

Implementation of WEGOS with TikTok in Problem-Based Differentiated Learning to Enhance Self-Efficacy

Gugun Manosor Simatupang^{*1}, Mujahidawati¹, Febbry Romundza², and Novferma¹

¹Mathematics education, Universitas Jambi, Jambi, Indonesia

²Chemistry education, Universitas Jambi, Jambi, Indonesia

^{*}gugun.simatupang@unja.ac.id

Article Info	Abstract
Article history: Received: March 3, 2026 Accepted: April 25, 2026 Published: April 29, 2026 Keywords: Differentiated learning Self-efficacy TikTok Web Google Sites This article is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License. © 2026 Vidya Karya	This study investigated the effectiveness of WEGOS, a Google Sites-based learning web integrated with TikTok, implemented within a problem-based differentiated learning framework to improve students' academic self-efficacy. The study employed a quasi-experimental pretest-posttest control group design involving 84 second-year students in the Mathematics Education Study Program at Universitas Jambi, consisting of 42 students in the experimental group and 42 students in the control group. The intervention was conducted over a period of four weeks. The experimental group participated in differentiated problem-solving activities supported by WEGOS and TikTok-based instructional videos, while the control group received conventional instruction. Data were collected using an adapted academic self-efficacy scale consisting of 20 Likert-type items. The results showed that the experimental group achieved a higher mean posttest score (84.21) than the control group (74.35), with a statistically significant difference ($p < 0.05$) and a large effect size (Cohen's $d = 0.95$). These findings indicate that the intervention was associated with an improvement in students' academic self-efficacy within the study context. However, the findings should be interpreted cautiously due to the short duration of the intervention and the use of participants from a single study program. This study contributes to the growing body of research on technology-supported differentiated learning in higher education.
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INTRODUCTION

Higher education in the era of digital transformation demands instructional innovation that not only enhances cognitive achievement but also deliberately strengthens affective dimensions, particularly students' academic self-efficacy (Hu et al., 2024; Rizal et al., 2023; Ulfert-Blank & Schmidt, 2022). Self-efficacy, defined as individuals' beliefs in their capabilities to organize and execute actions required to accomplish specific tasks, plays a central role in determining how students approach academic challenges (In'am & Sutrisno, 2020; O'Connor & Mahony, 2023). Within social cognitive theory, self-efficacy is considered a critical determinant of persistence, effort regulation, resilience, and performance outcomes (Alfares, 2021; Huda et al., 2023).

Students with strong efficacy beliefs are more likely to engage actively in learning tasks, persist when encountering difficulties, and regulate their strategies effectively. Empirical studies consistently indicate that academic self-efficacy significantly predicts engagement,

motivation, and academic success in higher education ([Hermita & Thamrin, 2022](#); [Safithri & Huda, 2021](#)). However, despite the increasing integration of digital technologies in university classrooms, many students continue to exhibit low confidence when confronted with complex problem-solving activities, particularly in courses that demand independent reasoning, collaboration, and public presentation of ideas.

The rapid development of web-based learning platforms provides opportunities to create structured, flexible, and learner-centered instructional environments ([Hartari et al., 2025](#); [Isaeva et al., 2025](#); [Rozal et al., 2021](#)). In this study, the web-based platform developed using Google Sites is referred to as WEGOS (Web Google Sites), a term used to identify the specific instructional intervention examined in this research. Platforms such as Google Sites enable educators to design organized digital ecosystems that integrate multimedia materials, task instructions, interactive forms, and structured feedback mechanisms ([Hartari et al., 2025](#); [Lindra et al., 2025](#); [Thomas et al., 2022](#)). Such platforms potentially enhance clarity, accessibility, and autonomy in learning processes ([Arrahma et al., 2025](#); [Daud et al., 2024](#); [Sari et al., 2024](#)). Concurrently, social media platforms, especially TikTok, have emerged as dominant digital spaces among university students. Short-form video content has been found to increase accessibility, engagement, and conceptual understanding when embedded within structured instructional design ([Aurelia, 2023](#); [Gallardo et al., 2025](#); [Gálvez-Ruiz et al., 2025](#)). Nevertheless, research emphasizes that the effectiveness of social media integration depends not merely on technological novelty but on pedagogical intentionality and alignment with learning objectives ([Cai & Lai, 2025](#); [Yani et al., 2024](#)).

Problem-Based Differentiated Learning (PBDL) offers a pedagogical framework capable of addressing both cognitive and affective development ([Mulbar et al., 2017](#); [Rahmah et al., 2022](#)). As an instructional approach, PBDL integrates authentic problem-solving processes with differentiation principles that accommodate learners' readiness levels, learning profiles, and interests ([Marliana et al., 2024](#); [Puspitasari & Walujo, 2020](#)). Unlike conventional problem-based learning that may apply uniform task structures, PBDL explicitly ensures that learning tasks, scaffolding strategies, and resources are adapted to student diversity ([Tomlinson & Moon, 2022](#)). Differentiated instruction fosters autonomy and perceived competence because learners engage in tasks aligned with their individual capabilities. Within Bandura's framework, mastery experiences represent the most influential source of self-efficacy development ([Lightsey, 2021](#)). When students encounter challenges that are optimally demanding rather than overwhelming, they are more likely to experience success, thereby reinforcing their efficacy beliefs. In this context, the integration of WEGOS as a structured Google Sites-based learning platform and TikTok as a source of concise instructional video modeling can strengthen the implementation of PBDL by providing accessible learning resources, clear task organization, and engaging examples of problem-solving processes. Therefore, combining WEGOS and TikTok within a PBDL framework may create a psychologically supportive learning environment that promotes autonomy, personalized scaffolding, and mastery experiences, thereby supporting the development of students' academic self-efficacy.

Despite growing attention to digital learning environments and differentiated instruction, few studies have examined the combined use of structured web platforms, TikTok-based microlearning, and Problem-Based Differentiated Learning (PBDL) to enhance academic self-efficacy. Previous research has generally explored these elements separately, focusing on digital tools, problem-based learning, or differentiation as independent approaches rather than as an integrated instructional design. In addition, much of the existing literature has emphasized cognitive outcomes, such as achievement and problem-solving performance, while affective outcomes, particularly academic self-efficacy, have received less attention. Consequently, there is still limited empirical

understanding of how the integration of WEGOS, TikTok-based instructional media, and PBDL can support students' confidence in managing academic tasks. This gap is especially relevant in the context of higher education in Indonesia and, to the best of the authors' knowledge, has not been examined in the Mathematics Education Study Program at Universitas Jambi.

Preliminary classroom observations in the Numerical Methods course at Universitas Jambi, particularly in classes R001, R002, and R003, showed that many undergraduate students were hesitant to articulate ideas, reluctant to present solutions publicly, and lacked confidence in completing complex assignments independently. These behaviors reflect low academic self-efficacy, which may hinder deeper engagement and sustained learning persistence. The findings highlight the need for instructional innovation that not only supports effective content delivery but also strengthens students' competence beliefs. A learning design integrating structured web-based environments, short-form instructional video modeling, and differentiated problem-solving pathways may therefore provide the mastery experiences, observational learning opportunities, and supportive feedback needed to enhance academic self-efficacy.

The novelty of this study lies in the contextual integration of a structured web-based learning platform (WEGOS), TikTok-supported instructional media, and a problem-based differentiated learning framework within a single instructional design. Rather than proposing a new theoretical model, this study focuses on how these components can be systematically combined to support affective learning outcomes, particularly academic self-efficacy, in higher education settings. However, limited studies have examined how structured web platforms, social media-based microlearning, and differentiated problem-based instruction interact within a unified design to influence affective outcomes such as academic self-efficacy.

Conceptually, each component of the intervention serves a distinct pedagogical function. WEGOS (Web Google Sites) provides a structured digital learning environment that enhances accessibility, organization, and clarity of learning resources. TikTok-based instructional videos function as micro-learning tools that support observational learning, enabling students to visualize problem-solving processes in a concise and engaging format. Meanwhile, problem-based differentiated learning ensures that tasks are adapted to students' readiness levels, allowing learners to engage in optimally challenging activities that promote mastery experiences. The integration of these components is therefore expected to support the development of academic self-efficacy through complementary mechanisms rather than through a single instructional factor.

Therefore, this study aims to examine the implementation and effectiveness of WEGOS integrated with TikTok within a problem-based differentiated learning model to enhance university students' academic self-efficacy. Accordingly, the hypotheses were formulated as follows: H_0 : the intervention has no significant effect on students' academic self-efficacy; and H_a : the intervention has a significant effect on students' academic self-efficacy.

METHODS

This study employed a quantitative approach using a quasi-experimental pretest–posttest control group design to examine the effectiveness of WEGOS integrated with TikTok within a problem-based differentiated learning framework in enhancing students' academic self-efficacy. The study was conducted in the Mathematics Education Study Program at Universitas Jambi during the 2024/2025 academic year and involved two intact classes. Because the unit of assignment was the class rather than individual students, the sampling procedure is more appropriately categorized as cluster random sampling. One class consisting of 42 students was assigned as the experimental group, while another class

consisting of 42 students served as the control group. To ensure initial comparability, an independent sample t-test was conducted on the pretest scores, and the results showed no significant difference between the two groups ($p > 0.05$), indicating relatively similar initial levels of academic self-efficacy.

The primary instrument used to measure students' academic self-efficacy was an adapted Academic Self-Efficacy Scale based on Bandura's social cognitive framework (Bandura, 1997; Lightsey, 2021). The instrument consisted of 20 Likert-type items ranging from 1 (strongly disagree) to 5 (strongly agree). The adaptation process involved modifying item wording to align with the context of higher education mathematics learning. The items were adapted to suit the context of mathematics learning in higher education and were reviewed by two experts in mathematics education and educational psychology to establish content validity. The reliability analysis showed a Cronbach's alpha coefficient of 0.87, indicating high internal consistency. Sample items included statements such as "I am confident in solving difficult academic problems independently" and "I can explain my ideas clearly during class discussions."

The intervention was implemented over four weeks in eight meetings, with two meetings conducted each week. The experimental group participated in problem-based differentiated learning supported by WEGOS and TikTok-based instructional videos. Each learning cycle included problem orientation through short TikTok videos, group discussion and problem exploration, differentiated task assignment based on students' readiness levels, presentation and feedback, and reflection. A total of 12 TikTok videos with a duration of approximately 1–3 minutes each were used to present problem contexts, conceptual explanations, and solution strategies. WEGOS functioned as a structured Google Sites-based learning platform that provided access to learning materials, task instructions, discussion guides, and supporting resources. Students were grouped into high, medium, and low readiness categories based on prior academic performance, and each group received tasks with different levels of complexity while maintaining the same learning objectives.

To minimize technical disruptions during implementation, learning materials and video links were prepared in advance and made accessible through WEGOS before each meeting. Students were also informed about access procedures at the beginning of the intervention, and alternative access through shared links was provided when needed to anticipate possible internet or device-related constraints. In addition, several efforts were made to strengthen the internal validity of the study. Both groups were taught within the same course context, covered the same learning objectives, and completed the pretest and posttest using the same instrument. The intervention was conducted within the same instructional period to reduce history effects, and pretest analysis was used to confirm the equivalence of the two groups before treatment. These procedures were intended to reduce potential bias and support a more valid comparison of the intervention effects.

Data analysis was conducted using SPSS version 26. Descriptive statistics were used to calculate mean and standard deviation scores. Prior to hypothesis testing, data normality was examined using the Shapiro–Wilk test and homogeneity of variance using Levene's test. The hypothesis was tested using an independent sample t-test with a significance level of 0.05. The magnitude of the intervention effect was determined using Cohen's d to evaluate practical significance (Cohen, 2013).

The research procedure was conducted in four stages. First, the preparation stage involved developing WEGOS, designing TikTok instructional videos, validating the instrument, and preparing differentiated learning materials. Second, both groups were administered a pretest to measure initial self-efficacy levels. Third, the treatment stage was implemented over four weeks, during which the experimental group engaged in problem-based differentiated learning supported by WEGOS and TikTok, while the control group

received conventional instruction. Finally, a posttest was administered, and the collected data were analyzed to determine the effectiveness of the intervention.

RESULTS AND DISCUSSION

The implementation of the intervention was carried out over four weeks in eight meetings in the Numerical Methods course. In the experimental group, learning was conducted through problem-based differentiated learning supported by WEGOS and TikTok-based instructional videos. At the beginning of each learning cycle, students were introduced to problem situations through short TikTok videos and supporting materials available on WEGOS. They then worked collaboratively to analyze the problems, discuss possible solution strategies, and complete differentiated tasks according to their readiness levels. The learning process concluded with class presentations, feedback sessions, and reflection activities. In contrast, the control group participated in conventional instruction consisting of lecturer explanation, textbook-based exercises, and whole-class discussion without differentiated task design or digital platform integration. This difference in learning treatment provided the basis for comparing the effect of the intervention on students' academic self-efficacy.

Descriptive statistics were calculated to examine differences in students' academic self-efficacy before and after the intervention. The comparison of pretest and posttest scores between the experimental and control groups is presented in Table 1.

Table 1 Descriptive statistics of self-efficacy scores

Group	Test	N	Minimum	Maximum	Mean	SD
Experimental	Pretest	42	60	82	71.24	6.47
Experimental	Posttest	42	68	96	84.21	6.85
Control	Pretest	42	58	80	70.11	6.62
Control	Posttest	42	60	88	74.35	7.12

Table 1 shows that both groups had relatively similar pretest mean scores, indicating comparable initial self-efficacy levels. The experimental group obtained a pretest mean of 71.24, while the control group scored 70.11. After the treatment, the experimental group's mean score increased to 84.21, representing a substantial improvement of 12.97 points. In contrast, the control group showed a smaller increase of 4.24 points, reaching a posttest mean of 74.35. This difference indicates that the implementation of WEGOS with TikTok contributed to a greater enhancement of students' self-efficacy compared to conventional instruction.

A paired sample t-test was conducted to examine within-group improvements. The results showed that the experimental group experienced a statistically significant increase in self-efficacy from pretest to posttest ($p < 0.05$). The control group also showed an increase; however, the magnitude of improvement was smaller compared to the experimental group.

Prior to hypothesis testing, the assumptions of normality and homogeneity were examined. The Shapiro-Wilk test indicated that the data were normally distributed for both groups ($p > 0.05$). The Levene's test showed a significance value of 0.417 (> 0.05), indicating that the variance between the experimental and control groups was homogeneous. Therefore, the data met the assumptions for parametric testing. The results are presented in Table 2.

Table 2 Independent sample t-test results

Variable	<i>t</i>	<i>df</i>	Mean Difference	Sig. (2-tailed)
Self-Efficacy	6.104	82	9.86	0.000

Table 2 shows that the significance value was 0.000, which is lower than 0.05, indicating a statistically significant difference between the experimental and control groups. The mean difference of 9.86 also shows that the experimental group achieved a higher posttest score than the control group. Thus, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted, indicating that the intervention had a significant effect on students' academic self-efficacy.

To evaluate the practical magnitude of the intervention, Cohen's d was calculated. The effect size obtained was 0.95, which falls into the large category. This indicates that the intervention not only produces statistical significance but also suggests substantial educational impact. The large effect size suggests that the integration of structured web-based learning, TikTok-supported instructional media, and differentiated problem-solving activities meaningfully enhances students' confidence in managing academic challenges. The effect size (Cohen's $d = 0.95$) was calculated using the pooled standard deviation of posttest scores, indicating a large effect according to Cohen's criteria.

Overall, the results reveal that students who participated in the WEGOS-integrated differentiated problem-based learning environment exhibited higher levels of academic self-efficacy compared to those receiving conventional instruction. These results indicate that the intervention was associated with a greater improvement in students' self-efficacy compared to conventional instruction.

The findings of this study suggest that the implementation of WEGOS integrated with TikTok within a Problem-Based Differentiated Learning (PBDL) framework significantly enhances university students' academic self-efficacy. The experimental group showed a substantial improvement, which was also supported by a large effect size. This finding suggests that the intervention did not merely produce statistical differences but also contributed to a meaningful improvement in students' academic self-efficacy. Self-efficacy is widely recognized as a foundational determinant of students' academic functioning, influencing how individuals interpret challenges, allocate cognitive effort, regulate persistence, and respond to failure (Hermita & Thamrin, 2022; Lightsey, 2021). Students with strong efficacy beliefs tend to perceive demanding academic tasks as surmountable rather than threatening, which enhances their willingness to engage in complex reasoning processes. The significant enhancement observed in this study suggests that the instructional design may contribute to modified students' internal belief systems regarding their academic capabilities.

From a social cognitive perspective, self-efficacy develops through the interaction of personal, behavioral, and environmental factors. Lightsey (2021), drawing on Bandura's framework, identifies four principal sources of efficacy beliefs: mastery experiences, vicarious experiences, social persuasion, and physiological or affective states. In the context of this study, the implementation of problem-based differentiated learning supported by WEGOS and TikTok may have created conditions that were conducive to the development of these four sources within a digitally structured learning environment. The following discussion explains how each of these mechanisms may help account for the improvement in students' academic self-efficacy.

First, mastery experiences were likely fostered through the differentiated problem-solving tasks used in the intervention. By adjusting task difficulty to students' readiness levels, the instructional design allowed learners to engage with challenges that were demanding yet still achievable. This is important because tasks that are excessively difficult may trigger frustration and reduce confidence, whereas appropriately scaffolded tasks can promote successful task completion and strengthen students' sense of competence. Repeated engagement in such attainable but meaningful learning experiences may therefore have contributed to the development of stronger academic self-efficacy, as

mastery experience is widely regarded as the most influential source of efficacy beliefs (Du et al., 2023; Lightsey, 2021).

Second, vicarious experiences were reinforced through the integration of TikTok-based instructional media. Observational learning plays a central role in shaping efficacy beliefs, particularly when learners perceive similarity between themselves and the model (Gallardo et al., 2025). Short-form video demonstrations presented procedural explanations, conceptual clarifications, and modeled reasoning strategies in concise and relatable formats. Unlike lengthy lecture-based explanations, TikTok-based micro-learning segments reduced cognitive barriers and allowed students to repeatedly observe problem-solving processes before engaging independently. Research on digital microlearning environments suggests that concise, visually engaging content enhances attention and retention while lowering anxiety associated with complex tasks (Gálvez-Ruiz et al., 2025). In this study, TikTok functioned not as an isolated social media tool but as a structured instructional scaffold embedded within pedagogical objectives. This alignment likely strengthened students' confidence prior to attempting differentiated problem-solving tasks.

Third, social persuasion may have been fostered through structured feedback and collaborative interactions within the PBDL framework. Differentiated problem-solving environments encourage peer discussion and lecturer guidance that are responsive to learners' needs. Positive reinforcement, constructive feedback, and guided questioning can function as persuasive cues that strengthen students' belief in their ability to succeed. When learners receive affirmation that is closely aligned with their observable progress, they are more likely to internalize such responses as evidence of competence. In this study, the contribution of WEGOS should not be understood merely as a technological feature but as part of a pedagogically intentional learning design. Its role in organizing task instructions, supporting access to feedback, and structuring learning resources helped create a cleaner and more supportive environment for student participation. This pedagogical intentionality was crucial, as it ensured that digital support was meaningfully aligned with students' learning needs and with the broader goal of strengthening academic self-efficacy (Dwi Agustina et al., 2023; Johdi et al., 2024; Ningsih & Haryanto, 2025). Such environmental stability contributes to psychological safety, which is essential for confidence development.

Fourth, affective and physiological states may also have been influenced by the supportive digital ecosystem created during the intervention. Anxiety, confusion, and cognitive overload often weaken self-efficacy by generating negative emotional responses to academic tasks. In this study, WEGOS helped reduce disorientation by providing systematic navigation, categorized learning materials, and differentiated task pathways that students could access according to their readiness levels. In addition, feedback was delivered through several complementary forms, including direct lecturer feedback during classroom discussions and presentations, clarification of task procedures through the platform, and peer responses during group discussions. These forms of support likely helped students feel more guided and less uncertain when engaging with complex tasks. Research on learner autonomy in digital environments suggests that structured platforms can enhance perceived control and reduce stress, thereby strengthening efficacy beliefs (Bond et al., 2020). In this context, WEGOS supported students' sense of agency by enabling them to access materials independently and regulate their learning pace. This increased sense of control may have contributed to greater confidence in managing academic tasks.

The differentiated dimension of PBDL further clarifies the substantial effect observed. Differentiated instruction recognizes heterogeneity in learners' readiness, interests, and cognitive profiles (Mulbar et al., 2017). Uniform instructional approaches often create mismatches between task demands and learner capacity, leading to disengagement or performance anxiety. By contrast, differentiated problem-based tasks provide multiple

entry points to complex concepts, allowing students to engage at appropriate levels of challenge. Rahmah et al., (2022) emphasize that differentiation enhances academic confidence when learners perceive tasks as attainable yet meaningful. In the present study, differentiated pathways likely reduced fear of failure and enhanced competence perception. This mechanism explains why the improvement in self-efficacy was not marginal but substantial.

The synergy between WEGOS, TikTok, and PBDL represents a critical contribution to digital pedagogy research. Prior investigations frequently examine digital tools, social media, or problem-based learning independently. However, the current findings indicate that technological tools achieve maximal affective impact only when embedded within coherent instructional frameworks. Technology alone does not automatically foster self-efficacy; rather, its influence depends on structured alignment with pedagogical principles. The integration of web-based organization (WEGOS), micro-modeling (TikTok), and differentiated authentic tasks (PBDL) created a multimodal environment that simultaneously addressed cognitive clarity, emotional support, and learner autonomy. This integrated ecosystem appears to be responsible for the large effect size observed.

Moreover, the findings suggest that self-efficacy enhancement in higher education is not incidental but can be systematically engineered through instructional design. The interaction between structured digital scaffolding and differentiated cognitive challenge forms a dynamic cycle: clarity reduces anxiety, manageable challenge promotes mastery, mastery reinforces confidence, and confidence increases persistence in subsequent tasks. This cyclical reinforcement aligns with reciprocal determinism in social cognitive theory, where behavior, personal belief, and environment continuously interact (Bandura, 1997). This integrated synergy also represents an important contribution of the present study, as previous research has more often examined digital platforms, social media-based learning, and differentiated or problem-based instruction as separate components rather than as an interconnected instructional design. The digital-differentiated ecosystem implemented in this study therefore, appears to have strengthened this reciprocal cycle in favor of positive efficacy development.

It is important to note that this study did not directly measure the specific mechanisms underlying self-efficacy development, such as mastery experience, vicarious experience, or social persuasion. Therefore, the interpretation of these mechanisms remains theoretical and should be considered as a plausible explanation rather than empirical confirmation.

The study also contributes to the broader discourse on affective outcomes in digital transformation. Much of the literature on educational technology emphasizes cognitive performance indicators such as achievement, problem-solving ability, or knowledge retention. While these outcomes remain important, affective constructs such as self-efficacy serve as foundational drivers of long-term academic persistence and resilience. By demonstrating a substantial effect on academic self-efficacy, this study highlights the necessity of evaluating digital innovation beyond surface-level performance metrics. Effective digital transformation in higher education should therefore consider affective architecture alongside cognitive design.

Several alternative explanations should also be considered. The observed improvement may be partially influenced by novelty effects associated with the use of TikTok-based learning media, increased student motivation due to the experimental treatment, or differences in instructional delivery between groups. In addition, the use of self-report instruments may introduce social desirability bias, where students respond in a manner they perceive as favorable.

Overall, the findings suggest that the integration of WEGOS, TikTok-based instructional media, and problem-based differentiated learning may contribute to improving students' academic self-efficacy. However, the results should be interpreted

within the limitations of the study, particularly the short duration of the intervention and the reliance on self-report measures. Further research is needed to explore the underlying mechanisms and long-term effects of such instructional designs.

CONCLUSION

This study indicates that the implementation of WEGOS integrated with TikTok within a problem-based differentiated learning framework significantly enhances university students' academic self-efficacy. The substantial improvement in posttest scores and the large practical effect indicate that structured web-based learning, multimodal video scaffolding, and differentiated problem-solving tasks collectively strengthen students' confidence in managing academic challenges. The findings highlight that digital innovation becomes pedagogically meaningful when embedded within coherent and learner-centered instructional design. By integrating mastery-oriented tasks, differentiated pathways, and accessible modeling support, the intervention systematically fostered competence beliefs in higher education settings.

However, the results should be interpreted with caution due to several limitations, including the short duration of the intervention, the use of self-report measures, and the focus on a single study program. These limitations may affect the generalizability of the findings. Future research is recommended to involve more diverse participants, longer implementation periods, and additional data sources to examine both affective and behavioral outcomes. Despite these limitations, this study contributes to the development of technology-supported differentiated learning in higher education.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptual design was carried out by GMS and M; the research methodology was developed by GMS and FR; formal data analysis was undertaken by M and N; the investigation process was led by GMS and N; data management and organization were handled by FR; the initial manuscript draft was prepared by M; manuscript review and revisions were conducted by GMS and FR; visual presentation of the data was created by M; and overall supervision was provided by GMS. All authors have reviewed and approved the final version of the manuscript for publication.

AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the authors used AI-assisted language tools to improve grammar and writing clarity. The AI tools were applied only for editorial support and did not generate scientific content, analyze data, or influence the interpretation of the results. The authors take full responsibility for the content and the final version of the manuscript.

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AUTHOR PROFILES



Gugun Manosor Simatupang
gugun.simatupang@unja.ac.id
Expertise: Statistics, mathematics education
Affiliation: Universitas Jambi
[Gugun Simatupang - Google Scholar](#)
[SINTA - Science and Technology Index](#)
[Simatupang, Gugun M. - Author details - Scopus Preview](#)



Mujahidawati
mujahida.wati@unja.ac.id
Expertise: Applied Mathematics, mathematics education
Affiliation: Universitas Jambi
[Mujahidawati - Google Scholar](#)
[SINTA - Science and Technology Index](#)
[Mujahidawati, - Author details - Scopus Preview](#)



Febbry Romundza
Febbryromundza@unja.ac.id
Expertise: Educational Studies, Chemistry education
Affiliation: Universitas Jambi
[Febbry Romundza - Google Scholar](#)
[SINTA - Science and Technology Index](#)
[Romundza, Febbry - Author details - Scopus Preview](#)



Novferma
Novferma@unja.ac.id
Expertise: Educational Studies, mathematics education
Affiliation: Universitas Jambi
[Novferma, S.Pd., M.Pd - Google Scholar](#)
[SINTA - Science and Technology Index](#)
[Novferma, - Author details - Scopus Preview](#)