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The Use of STEM Integrated Project-Based Learning Media Assisted by TikTok Application to Improve Students' Creative Thinking Skills

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Abstract – Creativity is recognized as a central competency for twenty-first-century learners. Yet, physics classrooms often remain dominated by formulaic instruction that limits opportunities for students to exercise higher-order thinking. This study addresses the urgent need to foster creative thinking in physics, particularly in abstract topics such as projectile motion, by integrating TikTok media into a Project-Based Learning integrated STEM framework. The research aimed to investigate the effect of this integration on students' creative thinking skills, measured across four indicators: fluency, originality, flexibility, and elaboration. Employing a quasi-experimental design with a nonequivalent control group, the study involved 67 Grade XI students from a senior high school in Makassar, Indonesia. The experimental group ($n = 35$) received instruction using Project-Based Learning–STEM with TikTok, while the control group ($n = 32$) learned through Project-Based Learning–STEM without TikTok. Data were collected using an essay-based test validated by experts and analyzed using normalized gain (N -gain) and an independent samples t -test. Results showed that the experimental class achieved significantly higher posttest scores, with N -gain in the high category (0.74) compared to the medium category in the control group (0.52). The greatest improvements were observed in elaboration and originality, reflecting the platform's affordances for encouraging detailed explanations and unique representations of physics concepts. The findings confirm that integrating culturally relevant digital platforms within structured pedagogical designs enhances creativity beyond affective engagement. This study contributes to physics education by providing empirical evidence that TikTok, when aligned with PjBL–STEM, can bridge everyday digital practices with disciplinary learning to foster creativity, offering a novel and practical pathway for innovation in science education.

Keywords: creative thinking skills; physics education; project-based learning; STEM education; TikTok integration

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I. INTRODUCTION

The teaching and learning of physics continues to be a critical area of educational research, given its role in fostering scientific literacy and equipping learners with the higher-order thinking

skills necessary in the twenty-first century. Across different contexts, physics is often described as one of the most challenging school subjects due to its abstract concepts, reliance on mathematical reasoning, and demand for visualization skills (Papagiannis & Pallaris, 2024; Vasconcelos & Santos, 2025). While physics is central to the development of STEM-related competencies, the persistent perception of its difficulty has contributed to low motivation and achievement among students (Lucas, 2022; OECD, 2023). Recent international reports highlight that learners frequently struggle with core topics such as mechanics, waves, and electromagnetism. Projectile motion is consistently identified as one of the most problematic due to its two-dimensional nature and the necessity to integrate conceptual and mathematical understanding (Bakri et al., 2023; Hashim et al., 2022). The challenges students face in mastering physics underscore the urgency of adopting instructional strategies that are not only effective in clarifying concepts but also engaging in ways that resonate with the realities of contemporary learners (Praptama et al., 2023; Fiteriani et al., 2021).

The importance of equipping students with critical thinking and creative problem-solving skills has been widely acknowledged in international education agendas. Within this framework, STEM education has emerged as a powerful paradigm for integrating disciplinary knowledge with real-world applications, thereby promoting both cognitive and affective learning outcomes (Nurilma et al., 2023; Tuveri et al., 2024). STEM approaches encourage inquiry, design, and collaboration, and align with the broader goal of preparing learners for future careers in science and technology-driven fields (Martawijaya et al., 2023; Mohottala et al., 2023). In particular, the integration of Project-Based Learning (PjBL) within STEM contexts has been shown to provide authentic and meaningful experiences for students. Through PjBL, learners engage in the construction of knowledge while solving complex problems and producing tangible outputs that demonstrate their understanding (Parno et al., 2020; Retno et al., 2025). These outcomes are consistent with studies showing that student-centered pedagogies improve motivation, creativity, and persistence when compared with more traditional lecture-based approaches (Bouquet et al., 2017; Kwon & Lee, 2025).

Despite these advancements, the teaching of projectile motion remains a major concern in physics classrooms. Students consistently encounter difficulties in understanding the independence of horizontal and vertical components of motion, interpreting the parabolic trajectory of a projectile, and applying the relationships between initial velocity, angle, and displacement (Wang et al., 2025; Escamilla-Fajardo et al., 2021). These misconceptions persist across diverse educational settings and often result in superficial learning that does not extend beyond rote memorization (Retno et al., 2025; Ahmad et al., 2021). Traditional approaches, such as teacher explanations and textbook exercises, have failed to address these conceptual barriers

adequately, despite being common. Scholars therefore argue for the adoption of strategies that embed active learning and technological innovation to provide dynamic representations of abstract phenomena (Cortés-Ramos et al., 2021; Prajoko et al., 2023).

General solutions have emerged in the form of inquiry-based strategies, digital simulations, and interactive problem-solving activities, all of which are designed to increase student engagement and improve conceptual mastery (Syafuddin et al., 2022; Escamilla-Fajardo et al., 2021). However, these strategies are not always implemented effectively, often due to limited access to resources or insufficient professional development for teachers (Octafianellis et al., 2021). Additionally, there is evidence that while digital platforms hold potential for enhancing physics education, their integration into formal learning remains inconsistent and under-theorized (Peña-Martínez et al., 2025). The gap between the potential of technology to transform learning and its actual implementation in classrooms highlights the necessity for further empirical research into effective integration models.

A more specific solution involves leveraging social media platforms, particularly TikTok, as educational media within a structured pedagogical framework. TikTok, popularized initially as an entertainment platform, has rapidly gained traction among younger generations due to its short, engaging, and easily consumable video format (Qiyang & Jung, 2019). Recent research has begun to examine TikTok's potential for education, suggesting that it can be repurposed to deliver concise explanations, visual demonstrations, and collaborative learning activities (Sholina et al., 2023; Suganda et al., 2021). In physics education, TikTok offers possibilities for visualizing abstract concepts such as projectile motion through animated trajectories, experimental recordings, or simplified problem-solving explanations (Yélamos-Guerra et al., 2022). Its popularity among students suggests that TikTok could serve not only as a tool to enhance motivation but also as a platform for creative expression when integrated with project-based and STEM-oriented pedagogies.

The literature surrounding the intersection of PjBL, STEM education, and TikTok integration provides promising yet incomplete insights. While studies have documented the benefits of PjBL-STEM in fostering creativity, collaboration, and conceptual understanding (Papagiannis & Pallaris, 2024; Vasconcelos & Santos, 2025), and others have highlighted the potential of TikTok in supporting engagement and motivation (Sholina et al., 2023; Yélamos-Guerra et al., 2022), few investigations have systematically explored their combined implementation. The absence of research that explicitly integrates TikTok within PjBL-STEM frameworks leaves an important gap in the literature, particularly regarding how this combination might address persistent misconceptions in physics and foster creative thinking among learners (Escamilla-Fajardo et al., 2021; Octafianellis et al., 2021).

Therefore, the present study aims to investigate the effectiveness of integrating PjBL with STEM education supported by TikTok media to enhance students' creative thinking skills in physics, particularly in the topic of projectile motion. Creative thinking, which encompasses fluency, flexibility, originality, and elaboration, has been identified as an essential component of 21st-century learning that remains underdeveloped in many physics classrooms (Retno et al., 2025; Ahmad et al., 2021). By embedding TikTok within a PjBL-STEM framework, this study provides a novel instructional design that simultaneously addresses conceptual challenges and fosters creativity, motivation, and engagement. The originality of this research lies in its attempt to systematically evaluate how short-video media can be transformed from a source of entertainment into a meaningful educational resource when combined with STEM and project-based pedagogies. The findings are expected to contribute to both theory and practice by offering evidence-based insights for physics educators, curriculum designers, and policymakers seeking innovative ways to enhance learning in complex scientific domains.

II. METHODS

This study employed a quasi-experimental design with a nonequivalent control group to examine the effects of integrating TikTok within a PjBL integrated STEM framework on students' creative thinking skills in physics. Quasi-experimental designs are particularly suitable for educational research conducted in real classroom settings where random assignment is often not feasible. Yet, researchers aim to establish causal inferences between instructional interventions and learning outcomes (Lakens, 2013). The use of a nonequivalent control group allows for comparison between two intact classes, one receiving the treatment and the other serving as a control, while acknowledging the limitations inherent in non-randomized designs. This methodological choice is aligned with the pragmatic goal of balancing internal validity with ecological authenticity in classroom-based research.

The participants consisted of two Grade XI classes from a public senior high school in Makassar, Indonesia, selected purposively based on equivalence of academic track and availability of instructional time. The experimental class comprised 35 students, while the control class included 32 students. The same physics teacher taught both classes to minimize instructor variability. The experimental group was exposed to physics instruction using PjBL-STEM integrated with TikTok-based projects, whereas the control group followed PjBL-STEM without the integration of TikTok. The learning topic selected for this study was projectile motion, a core component of kinematics that requires students to apply mathematical models to describe two-

dimensional motion. This topic was chosen because of its abstract nature, and the persistent difficulties students face in representing and conceptualizing parabolic trajectories.

The intervention followed the general framework of PjBL–STEM, in which students were assigned authentic projects requiring them to collaboratively design solutions, integrate concepts from science, technology, engineering, and mathematics, and present their findings. In the experimental class, students were required to synthesize their learning outcomes into short TikTok videos that creatively explained projectile motion phenomena using a variety of representational modes, such as narrative, visual animation, and experimental demonstration. The integration of TikTok was intended to leverage the platform’s affordances of brevity, multimodality, and accessibility to encourage students to articulate concepts concisely while exercising originality and elaboration. Figure 1 illustrates the overall flow of the research procedure, from the initial pretest, through the implementation of PjBL–STEM with TikTok, to the posttest evaluation.

Research Procedure Flowhart

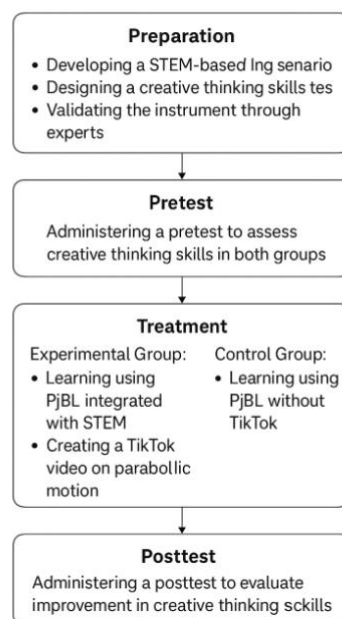


Figure 1. Research procedure for quasi-experimental design with PjBL–STEM integrated TikTok media

Students’ creative thinking skills were assessed using an essay test composed of five open-ended items, each aligned with Torrance’s four dimensions of creativity: fluency, originality, flexibility, and elaboration (Torrance, 1974). The instrument underwent content validation by two experts in physics education, ensuring the appropriateness of items for capturing creativity in the context of projectile motion. Scoring rubrics were developed for each dimension to guide consistent evaluation. The reliability of the instrument was examined using Cronbach’s alpha,

yielding a coefficient above 0.70, which is considered acceptable for educational assessments (Taber, 2018). Examples of tasks included generating multiple representations of a projectile trajectory, proposing original contexts where parabolic motion could be observed, and elaborating on the underlying principles governing motion. Table 1 presents the operational definitions of each indicator of creative thinking as applied in this study.

Table 1. Indicators of creative thinking in the context of projectile motion

Indicator	Definition
Fluency	The ability to generate multiple correct responses to problems related to projectile motion
Originality	The ability to provide unique or uncommon ideas in explaining parabolic trajectories
Flexibility	The ability to approach the problem using different perspectives, methods, or representations
Elaboration	The ability to expand ideas with detailed explanations and justifications of projectile motion concepts

Data collection followed a pretest–posttest procedure. Both groups completed the essay-based creative thinking test before and after the instructional intervention. Pretest results established baseline comparability, while posttest data allowed examination of changes attributable to the treatment. In analyzing the data, descriptive statistics were first calculated to provide an overview of mean scores and standard deviations across indicators. Inferential analyses were followed to test for significant differences between groups. Before hypothesis testing, assumptions of normality and homogeneity of variance were examined using the Kolmogorov–Smirnov test and Levene’s test, respectively, with results confirming that the data met parametric assumptions.

The primary measure of learning gain was the normalized gain (N-gain), calculated using the formula proposed by Hake (1999):

$$N - gain = \frac{score_{posttest} - score_{pretest}}{score_{maximum} - score_{pretest}} \quad 1)$$

The interpretation of N-gain followed Hake’s classification: high ($g \geq 0.70$), medium ($0.30 \leq g < 0.70$), and low ($g < 0.30$). This measure provides insight into the effectiveness of the intervention relative to students’ prior knowledge and potential improvement.

To determine the statistical significance of differences between the experimental and control groups, an independent samples t-test was conducted on the posttest scores. This choice of analysis is appropriate for comparing the means of two groups when data assumptions are satisfied (Field, 2013). In addition to statistical significance, effect sizes were calculated using Cohen’s *d* to evaluate the magnitude of the observed differences, providing a more comprehensive understanding of the intervention’s impact (Lakens, 2013).

Ethical considerations were observed throughout the research process. Permission for conducting the study was obtained from the school administration, and informed consent was secured from all participants. Students' identities were anonymized in reporting results, and participation did not affect their course grades. The intervention was implemented as part of the standard curriculum delivery, ensuring minimal disruption to instructional practices while providing opportunities for pedagogical innovation.

III. RESULTS AND DISCUSSION

The results of this study provide a comparative overview of students' creative thinking skills between the experimental class, which received instruction through PjBL–STEM integrated with TikTok, and the control class, which experienced PjBL–STEM without TikTok. The findings are presented in three parts: descriptive statistics, normalized gain (N-gain) analysis, and inferential statistics testing the significance of differences between groups. Descriptive statistics indicated that students in the experimental group outperformed their peers in the control group across all four dimensions of creative thinking. Table 2 summarizes the mean and standard deviation scores for both pretest and posttest measures.

Table 2. Descriptive statistics of students' creative thinking scores

Indicator	Group	Pretest (M ± SD)	Posttest (M ± SD)
Fluency	Experimental	48.5 ± 6.21	81.2 ± 7.15
	Control	47.9 ± 5.94	68.3 ± 6.87
Originality	Experimental	46.7 ± 6.02	82.4 ± 7.36
	Control	45.8 ± 6.15	70.1 ± 7.02
Flexibility	Experimental	47.2 ± 6.44	79.8 ± 6.94
	Control	46.9 ± 6.23	68.7 ± 7.11
Elaboration	Experimental	48.1 ± 6.39	83.5 ± 7.28
	Control	47.5 ± 6.18	69.4 ± 6.97

The data in Table 2 reveal that, while both groups demonstrated improvements from pretest to posttest, the experimental class achieved markedly higher mean scores. Notably, the highest posttest improvement was observed in elaboration (M = 83.5) and originality (M = 82.4), suggesting that the use of TikTok facilitated students' ability to expand on ideas and to generate unique approaches in explaining projectile motion phenomena.

The results illustrated in Figure 2 reveal clear differences in the N-gain between the experimental and control classes across all creativity indicators. The experimental class consistently outperformed the control class. The highest gain occurred in fluency (g = 1.00)

followed by elaboration ($g = 0.79$), flexibility ($g = 0.78$), and originality ($g = 0.64$). In contrast, the control class showed lower gains in all indicators, with fluency ($g = 0.42$), originality ($g = 0.37$), flexibility ($g = 0.52$), and elaboration ($g = 0.48$). These results indicate that the PjBL–STEM approach supported by TikTok media effectively enhanced students' creative thinking skills across multiple dimensions compared to conventional instruction.

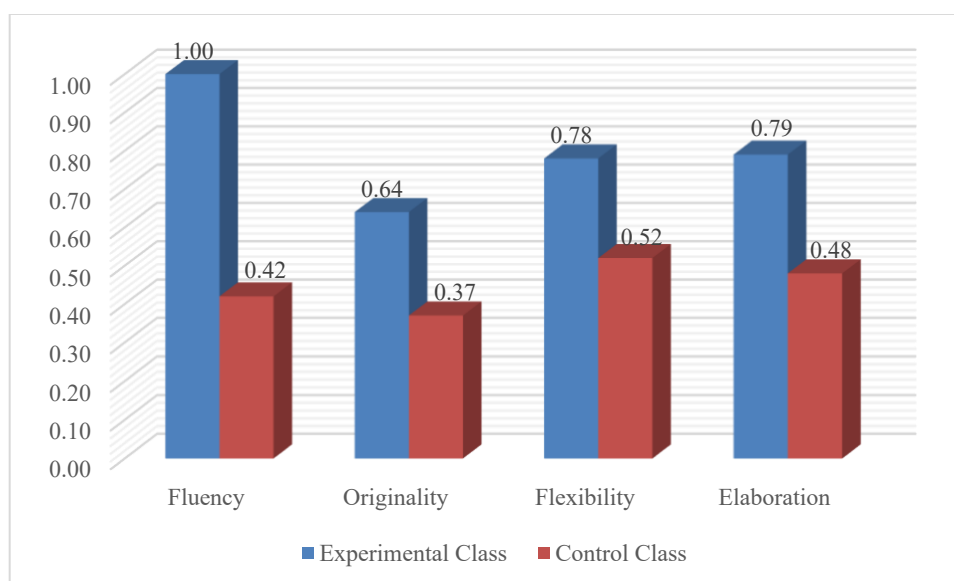


Figure 2. Comparison of the N-gain scores between experimental and control groups

Inferential statistical analysis confirmed these descriptive and gain-based observations. Results of the independent samples t-test revealed a statistically significant difference between the two groups in their posttest scores, $t(65) = 8.68$, $p < 0.001$. This indicates that the experimental group's creative thinking scores were significantly higher than those of the control group. This substantial effect underscores the strong impact of integrating TikTok into PjBL–STEM on fostering students' creative thinking in physics.

The present study provides evidence that integrating a PjBL model within a STEM framework, coupled with short-video production on TikTok, leads to substantially greater gains in creative thinking than conventional PjBL alone on the topic of projectile motion. This pattern aligns with a broad body of work positioning contemporary physics instruction within a competency-oriented agenda that emphasizes creativity, problem solving, and authentic application (OECD, 2023; Lucas, 2022; Papagiannis & Pallaris, 2024). In line with recent classroom reports and programmatic evaluations, the findings suggest that when students tackle designable, real-world problems while drawing upon cross-disciplinary lenses, their motivation and higher-order thinking tend to increase (Nurilma et al., 2023; Tuveri et al., 2024; Martawijaya

et al., 2023; Mohottala et al., 2023). The significant between-group differences observed in our results support the inference that the added media workflow conceiving, scripting, and producing concise explanatory videos functioned as a powerful amplifier of the PjBL–STEM cycle.

One plausible mechanism is that PjBL structures provide the epistemic backbone for problem framing, iterative investigation, and public product, while STEM integration ensures that students coordinate conceptual physics reasoning with mathematical modeling, technological tools, and elementary engineering design (Parno et al., 2020; Prajoko et al., 2023; Syaifuddin et al., 2022). Short-video creation then becomes the communicative and metacognitive layer through which students externalize and refine their ideas. Prior work on classroom technology and social platforms indicates that carefully guided production tasks can heighten engagement, collaboration, and audience awareness compared with passive consumption (Escamilla-Fajardo et al., 2021; Sholina et al., 2023; Qiyang & Jung, 2019; Suganda et al., 2021; Yélamos-Guerra et al., 2022). This finding is consistent with those claims: students in the treatment group not only achieved higher posttest scores but also showed larger normalized gains, suggesting that the combination of PjBL–STEM with TikTok helped convert participation into measurable learning.

The indicator-level pattern, with the most significant improvements in originality and fluency, merits closer discussion. Creative fluency benefits from repeated generative cycles in which students brainstorm multiple solution paths, trial micro-experiments, and compress explanations into time-bounded narratives (Lucas, 2022; Papagiannis & Pallaris, 2024). Originality, in turn, is nurtured when learners are asked to devise distinctive representations, examples, or contexts to make projectile motion intelligible to a lay audience, an affordance of the public product requirement of PjBL (Parno et al., 2020) and the stylistic expectations of platform-based media (Escamilla-Fajardo et al., 2021; Sholina et al., 2023). The pattern was observed coheres with studies reporting that student authorship and audience-aware explanation can shift creative output from routine to adaptive, especially when tasks culminate in shareable artifacts (Retno et al., 2025; Bouquet et al., 2017; Kwon & Lee, 2025).

Another locus of impact concerns persistent conceptual obstacles in projectile motion—especially the independence of horizontal and vertical components, mapping kinematics variables onto 2-D trajectories, and coordinating symbolic, graphical, and verbal representations. Prior research has repeatedly documented these difficulties and their consequences for problem solving (Bakri et al., 2023; Hashim et al., 2022; Ahmad et al., 2021; Cortés-Ramos et al., 2021; Wang et al., 2025). Our intervention addressed these by coupling PjBL inquiry data collection, modeling, and design justification with micro-explanations that forced students to distill relations such as angle-velocity-range into coherent multimodal narratives. The requirement to storyboard and shoot scenes that visibly separate vertical acceleration from constant horizontal velocity appears

to have helped learners reconcile formalism with phenomena, a reconciliation often missing in purely worksheet-driven approaches (Praptama et al., 2023; Fiteriani et al., 2021).

The STEM dimension likely contributed in two complementary ways. First, it framed projectile motion as a design-relevant phenomenon (e.g., optimizing launch parameters or evaluating device function), making the mathematics instrumentally necessary rather than a detached exercise (Nurilma et al., 2023; Tuveri et al., 2024). Second, it normalized the use of technological tools for measurement, modeling, and communication, ranging from tracker-style apps and plotting utilities to video editors, thus embedding representational translation into the learning sequence (Martawijaya et al., 2023; Mohottala et al., 2023). The resultant representational fluency is a strong candidate explanation for the elevated gains was recorded, particularly in fluency and originality, which depend on both the quantity and distinctiveness of ideas generated and expressed (Lucas, 2022; Retno et al., 2025).

At the same time, the literature warns that technology integration alone does not guarantee learning gains; implementation quality, task authenticity, and teacher guidance are decisive (OECD, 2023; Peña-Martínez et al., 2025; Octafianellis et al., 2021). Our design emphasized structured prompts, iterative feedback, and explicit criteria for scientific accuracy in videos—conditions that previous studies identify as levers for transforming engagement into understanding (Escamilla-Fajardo et al., 2021; Sholina et al., 2023; et al., 2022). This may help explain why the treatment advantage was not merely statistically significant but also practically meaningful. Still, the approach carries demands: equitable access to devices, time for production cycles, and teacher capacity to coach both content and media literacy (OECD, 2023; Vasconcelos & Santos, 2025). These implementation factors likely moderate effects across contexts and should be considered in scaling efforts.

It is also important to interpret these results alongside critiques that overreliance on short-form media can encourage superficiality or aesthetic over substance if tasks lack disciplinary focus (Peña-Martínez et al., 2025). The present study mitigated that risk by embedding TikTok within a PjBL–STEM sequence that foregrounded physics goals, data-informed reasoning, and criteria-referenced explanation. The literature on PjBL in physics underscores that when products are evaluated for conceptual clarity and representational accuracy, not merely creativity, students are more likely to integrate ideas rather than assemble decorative artifacts (Parno et al., 2020; Syaifuddin et al., 2022; Prajoko et al., 2023). Our indicator-specific results are consonant with that stance.

Methodologically, the quasi-experimental, nonequivalent group design constrains causal generalization; intact classes may differ in unobserved ways. Nevertheless, the convergence of assumption checks, the magnitude of the between-group difference, and the consistency of

indicator-level gains lend credence to a substantive effect of the intervention. These outcomes are compatible with multi-site reports that PjBL–STEM improves engagement and conceptual outcomes relative to conventional instruction (Nurilma et al., 2023; Tuveri et al., 2024; Martawijaya et al., 2023; Mohottala et al., 2023). Future studies should extend the design with longitudinal follow-ups and broader samples to probe durability and transfer, as advocated in recent STEM-education syntheses (Kwon & Lee, 2025; Wang et al., 2025).

In practical terms, the findings invite physics teachers to treat short-video production not as an add-on but as a principled communicative phase of PjBL in which students consolidate and externalize their models. This move is especially pertinent for topics like projectile motion, where the conceptual core hinges on coordinating multiple representations across time and space (Bakri et al., 2023; Hashim et al., 2022; Ahmad et al., 2021). Schools and districts considering adoption should invest in lightweight production workflows, rubrics that value both scientific accuracy and creative expression, and professional learning that helps teachers orchestrate inquiry, modeling, and media critique (OECD, 2023; Vasconcelos & Santos, 2025). When these enabling conditions are present, the literature and our data jointly indicate that PjBL–STEM with TikTok can advance both the cognitive and creative aims of physics education (Papagiannis & Pallaris, 2024; Lucas, 2022; Retno et al., 2025; Escamilla-Fajardo et al., 2021; Sholina et al., 2023).

IV. CONCLUSION AND SUGGESTION

The findings of this study demonstrate that integrating TikTok within a PjBL integrated STEM framework significantly enhanced students' creative thinking in learning projectile motion. Students in the experimental group outperformed those in the control group across all four dimensions of creativity: fluency, originality, flexibility, and elaboration. Their normalized gain values reached the high category, indicating a large effect size. The most pronounced improvements were observed in elaboration and originality, indicating that the affordances of short-video production encouraged students to expand their explanations and generate unique representations of physics concepts. These results affirm the potential of combining structured STEM-oriented pedagogy with student-familiar digital platforms to cultivate creativity in abstract areas of physics.

While the outcomes are promising, several limitations must be acknowledged. The use of a quasi-experimental design with nonequivalent groups limits the extent to which causal claims can be generalized. The study was conducted in a single school with one physics topic. Although the assessment instrument was validated, it was limited to essay-based tasks that may not capture the full spectrum of creative performance. Future research should consider replication across different

schools, broader physics domains such as energy or waves, and the inclusion of performance-based or longitudinal assessments to capture the durability of learning gains. Despite these limitations, the study makes a meaningful contribution to the field of physics education by providing empirical evidence that integrating widely used social media platforms within structured pedagogical frameworks can bridge the gap between students' everyday digital practices and disciplinary learning goals. This work underscores the value of leveraging technology-enhanced project-based learning to foster creativity, a competency increasingly vital in twenty-first-century science education.

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