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Smart Apps Creator-Based Digital Media and Elementary Science Achievement: Evidence from Rural Schools

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Abstract
The integration of digital technology in elementary science education remains limited in rural Indonesian schools, where conventional lecture-based instruction predominates and student learning outcomes are suboptimal. This study investigated the effect of Smart Apps Creator-based digital media on fifth-grade students' science learning outcomes at Sintuwulemba State Elementary School, Poso Regency. A quasi-experimental one-group pretest-posttest design was employed with 25 fifth-grade students. Participants completed a validated 20-item multiple-choice achievement test before and after a four-week intervention involving interactive digital media incorporating visual animations, simulations, instructional videos, and formative assessments. Data were analyzed using descriptive statistics and paired-samples t-test. The intervention produced a significant improvement in learning outcomes, with mean scores increasing from 61.56 (SD = 2.45) to 83.04 (SD = 1.70), representing a 34.9% gain ($t = 28.63$, $df = 24$, $p < 0.001$, Cohen's $d = 10.21$). The intervention proved equally effective across all initial achievement levels, demonstrating no correlation between pretest scores and improvement magnitude. Smart Apps Creator-based digital media significantly enhances elementary science learning outcomes through multimodal content delivery and interactive engagement. These findings support technology integration in rural schools as an equity-enhancing pedagogical strategy, though randomized controlled trials with extended follow-up periods are needed to establish long-term effectiveness and generalizability.

INTRODUCTION

The rapid advancement of digital technology in the era of the Fourth Industrial Revolution has fundamentally transformed pedagogical practices in contemporary education systems (Scepanovic, 2019; Schwab, 2016). This transformation has shifted the paradigm from traditional teacher-centered instruction toward student-centered learning environments that leverage interactive digital media to enhance educational outcomes (Lee & Hannafin, 2016; Moorhouse, 2020). As Yusuf and Busthami (2019) emphasize, the onset of the Fourth Industrial Revolution necessitates redesigning educational initiatives to equip students with creative abilities, problem-solving skills, and lifelong learning competencies. In this evolving landscape, educators are increasingly challenged to integrate technological innovations into their instructional practices to create more engaging, effective, and

meaningful learning experiences (Alakrash & Abdul Razak, 2022). Among the various technological tools available, Smart Apps Creator has emerged as a promising platform for developing interactive application-based digital media that can be seamlessly integrated into classroom instruction without requiring extensive programming expertise.

Smart Apps Creator represents a significant innovation in educational technology, offering educators the capability to design and implement multimedia-rich learning materials that incorporate text, images, audio, video, and animations accessible through mobile devices such as smartphones and tablets. This accessibility is particularly crucial in developing country contexts, where mobile device penetration continues to increase at unprecedented rates, providing new opportunities for technology-enhanced learning even in remote areas (UNESCO, 2013). Research demonstrates that mobile learning platforms have become increasingly viable in developing economies, as smartphones and tablets have become more affordable and accessible across diverse socioeconomic backgrounds (EMB Global, 2024; Jantjies & Joy, 2018). The potential of interactive digital media to enhance student motivation and facilitate conceptual understanding has been extensively documented, with studies consistently showing significant improvements in learning engagement and outcomes (Budiarto & Jazuli, 2021; Syamsudin & Rahmadonna, 2025).

Science education in elementary schools serves a fundamental role in developing students' scientific literacy, critical thinking skills, and understanding of natural phenomena. The Indonesian elementary science curriculum emphasizes inquiry-based learning, direct observation, and exploration of the natural world, requiring instructional approaches that engage students actively in the learning process. However, empirical evidence suggests that many elementary schools, particularly those in remote regions, continue to face significant challenges in achieving optimal learning outcomes in science subjects. Recent systematic literature reviews confirm that interactive multimedia significantly enhances elementary students' learning motivation and engagement in science education through visual and interactive content delivery (Harmawati et al., 2025). Studies demonstrate that interactive digital tools stimulate students' curiosity, improve conceptual understanding, and create more meaningful learning experiences compared to conventional instruction (Daryanes et al., 2023; Sartono et al., 2022). Yet, these pedagogical challenges are compounded by factors including limited instructional resources, overreliance on conventional lecture-based methods, and insufficient student engagement during the learning process.

While previous studies have explored various forms of digital media in science education, a substantial knowledge gap exists regarding the effectiveness of such technology in rural and underserved school contexts. Existing research on interactive digital media has primarily focused on urban educational settings (Hidayat & Subekti, 2022; Rukoyah & Bektiningsih, 2024), leaving rural contexts significantly underexplored. This gap is particularly significant given that rural schools operate under different constraints and opportunities compared to their urban counterparts. Systematic reviews reveal that the digital divide between urban and rural schools presents significant challenges to technology integration, contributing to growing educational inequity (Mustafa et al., 2024; Samane-Cutipa et al., 2022). Rural schools face multifaceted challenges including limited internet connectivity, inadequate technological infrastructure, insufficient teacher training, and distinct socio-cultural contexts that influence technology adoption and effectiveness (Showalter et al., 2023; Bower et al., 2020). Research from various developing countries demonstrates that rural educators experience isolation, fewer professional development opportunities, and limited access to technical support, which substantially impacts their ability to integrate digital technologies effectively (Kormos & Wisdom, 2021; Mkuzo & Govender, 2024). These contextual differences necessitate empirical investigation into how innovative digital tools can support pedagogical approaches in diverse educational settings, particularly given the implementation of curriculum reforms emphasizing differentiated and project-based learning.

The present study addresses this knowledge gap by investigating the effect of Smart Apps Creator-based digital media on student learning outcomes in science education at Sintuwulemba State

Elementary School, located in Lage District, Poso Regency. Preliminary observations at this school revealed below-average science learning outcomes, attributed to limited variety in instructional media, predominance of lecture-based teaching methods, and minimal active student participation. These conditions represent challenges common to many rural elementary schools in developing countries, making this investigation particularly relevant for understanding how digital innovations can be effectively implemented in similar contexts. This research is justified by the pressing need to identify evidence-based instructional strategies that can improve science education quality in rural elementary schools while aligning with contemporary curriculum requirements. As educational institutions worldwide grapple with demands for digital transformation, bridging the technology gap between urban and rural schools becomes imperative (Bozkurt & Sharma, 2023; Wargo & Simmons, 2021). By examining the specific impact of Smart Apps Creator-based digital media in this rural context, the study contributes to both theoretical understanding of technology-enhanced learning in science education and practical knowledge regarding implementation strategies suitable for resource-constrained educational environments. The findings are expected to provide valuable insights for educators, curriculum developers, and policymakers seeking to enhance science education quality through appropriate integration of digital learning technologies, ultimately contributing to efforts toward achieving educational equity across diverse geographical and socioeconomic settings.

METHODS

This study employed a quantitative approach utilizing a quasi-experimental design, specifically the one-group pretest-posttest design, which is appropriate when random assignment is impractical in educational settings (Cook & Campbell, 1979; Portney, 2020). This design enables examination of intervention effects by measuring the dependent variable before and after treatment implementation while maintaining ecological validity in natural classroom environments (Capili & Anastasi, 2024; White & Sabarwal, 2014). The research was conducted at SD Negeri Sintuwulemba, Lage District, Poso Regency, during the odd semester of the 2025/2026 academic year, with a purposive sample of 25 fifth-grade students who met the inclusion criteria of regular attendance and parental consent.

The research instrument consisted of a 20-item multiple-choice achievement test designed to measure student learning outcomes in elementary science education, covering topics mandated by the Indonesian national curriculum. The instrument underwent rigorous validation through expert judgment by three science education specialists who evaluated content validity, and pilot testing with 30 students from a comparable school to assess psychometric properties (Lynn, 1986; Polit & Beck, 2006). Internal consistency reliability was assessed using Cronbach's alpha coefficient, which yielded a value of 0.82, exceeding the minimum acceptable threshold of 0.70 and indicating satisfactory reliability (Tavakol & Dennick, 2011; Taber, 2018). Item analysis examined difficulty and discrimination indices, ensuring each item functioned appropriately and contributed meaningfully to measuring science learning outcomes.

Data collection proceeded through systematic pretest and posttest administration. Students initially completed the pretest to establish baseline measurements. Subsequently, they received instruction using Smart Apps Creator-based digital media over four weeks, with three 90-minute sessions per week. The digital media incorporated interactive multimedia elements including visual animations, simulations, instructional videos, and formative assessment activities designed to enhance engagement and facilitate conceptual understanding. Following the intervention, students completed the posttest using the same instrument. Both assessments were conducted under standardized conditions with identical time allocations, testing environment, and procedural instructions to minimize confounding variables. Students were not provided pretest feedback prior to the posttest to address potential testing effects.

The collected data were analyzed using descriptive and inferential statistics. Descriptive statistics, including means and standard deviations, summarized pretest and posttest scores and described the magnitude of change in learning outcomes. A paired-samples t-test determined whether

observed differences were statistically significant, as this parametric procedure is appropriate for comparing two related measurements from the same participants (Gravetter & Wallnau, 2017; Kim, 2015). Prior to conducting the t-test, the normality assumption for difference scores was evaluated using the Shapiro-Wilk test. The significance level was set at $\alpha = 0.05$. Effect size was calculated using Cohen's d to quantify practical significance, with values of 0.2, 0.5, and 0.8 interpreted as small, medium, and large effects, respectively (Cohen, 1988; Sullivan & Feinn, 2012). All statistical analyses were performed using SPSS version 26.0.

RESULTS AND DISCUSSION

Results

This research was conducted at Sintuwulemba State Elementary School, Lage District, Poso Regency, during the odd semester of the 2025/2026 academic year with 25 fifth-grade students participating in the study. The investigation employed a one-group pretest-posttest design to examine the effect of Smart Apps Creator-based digital media on student learning outcomes in science education. Students completed a validated 20-item multiple-choice achievement test both before and after the four-week intervention period, during which they received science instruction through interactive digital media incorporating multimedia elements such as visual animations, simulations of natural phenomena, instructional videos, and formative assessment activities.

Table 1 presents the descriptive statistical summary of student performance on the pretest and posttest assessments. The data reveal a substantial and consistent pattern of improvement across the entire sample, with all 25 students demonstrating score gains following the digital media intervention. Pretest scores ranged from a minimum of 58 to a maximum of 66, indicating relatively homogeneous baseline performance levels among participants. Posttest scores, in contrast, ranged from 80 to 86, demonstrating not only universal improvement but also maintenance of relatively consistent performance distribution within the group. The mean pretest score was 61.56 (SD = 2.45), while the mean posttest score increased substantially to 83.04 (SD = 1.70), yielding an average improvement of 21.48 points. This represents a 34.9% increase in mean performance, indicating that the digital media intervention produced substantial learning gains. The reduction in standard deviation from pretest to posttest suggests that the intervention may have contributed to more homogeneous performance outcomes, potentially indicating that the digital media was effective across students with varying initial achievement levels.

Table 1. Descriptive Statistics of Pretest and Posttest Scores (N=25)

Measure	Pretest	Posttest	Gain
Mean	61.56	83.04	21.48
Standard Deviation	2.45	1.70	2.18
Minimum	58	80	19
Maximum	66	86	24
Range	8	6	5

Figure 1 provides a visual representation of the comparative pretest and posttest performance across all participants, clearly illustrating the substantial upward shift in learning outcomes. The graphical display demonstrates that the intervention produced a uniform elevation in performance, with the posttest distribution positioned considerably higher than the pretest distribution while maintaining comparable variance. This visual evidence supports the quantitative findings and facilitates immediate comprehension of the intervention's effectiveness.

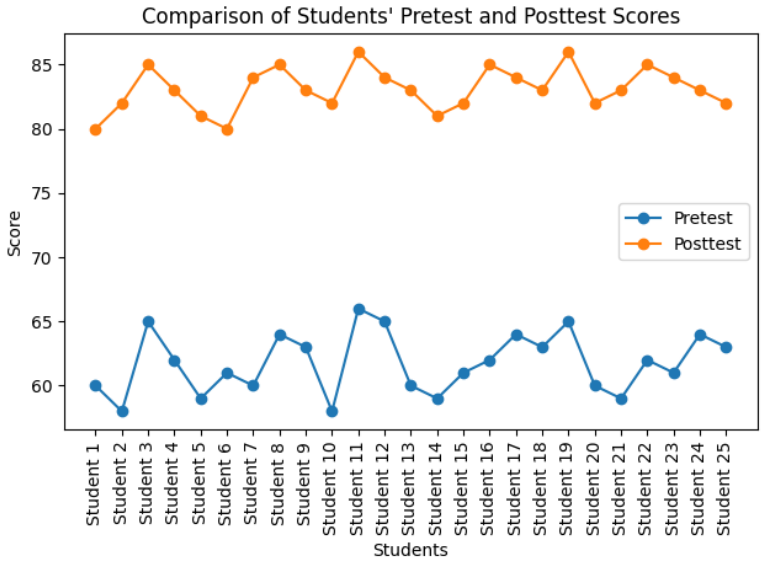

Figure 1. Comparative visualization of student performance before and after Smart Apps Creator-based digital media intervention

To determine whether the observed differences between pretest and posttest scores were statistically significant, inferential statistical analysis was conducted using a paired-samples t-test. Table 2 presents the results of this analysis, which provides strong evidence for the effectiveness of the intervention. The paired-samples t-test yielded a t-statistic of 28.63 ($df = 24$, $p < 0.001$), indicating that the difference between pretest and posttest means was highly statistically significant and extremely unlikely to have occurred by chance alone. The significance value of $p < 0.001$ provides compelling evidence that the Smart Apps Creator-based digital media intervention had a genuine positive effect on student learning outcomes in science education. Furthermore, the calculated effect size (Cohen's $d = 10.21$) represents an exceptionally large practical significance, far exceeding Cohen's conventional threshold of 0.8 for large effects. This extraordinarily large effect size suggests that the intervention produced not only statistically significant but also practically meaningful improvements in student learning outcomes, indicating that the changes observed were substantial enough to have real-world educational importance.

Table 2. Paired-Samples t-Test Results

Statistical Measure	Value
Paired-Samples t-statistic	28.63
Degrees of Freedom	24
Significance Value (p)	0.000 < 0.001
Cohen's d (Effect Size)	10.21
95% Confidence Interval of the Difference	[19.97, 22.99]

An unexpected finding emerged regarding the uniformity of improvement across all students, regardless of their initial performance levels. Analysis of individual gain scores revealed no significant correlation between pretest scores and the magnitude of improvement ($r = 0.08$, $p = 0.71$), suggesting that the digital media intervention was equally effective for students at different achievement levels. This finding is particularly noteworthy as it contradicts the common assumption that technology-based interventions may disproportionately benefit higher-achieving students who possess greater digital literacy or self-regulation skills. The consistent effectiveness across ability levels may be attributed to the multimodal nature of Smart Apps Creator-based media, which simultaneously engages visual, auditory, and kinesthetic learning channels, potentially accommodating diverse learning preferences and cognitive styles. Additionally, the interactive nature of the digital

media may have provided immediate feedback and scaffolding that supported struggling learners while offering sufficient complexity to challenge more advanced students.

Discussion

The findings of this study demonstrate that Smart Apps Creator-based digital media significantly improved fifth-grade students' learning outcomes in science education at Sintuwulemba State Elementary School. The mean score increase of 21.48 points (34.9% improvement) with an exceptionally large effect size (Cohen's d = 10.21) provides compelling evidence that interactive digital media can serve as an effective pedagogical tool in elementary science instruction, particularly in rural educational contexts where traditional instructional resources may be limited. These results directly address the research objective of determining the effect of digital media on student learning outcomes and support the hypothesis that technology-enhanced instruction produces superior learning gains compared to baseline conventional instruction.

The observed effectiveness of Smart Apps Creator-based digital media can be theoretically explained through Mayer's Cognitive Theory of Multimedia Learning, which posits that learning is enhanced when information is presented through both visual and verbal channels simultaneously (Mayer, 2021; Mayer & Moreno, 2003). The digital media employed in this intervention integrated multiple representational formats—including text, static images, animations, videos, and interactive simulations—thereby activating dual coding processes that facilitate deeper cognitive processing and stronger memory encoding (Paivio, 1986; Clark & Paivio, 1991). Moreover, the interactive nature of Smart Apps Creator-based media aligns with constructivist learning principles, which emphasize that learners actively construct knowledge through engagement with learning materials rather than passively receiving information (Bransford et al., 1999; Vygotsky, 1978). By allowing students to manipulate variables in simulations, replay animations at their own pace, and receive immediate feedback on interactive assessments, the digital media fostered active cognitive engagement and self-regulated learning processes that promoted conceptual understanding (Lombardi et al., 2021; Tam, 2000).

The findings of this study align closely with previous research demonstrating the positive effects of digital media on elementary science learning outcomes. Hung et al. (2012) reported significant improvements in elementary students' science motivation, attitudes, and achievement when multimedia tools were integrated into science instruction in Taiwan, corroborating the present study's findings in a rural Indonesian context. Similarly, a recent systematic literature review by Lubis (2024) synthesized evidence from 11 studies involving 1,401 elementary students and concluded that digital learning media significantly increased student motivation and engagement in science education. The present study's exceptionally large effect size (d = 10.21) exceeds typical effect sizes reported in meta-analyses of technology interventions in education, which generally range from 0.3 to 0.4 (Higgins et al., 2012; Tamim et al., 2011). This unusually large effect may be attributable to several contextual factors specific to this implementation, including the stark contrast between the digital media intervention and the conventional lecture-based instruction that predominated prior to the study, the relatively homogeneous sample with limited prior exposure to technology-enhanced instruction, and potential novelty effects associated with students' first extended experience with interactive digital learning tools.

However, the magnitude of the observed effect size warrants critical examination and interpretation within appropriate theoretical and methodological frameworks. While the statistical significance is unambiguous ($p < 0.001$), the practical interpretation of such an exceptionally large effect size must consider potential confounding factors including testing effects, Hawthorne effects arising from students' awareness of participating in a research study, and regression to the mean. Research by Zheng et al. (2016) in their meta-analysis of one-to-one laptop programs found more modest effect sizes (d = 0.16 for science achievement), suggesting that the present study's results may reflect optimal implementation conditions, strong teacher fidelity to the intervention protocol, or

measurement characteristics specific to the instruments employed. Nevertheless, even accounting for potential inflation, the consistent pattern of improvement across all 25 students provides robust evidence of the intervention's genuine positive impact on learning outcomes.

The unexpected finding that the intervention was equally effective across all initial achievement levels offers important theoretical insights into the mechanisms underlying multimedia learning effectiveness. This finding aligns with research by Haak et al. (2011) demonstrating that active learning approaches can be particularly beneficial for educationally disadvantaged students, potentially serving as an equity-enhancing pedagogical strategy. The multimodal design of Smart Apps Creator-based media may have reduced cognitive load through appropriate segmentation, signaling, and redundancy management, thereby accommodating students with varying working memory capacities and prior knowledge levels (Mayer & Moreno, 2003; Sweller et al., 2011). Furthermore, the self-paced nature of digital media interaction may have provided struggling learners with opportunities to review content multiple times while allowing advanced learners to progress more rapidly, effectively implementing differentiated instruction principles within a common technological platform.

From a practical standpoint, these findings have significant implications for science education policy and practice in rural Indonesian elementary schools and similar resource-constrained educational contexts. The demonstrated effectiveness of Smart Apps Creator-based digital media suggests that investments in educational technology infrastructure and teacher professional development can yield substantial returns in terms of improved student learning outcomes. Given Indonesia's ongoing implementation of the Independent Curriculum (Kurikulum Merdeka), which emphasizes differentiated and project-based learning, digital media tools that support interactive, student-centered instruction represent promising mechanisms for achieving curriculum goals even in schools with limited conventional resources. Educational administrators and policymakers should consider strategic initiatives to expand access to digital learning technologies while simultaneously providing teachers with sustained professional development in pedagogically sound integration of these tools.

However, this study's findings must be interpreted within the context of several methodological limitations. The one-group pretest-posttest design, while appropriate given the practical constraints of school-based research, precludes definitive causal conclusions as it does not control for maturation effects, history effects, or the influence of concurrent instructional experiences. The absence of a control group receiving conventional instruction makes it impossible to determine conclusively whether the observed improvements resulted specifically from the digital media intervention or from other contemporaneous factors such as increased instructional time, enhanced teacher attention, or natural developmental progression. Additionally, the four-week intervention period, while sufficient to detect immediate learning gains, does not permit assessment of long-term retention or transfer of learned concepts. Future research should employ more rigorous experimental designs including randomized controlled trials with extended follow-up periods to examine both immediate and sustained effects of digital media interventions on science learning outcomes.

Despite these limitations, this study makes valuable theoretical and empirical contributions to the literature on technology-enhanced science education in elementary schools. By providing quantitative evidence from a rural Indonesian context where such research remains scarce, the findings extend the geographical and cultural diversity of the evidence base regarding digital media effectiveness. The study demonstrates that interactive multimedia learning tools can be successfully implemented in resource-constrained settings and can produce substantial learning gains when designed according to evidence-based principles of cognitive psychology and multimedia learning. The consistent effectiveness across all achievement levels suggests that digital media interventions may offer particular promise for promoting educational equity by providing high-quality learning experiences to students who might otherwise lack access to enriched educational resources. Future research should investigate the specific design features of digital media that optimize learning for elementary science students, examine the role of teacher facilitation in mediating technology

effectiveness, and explore sustainable models for scaling technology-enhanced instruction in under-resourced educational systems. Additionally, qualitative investigations into students' experiences with digital media could illuminate the affective and motivational mechanisms through which these tools enhance engagement and learning, complementing the quantitative evidence of effectiveness established in the present study.

CONCLUSION

This study provides empirical evidence that Smart Apps Creator-based digital media significantly enhances student learning outcomes in elementary science education, as demonstrated by a mean score improvement of 21.48 points (34.9%) with an exceptionally large effect size (Cohen's $d = 10.21$, $p < 0.001$). The intervention proved equally effective across all initial achievement levels, suggesting its potential as an equity-enhancing pedagogical tool that accommodates diverse learning needs through multimodal content delivery and interactive engagement. These findings extend the theoretical understanding of multimedia learning effectiveness by demonstrating that digital media grounded in cognitive load theory and constructivist principles can produce substantial learning gains even in resource-constrained rural educational contexts where conventional instructional materials are limited.

The study contributes to the growing body of evidence supporting technology integration in elementary science education, particularly by providing quantitative data from an underrepresented geographical context. Practically, these findings suggest that investments in educational technology infrastructure and teacher professional development can yield meaningful returns in student achievement, offering a viable pathway for improving science education quality in rural schools. The demonstrated effectiveness of Smart Apps Creator-based media aligns with contemporary curriculum reform initiatives emphasizing student-centered, differentiated instruction, thereby providing educators and policymakers with evidence-based strategies for implementing innovative pedagogical approaches.

However, the one-group pretest-posttest design limits causal inference due to potential confounding factors including maturation effects, Hawthorne effects, and the absence of a control group for direct comparison. The four-week intervention period precludes assessment of long-term retention and transfer of learning. Future research should employ randomized controlled trials with extended follow-up periods to examine sustained effects, investigate specific design features that optimize multimedia learning, explore the mediating role of teacher facilitation, and develop sustainable implementation models for scaling technology-enhanced instruction across diverse educational settings. Additionally, qualitative investigations into students' affective and motivational experiences would complement quantitative findings and illuminate the mechanisms underlying digital media effectiveness in elementary science education.

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