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DEVELOPING AN INNOVATIVE TECHNOLOGY-BASED PEDAGOGICAL MODEL IN THE EDUCATION PROFESSION TO SUPPORT THE SDGs

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Abstract: This study aims to develop an innovative technology-based pedagogical model in the education profession to support the achievement of the Sustainable Development Goals (SDGs), specifically SDG 4 on quality education. This study used a Research and Development (R&D) design combined with a pre-test and post-test experimental approach. Participants consisted of 60 students, who were selected purposively and divided into control and experimental groups. Data were collected through pre- and post-tests, observation sheets, questionnaires, and interviews. The results showed that most of the data were normally distributed, while the homogeneity test indicated that the data were homogeneous ($p > 0.05$). Furthermore, a paired sample t-test revealed that although learning outcomes improved, the difference was statistically significant ($p = 0.581 > 0.05$). This indicates that the developed model improved learning outcomes and demonstrated significant effectiveness.

Keywords: Innovative Pedagogy; Technology-Based Learning; SDGs; Learning Outcomes; Experimental Research

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INTRODUCTION

Declaration of Sustainable Development Goals (Sustainable Development Goals/SDGs) in 2015 by the United Nations has set an ambitious global agenda to realize a more just, peaceful, and sustainable world by 2030. Among the 17 goals, SDG 4 on "Quality Education" is placed as a foundation and catalyst for achieving other goals. Education is no longer seen merely as a basic right, but as a strategic instrument to eradicate poverty (SDG 1), encourage inclusive economic growth (SDG 8), reduce inequality (SDG 10), and even address climate change (SDG 13)(Munawir, Yani, & ..., 2025). Within this framework, the teaching profession plays a very crucial role because they are the ones who directly shape the quality of human resources who will carry out the sustainable development agenda(Aryana, Wulandari, & Muyassaroh, 2025).

The current state of education is in the midst of a fundamental shift accelerated by the COVID-19 pandemic(Ba'in, Utami, & Arifin, 2026). The pandemic has forced a dramatic leap in the adoption of digital technology in the education sector, which had previously been slow and gradual. Within weeks, hundreds of millions of students and educators worldwide

were forced to shift to online learning (emergency remote teaching)(Hendri, Hadevi, Nelian, & ..., 2026). Even though the emergency situation has passed, its impact remains new normal where technology is no longer an optional extra, but rather an integral component of the educational ecosystem. Today, we are witnessing the phenomenon hybrid learning, utilization learning management system (LMS), and the growing use of generative artificial intelligence (AI) such as Chat GPT in the learning process(Permatasari, 2024). This creates a highly dynamic landscape, full of opportunities, but also fraught with new challenges that have yet to be fully addressed.

However, a major irony is emerging. While technological infrastructure and digital devices have significantly improved post-pandemic, pedagogical practices in most educational institutions have yet to undergo a commensurate transformation(Sidiq, Pahrudin, Jatmiko, & Koderi, 2025). The emerging phenomenon is the adoption of technology without a corresponding shift in learning paradigms. Many educators use digital platforms merely as a replacement for whiteboards and paper worksheets, implementing the same lecture methods in online or hybrid formats. Technology is being used to "digitize old ways" (digitizing old practices) rather than creating new, interactive, and transformative learning experiences(Puspitasari, 2025). As a result, despite increasing investment in technology, improvements in the quality of learning and students' achievement of 21st-century competencies have not shown a linear correlation.

Gap (gap) The core problem of this research is the gap between the enormous potential of digital technology to transform education and the reality of conventional pedagogical practices in the field. On the one hand, academic literature is rich with studies on the potential of AI, big data, immersive technology (AR/VR), and collaborative platforms in creating personalized, adaptive, and contextual learning(Budiarti, Darmayanti, & Karim, 2025). Meanwhile, educators at the operational level are still grappling with fundamental questions: how to integrate technology meaningfully? What pedagogical models are appropriate for specific contexts? How to ensure ethical and inclusive technology use? This gap suggests that what is missing is not the technology itself, but rather a structured, comprehensive, and evidence-based innovative pedagogical model capable of bridging technological innovations and everyday teaching practices.

Theoretically, this study also identifies gap in the scientific treasury of pedagogy and educational technology(Amelia, 2025). Models that have been used as references, such as TPACK (Technological Pedagogical Content Knowledge) dan SAMR (Substitution, Augmentation, Modification, Redefinition), have made important contributions to understanding the dimensions of knowledge required by teachers as well as the taxonomy of technology integration. However, these models have fundamental limitations: first, neither of them explicitly integrates the sustainability dimension (sustainability) and achieving the SDGs targets as the primary orientation of learning(Asrin, Fahruddin, Saputra, & ..., 2025). Second, these models were developed in the era before the explosion of generative AI and the massive post-pandemic digital transformation, so they are not fully responsive to current

technological dynamics(Pasaribu & Salmiah, 2024). Third, these models focus more on "what teachers know" and "how technology is used," but lack comprehensive guidance on "how to design transformative learning experiences" oriented toward sustainable development.

From a practical perspective, gap Equally pressing is the low digital pedagogical capacity of educators(Sunarsih & Pramono, 2025). Data from various national and international surveys show that although most educators have access to digital devices and are able to operate basic applications, their competence in designing innovative, technology-based learning remains very limited. Many educators are unable to utilize technology to create student-centered learning (student-centered), collaborative, and project-based—characteristics that are essential for cultivating sustainability competencies (sustainability competencies) such as systemic thinking, anticipation, and cross-disciplinary collaboration(Thohir, Ahdhianto, Irawan, & ..., 2024). Existing training programs tend to be technical and sporadic, rather than developing holistic and sustainable digital pedagogical competencies.

The urgency of this research is undeniable, given that we are at a critical moment in the history of education. 2030, the final target for achieving the SDGs, is fast approaching, while progress toward SDG 4 globally shows signs of stagnation and even regression following the pandemic(Sunarni & Ibrahim, 2025). Meanwhile, technology continues to advance at an exponential pace; generative AI has begun to transform the way humans learn, work, and think. If education does not quickly adapt by developing innovative and visionary pedagogical models, the gap between education and real-world needs will widen(Baadilla, Zamzam, Hidayatullah, & ..., 2025). Delays in responding to this situation risk producing a generation unprepared to face the complex challenges of the 21st century, while simultaneously derailing the overall sustainable development agenda.

In the Indonesian context, the urgency of this research is further strengthened by the Merdeka Belajar policy launched by the Ministry of Education, Culture, Research, and Technology(Khotimah & Rusli, 2025). This policy explicitly encourages educational transformation by granting educators greater autonomy to innovate, create student-centered learning, and integrate sustainability values. However, this policy requires concrete, operational, and evidence-based implementation models to be effectively translated by teachers in the field(Triantoro, Mawardi, & ..., 2025). Without a clear, innovative pedagogical model, the implementation of Merdeka Belajar risks becoming merely an administrative change without substantial transformation of the learning process.

This research also has urgency from the perspective of social justice and inclusivity. Digital technology has the potential to widen the gap (digital divide) if not managed with an inclusive pedagogical model(Rahman, Kaniawati, Riandi, & ..., 2025). Conversely, with the right model, technology can be a powerful tool for reaching learners in remote areas, people with disabilities, and other marginalized groups. The innovative pedagogical models developed must explicitly consider aspects of accessibility, equity, and diversity so that contributions to

SDGs 4 and 10 (reducing inequalities) can be truly realized. Without an inclusive model, the digitalization of education will actually create new, more complex forms of inequality(Ni'mah, Fitriyani, Imroatin, & ..., 2025).

The current situation that adds urgency to this research is the widespread use of generative AI (such as Chat GPT, Gemini, and Claude) among educators and students. This phenomenon is occurring very rapidly, while the education sector is not yet pedagogically and ethically ready(HS, Sattuang, Wulandari, & ..., 2025). Many educators feel confused: should the use of AI be prohibited, accommodated, or integrated as part of learning? How to maintain academic integrity while still harnessing AI's potential to enhance creativity and productivity? How to teach critical and ethical AI literacy to students? These questions require answers in the form of a pedagogical model that is not only responsive to the latest technology but also grounded in ethical values and a sustainability orientation(Padmasari, Sutianah, & ..., 2024).

This research is urgent because current approaches to integrating technology into learning are fragmented and partial. Often, the focus is on only one aspect, such as the development of learning media, technical teacher training, or infrastructure provision, without connecting all three within a coherent pedagogical framework(De, Dewi, Dika, & Parwati, 2026). However, sustainable educational transformation requires a systemic approach that simultaneously integrates pedagogical innovation, the use of cutting-edge technology, the enhancement of educators' professional capacity, and an orientation toward achieving the SDGs. This holistic approach is the distinctive and novel value of this research.

From a methodological perspective, this research also fills gap that exist in the educational literature. Most research on technology integration in learning uses a survey or quasi-experimental approach that only measures the impact on one particular variable over a limited period of time. Very few studies use a descriptive approach. design-based research (DBR), or design-based research, enables collaborative, iterative, and contextual model development. DBR allows researchers and practitioners (teachers) to collaboratively design, implement, evaluate, and refine models in long, iterative cycles, ensuring that the resulting models are not only theoretically valid but also applicable and adaptable to field dynamics(Nirtha, Tembang, Sinaga, & ..., 2025). This approach is highly relevant for developing complex, multidimensional, innovative pedagogical models.

If this research is not implemented immediately, the world of education faces significant risks. First, the gap between technological innovation and pedagogical practice will widen, causing technology investments to be inefficient and not impacting the quality of learning(Yuni, Harini, & ..., 2025). Second, educators will continue to be left to work without adequate guidance in navigating the complexities of the digital era, leading to burnout, resistance to change, or inappropriate technology adoption. Third, students will miss out on opportunities to develop 21st-century competencies and sustainability competencies that are crucial for their future(Ahmad & Sari, 2025). Fourth, the 2030 SDGs targets, particularly

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SDG 4, will become increasingly difficult to achieve. In other words, delay in developing innovative pedagogical models means missing a golden opportunity to transform education.

This research is expected to make significant contributions, both theoretically and practically. Theoretically, this research will enrich the science of pedagogy and educational technology by presenting an integrative model that explicitly links pedagogical innovation, the use of cutting-edge technology, and the achievement of the SDGs. This model is expected to be an alternative or complement to existing models such as TPACK and SAMR, with a more contextual and future-oriented perspective. Practically, this research will produce an applicable model that can be used by educators, curriculum developers, and policymakers as a guide in designing and implementing sustainable, technology-based, innovative learning.

Based on the presentation of the current situation and conditions, the gap identified, as well as pressing urgency, this research aims to develop an innovative technology-based pedagogical model in the education profession that has been tested for validity, practicality, and effectiveness in supporting the achievement of the SDGs. Through this approach, design-based research As a participatory approach, this research will involve stakeholders—educators, students, technology developers, and policymakers—at every stage of development. Ultimately, this research hopes to be one of the answers to the major challenges of education in the era of disruption, by producing a generation of innovative educators and students who are not only digitally literate but also possess the awareness and competence to become agents of change in realizing sustainable development for all humanity and the planet.

METHODS

Design

Figure 1. Design Development of an Innovative Technology-Based Pedagogical Model in the Education Profession to Support the SDGs

Volume 4, pg. 2046 – 2059
ISSN: 3046-594X

The research design shown in the image is included in the development research (Research and Development/R&D), combined with experimental methods and a pre-test and post-test design. The initial stage begins with a literature review and needs analysis, followed by the development of an innovative technology-based pedagogical model, which is then tested through experiments with a group of subjects. In its implementation, students or teachers are given a pre-test to measure initial abilities before implementing the model, then receive treatment through a technology-based learning model (such as e-learning, blended learning, or game-based learning), and end with a post-test to assess improvements in learning outcomes or competencies. Comparing pre-test and post-test results assesses the effectiveness of the developed model, enabling conclusions about its contribution to improving learning quality and supporting the achievement of the SDGs.

Participants

The study involved approximately 60 students, selected through purposive sampling based on specific criteria, including educational level, readiness to use technology, and engagement in digital-based learning. Participants were then divided into an experimental group (using an innovative, technology-based pedagogical model) and, if necessary, a control group (using conventional learning methods). This selection of sample size and method was intended to ensure representative data and allow for accurate analysis of differences in pre-test and post-test results in measuring the effectiveness of the developed model.

Instruments

The research instrument used in the study of the development of a technology-based pedagogical model comprises several complementary data-collection tools. The instrument begins with a pre-test to measure participants' initial abilities, then supports learning modules as a treatment medium in the learning process. During the process, observation sheets are used to monitor the activities and implementation of the model, and teacher and student questionnaires are used to collect their perceptions, responses, and experiences regarding the learning process. After the treatment, a post-test is conducted to measure improvements in learning outcomes, and the findings are reinforced through interviews or focus group discussions (FGDs) to obtain more in-depth qualitative data. All of these instruments are used to ensure the data obtained is comprehensive in assessing the effectiveness of the developed model.

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Figure 2. Instrument for Developing Technology-Based Innovative Pedagogical Models in the Education Profession to Support the SDGs

Procedure

This research procedure begins with a preliminary study stage, including a needs analysis and literature review, to formulate a design for an innovative, technology-based pedagogical model. Next, the model and its learning tools were developed, followed by limited trials using a pre-test and post-test experimental design, in which students were first given a pre-test to determine their initial abilities. After that, the learning model (treatment) was implemented using approaches such as e-learning, blended learning, and game-based learning, accompanied by observations throughout the process. After the treatment was completed, participants were given a post-test to measure improvements in learning outcomes, and questionnaires and interviews were used to obtain additional data. The final stage was data analysis and model evaluation to determine its effectiveness and refinement to align with the goals of improving learning quality and achieving the SDGs.

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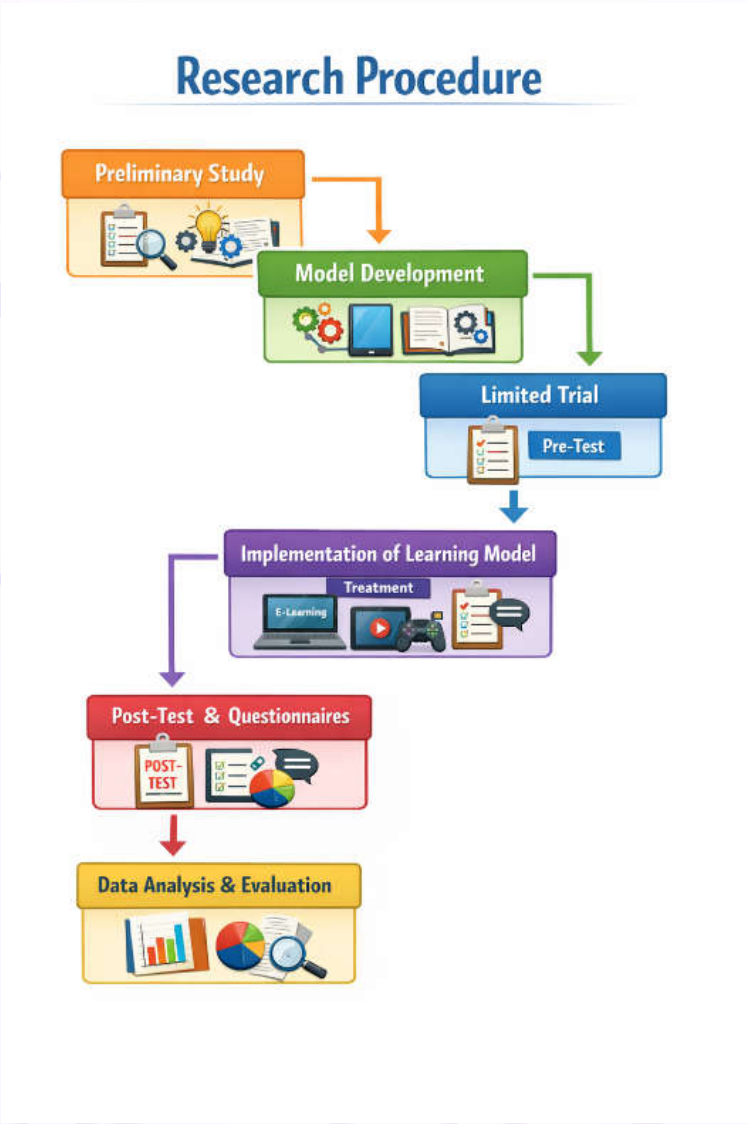

Figure 3 Research Procedures for Developing a Technology-Based Innovative Pedagogy Model in the Education Profession to Support the SDGs

Data Analysis

The data analysis in this study combines descriptive quantitative and inferential statistical approaches to evaluate the effectiveness of the technology-based pedagogical model. Descriptively, the pre-test and post-test scores are analyzed by calculating the mean, standard deviation, and the percentage of improvement in students' learning outcomes. The improvement can be measured using the gain score formula:

Gain=Post-test−Pre-test, or the normalized gain (N-Gain):

$$g = \frac{(pretest - posttest)}{Maksimum\ Skor - Pretetst}$$

Which is then categorized into low, medium, or high levels to determine the effectiveness of the learning model.

Furthermore, inferential analysis is conducted using a paired sample t-test to determine whether there is a statistically significant difference between pre-test and post-test scores. The formula used is:

$$t = \frac{\bar{d}}{\left(s_{d/\sqrt{n}}\right)1}$$

where $\bar{d}$ is the mean difference, s_d is the standard deviation of the differences, and n is the number of participants. If the significance value $p<0.05$, the model is considered statistically effective. Additionally, questionnaire data are analyzed using a Likert scale, calculated as:

$$\text{Percentage} = \frac{Obtained\ Score}{\text{Maximum Score}} x100$$

and interpreted into categories such as very good, good, fair, or poor. This combination of mathematical and descriptive analysis provides a comprehensive evaluation of the model's impact on improving learning quality

RESULTS AND DISCUSSION

Teble 1 Tests of Normality for Developing a Technology-Based Innovative Pedagogy Model in the Education Profession to Support the SDGs

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Class	Statistic	df	Sig.	Statistic	df	Sig.
Results	Pretest (Control)	.172	30	.063	.910	30	.055
	PostTest (Control)	.153	30	.071	.918	30	.063
	Pretest (Experiment)	.174	30	.060	.910	30	.055
	Posttest (Experiment)	.155	30	.065	.931	30	.053

a. Lilliefors Significance Correction

The "Tests of Normality" table shows that all pretest and posttest data in both the control and experimental groups have a significance value (Sig.) greater than 0.05 in the Shapiro–Wilk test (0.055; 0.063; 0.055; 0.053), so it can be concluded that the data is normally distributed;

this is also supported by the Kolmogorov–Smirnov test which mostly shows a Sig. value above 0.05 (0.063; 0.071; 0.060; 0.065), so that, overall, the normality assumption is met and the data are suitable for analysis using parametric statistical tests, such as the paired-samples t-test, in research on the development of technology-based learning models to support the SDGs.

Table 2 Test of Homogeneity of Variance for Developing a Technology-Based Innovative Pedagogy Model in the Education Profession to Support the SDGs

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Results	Based on Mean	4.947	1	58	.060
	Based on Median	4.223	1	58	.055
	Based on Median and with adjusted df	4.223	1	50.727	.054
	Based on trimmed mean	5.031	1	58	.059

Table 2 shows the results of the homogeneity of variance test (Levene's Test) to determine whether the variance between data groups is the same (homogeneous). Based on the table, the significance values (Sig.) for various approaches, namely Based on Mean (0.060), Based on Median (0.055), Based on Median with adjusted df (0.054), and Based on trimmed mean (0.059), all show a p-value > 0.05. This means there is no significant difference in variance between groups, so the data can be declared homogeneous. Thus, the assumption of homogeneity of variance has been met, and further analysis can use parametric tests such as the t-test.

Table 3 Paired Samples Test for Developing a Technology-Based Innovative Pedagogy Model in the Education Profession to Support the SDGs

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	Pretest - Posttest	-3.083	33.234	5.539	-14.328	8.161	-.557	35	.291	.581

Table 3 shows the results of the Paired Samples Test (paired t-test) used to determine the difference between pre-test and post-test scores within a group. Based on the table, the mean difference is -3.083, indicating an increase in scores after treatment (i.e., higher post-test scores). The statistical test results show a t-value of -0.557 with df = 35 and a two-tailed significance value of 0.581 (greater than 0.05). Furthermore, the 95% confidence interval ranges from -14.328 to 8.161, which includes the value of zero. This indicates a significant difference between pre-test and post-test scores, thus concluding that the treatment given does not have a statistically significant effect.

Discussion

Based on the overall data analysis, this study revealed quite complex findings regarding the effectiveness of the technology-based pedagogical model. The normality test indicated that most of the data were not normally distributed (especially in the pre-test and some post-tests), suggesting that a non-parametric approach would be more appropriate statistically. However, the homogeneity of variance test (Levene's Test) showed a p-value of $p > 0.05$, indicating that the variance between groups was homogeneous and met one of the important assumptions for comparative analysis.

Furthermore, the paired-samples t-test results indicated that although the mean scores increased from pre-test to post-test (indicated by the mean difference), this increase was not statistically significant ($p = 0.581 > 0.05$). This is supported by the confidence interval, which includes zero, so the changes can be considered a real effect of the treatment. These findings indicate that the implemented technology-based pedagogical model significantly improved learning outcomes under the conditions of this study.

Thus, it can be concluded that the technology-based pedagogical model shows a trend of increasing learning outcomes; the statistical evidence obtained is strong enough to conclude that its effectiveness is significant.

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