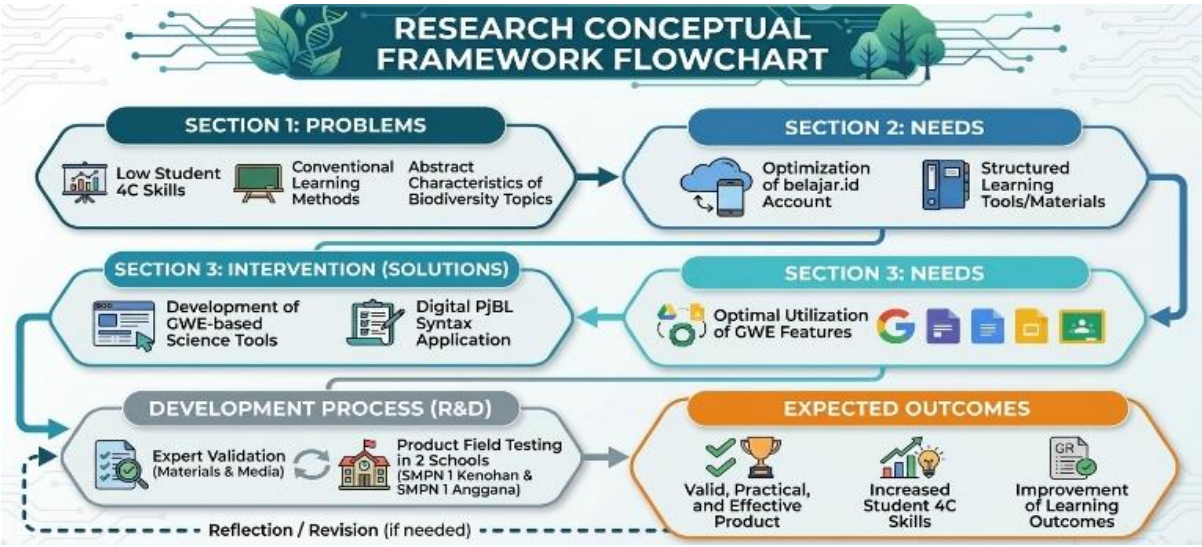


Figure 1. Research conceptual framework flowchart

Result and Discussion

Feasibility of Learning Tools (Validity)

Based on expert judgment during the Development phase of ADDIE, the developed learning tools received excellent evaluations. The Teaching Tools Validator awarded a total score of 200, the Material Validator awarded 120, the Media Validator awarded 80, and the Language Validator awarded 56. All tools recorded an Aiken's V Index well above the minimum threshold of 0.667. Formative revisions—such as refining Operational Verbs, adding navigation limits on Google Sites, and including literacy source credits—ensured that the products were highly feasible theoretically and ready for field implementation.

This assessment of feasibility aligns with research by Mayer (2017), which states that the evaluation and application of rigorous design principles within an e-learning ecosystem are essential for reducing extraneous cognitive load. By removing distracting visual and navigational elements—a process facilitated by the validators' curation—students' working memory capacity is not depleted by efforts to resolve technical confusion. Instead, students can navigate seamlessly and focus their full cognitive resources on completing their Biodiversity project.

Based on the feasibility of the GWE-based learning tools and supported by existing literature, the researcher recommends that the content be updated periodically, as the GWE ecosystem and the taxonomic status of biodiversity are constantly evolving. Therefore, it is suggested that the Science Teachers' Forum (MGMP IPA) in Kutai Kartanegara Regency review and update the digital content and links every 1–2 years. This measure is crucial to prevent "link rot," which could otherwise lead to technical issues in the future.

Practicality of Learning Tools

Practicality data were collected through teacher and student response questionnaires post-implementation. For student responses, the average total cumulative percentage reached 91.48% at SMPN 1 Kenohan and 91.93% at SMPN 1 Anggana ("Very Practical" criteria). Students stated that integrative features like Google Classroom and live comments on documents significantly boosted motivation (affective item scores > 90%). From an educator's perspective, cloud computing integration successfully served as logistical mitigation for conventional learning; replacing expensive physical observations with interactive web-portfolio collaborations based on local ecology (e.g., Mahakam Dolphin and Semayang Lake conservation issues).

The opinions expressed by the two teachers serve as a clear manifestation of the Technology Acceptance Model (TAM). This aligns with research by Kartimi et al. (2021), which asserts that the adoption of digital tools by teachers is heavily dependent on "Perceived Ease of Use" (the user-friendliness of the interface) and "Perceived Usefulness" (the benefits regarding time efficiency in teaching).

Based on the improvements in classroom management efficiency and supported by existing literature, the researcher recommends that schools establish operational standards for the use of GWE (Google Workspace for Education) features. Teachers

should be provided with training on how to configure Google Docs for offline use, ensuring that this efficiency is not disrupted during power outages or temporary losses of internet connectivity—a recommendation prompted by the high level of reliance on an internet connection.

Cognitive Improvement Effectiveness (N-Gain and T-Test)

To determine cognitive success, the researchers present a comparison of the N-Gain Scores derived from the difference between the pre-test and post-test across the GWE and conventional classes.

Table 1. Comparison of N-Gain Scores for Cognitive Learning Outcomes

Locus	Group	Pre-test Mean	Post-test Mean	N-Gain Score	Category
SMPN 1 Kenohan	Experimental (GWE)	73.75	92.70	0.72	High
SMPN 1 Kenohan	Control (Conventional)	71.75	80.95	0.33	Medium
SMPN 1 Anggana	Experimental (GWE)	73.90	93.00	0.73	High
SMPN 1 Anggana	Control (Conventional)	71.95	81.00	0.32	Medium

The data indicates a significantly higher cognitive leap in the experimental classes. After confirming normality and homogeneity, inferential hypothesis testing (Independent Sample t-test) proved a significant difference. The analysis yielded t-values of 11.842 (Kenohan) and 14.215 (Anggana) with an absolute p-value (Sig. 2-tailed) of 0.000 < 0.05. This demonstrates that the utilization of GWE is vastly superior to conventional pedagogical approaches (Akcil et al., 2021; Al-Samarraie et al., 2018; Emilzoli et al., 2025).

This achievement is rooted in the successful alignment of how students' brains process images and words simultaneously. This aligns with the findings of Klemer et al. (2020), who demonstrated that science visualized through web-based collaboration can transform abstract biological material into spatial mental models—models that become deeply embedded as permanent structures of understanding within students.

Given the high N-Gain scores observed at SMPN 1 Kenohan and SMPN 1 Anggana, and supported by existing literature, the researchers recommend conducting a delayed post-test 3–6 months after the project. This comparative step is necessary to assess students' long-term memory retention and to confirm that the improvement in their understanding of biodiversity concepts is holistic, rather than merely a transient "novelty effect" stemming from the use of new media. This follow-up assessment will serve as an honest reflection of whether the students' concern for the conservation of the Mahakam dolphin (Pesut Mahakam) or the vegetation of Lake Semayang which they mapped during the project has evolved into a lasting awareness. The researchers aim to ensure that these GWE-based digital tools have successfully left a humanistic, literacy-oriented imprint on the minds of the seventh-grade students, long after the classroom project has concluded.

Dynamics of 4C Skills Achievement

The impact of cloud platform integration on students' digital performance was deeply observed. The recapitulated percentage achievements of the experimental 4C dimensions are presented below.

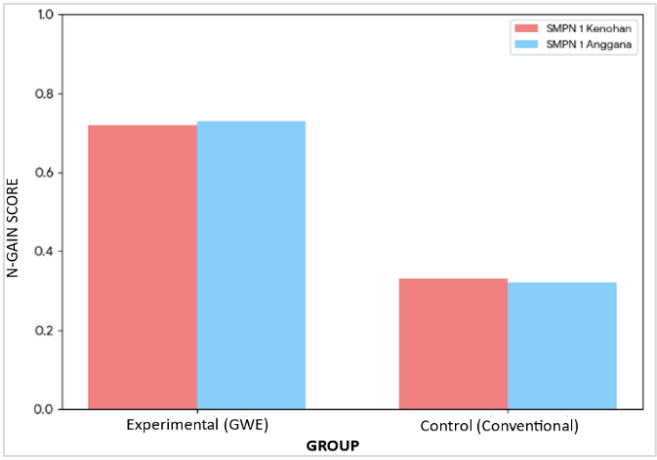


Figure 2. Comparison of n-gain scores between groups and schools

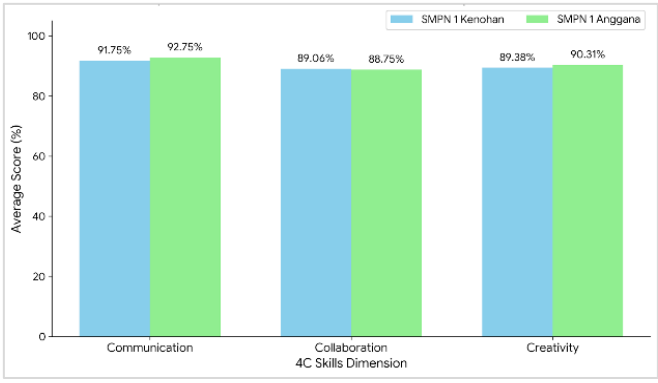


Figure 3. Comparison of students 4C skills achievement

Although both schools displayed "Very High" results, there were different dynamic characteristics (variance). Students at SMPN 1 Anggana, equipped with mature school digital literacy capital (Accreditation A), demonstrated high originality in designing digital catalog final products (Creativity 90.31%) and executed real-time collaboration management with minimal technical barriers. Conversely, students at SMPN 1

Kenohan (Accreditation B), who initially faced slight device disparities, successfully mitigated this through the facilitation of the school's computer laboratory. The implication was that Kenohan students demonstrated remarkable flexibility in brainstorming alternative ideas for the preservation of the Semayang Lake region, and the online comment space successfully reduced students' shyness to express opinions in class.

Table 2. Recapitulation of Experimental 4C Skills Achievement

4C Aspects & Readiness	4C Aspects & Readiness	4C Aspects & Readiness
Critical Thinking	Excellent in local contextual analysis (real environmental issues around Lake Semayang).	Very strong in digital reference search and synthesis of broader scientific data.
Creativity	Students excel in diversifying local ideas, although visual adaptation from print to digital media requires extra guidance.	Shows high originality in creating aesthetic digital works (catalogs/Google Sites).
Communication	Confident in expressing opinions via GWE comment fields; classical verbal communication is still developing.	Very fluent in conducting digital presentations and online inter-group scientific argumentation.
Collaboration	Role distribution within groups runs naturally; adaptation of document synchronization is still gradual.	Real-time collaboration management (sharing docs) is highly mature; minimal technical barriers.
Differentiating Factors	Limitations in individual device specifications; requires strengthening computer lab connectivity.	Solid school ICT infrastructure support; students' initial digital literacy is already high.

The success of this integration verifies Piaget's constructivism theory and Vygotsky's cognitive mediation; where the role of GWE technology is not merely to digitize paper worksheets, but to shift students into active environmental analysts who synthesize knowledge in a decentralized manner (Nurhasnah et al., 2024; Rosyida et al., 2026).

Conclusion

Based on development research conducted at SMPN 1 Kenohan and SMPN 1 Anggana, science learning materials based on Google Workspace for Education (GWE) covering the topic of Biodiversity have been proven theoretically highly valid according to expert assessments. They are also highly practical for both teachers and students, with a student-rated practicality level exceeding 91%. Furthermore, these materials are significantly effective in enhancing cognitive learning outcomes (with high N-Gain scores of 0.72 and 0.73; Sig. 0.000) and 4C skills (rated as "very high," ranging from 89% to 94%). Notably, differences in school accreditation status do not hinder the consistent positive impact of these materials, provided that adequate ICT facilities are available.

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Author Contributions

G.: Conceptualization, methodology design, digital product development (designing *Google Sites*, teaching modules, and digital worksheets), investigation and field data collection (at SMP Negeri 1 Kenohan and SMP Negeri 1 Anggana), quantitative and qualitative data curation, inferential statistical analysis (*N-Gain* and *t-test*), and writing—original draft preparation. E.T.M.: Primary supervision as the First Advisor, conceptual validation, material expert validation (biodiversity content and adjustment of Operational Verbs), and writing—critical review and editing. K.P.C.: Co-supervision as the Second Advisor, validation of the research methodology design, quantitative data analysis, and writing—critical review and editing. H.: Expert validation of the pedagogical layout and learning tools (synchronization of Learning Outcomes, learning objectives, and separation of the 4C skills assessment rubrics). E.R.: Expert validation of cloud computing-based learning media (*Google Sites* navigation structure and *Google Slides* material integration), and technical facilitation of the experiment implementation at the SMP Negeri 1 Anggana locus. Y.H.: Expert validation of the language and linguistic readability of the instrument manuscripts, and review of the scientific writing mechanics of the draft manuscript.

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statistical analysis, interpretation of results, or the preparation of this manuscript.

Conflicts of Interest

The authors declare no financial, personal, or professional conflicts of interest regarding the implementation, evaluation, writing, and publication of this study. Although this research specifically designs science learning tools and evaluates the effectiveness of the Google Workspace for Education (GWE) ecosystem within schools designated as Candidate Google Reference Schools (*Kandidat Sekolah Rujukan Google* - KSRG) in Kutai Kartanegara Regency (specifically SMP Negeri 1 Kenohan and SMP Negeri 1 Anggana), the authors explicitly confirm that this study is purely driven by academic and pedagogical inquiry. The authors hold no commercial affiliations, employment ties, or marketing sponsorships from Google LLC or any related third-party tech entities that could distort the objectivity of the empirical data, evaluation results, or conclusions drawn in this manuscript.

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