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The Impact of Digitally-Integrated Coloring Tasks on The Development of Fine Motor Proficiencies in Early Childhood Education Settings

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ABSTRACT

Purpose of the study: This study investigated the effects of digitally-integrated coloring tasks compared to traditional paper-based coloring activities on the development of fine motor skills in preschool children.

Materials and methods: A quasi-experimental study was conducted over an 8-week period with 60 preschool children (aged 4-5 years) from four early childhood education centers in Kabupaten Kampar, Riau, Indonesia. Participants were randomly assigned to either an experimental group using tablet-based coloring applications (n=30) or a control group using traditional paper-based coloring materials (n=30). Fine motor skills were assessed using the Peabody Developmental Motor Scales-Second Edition (PDMS-2) and the Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery VMI).

Results: Both groups showed improvements in fine motor skills, but the experimental group demonstrated significantly greater gains in visual-motor integration ($p<0.05$) and grasping skills ($p<0.05$) compared to the control group. Effect sizes indicated a medium to large impact of the digital intervention on fine motor development.

Conclusions: Digitally-integrated coloring tasks can effectively enhance fine motor proficiencies in early childhood, particularly in visual-motor integration and grasping skills. These findings suggest that thoughtfully implemented digital tools may serve as valuable supplements to traditional methods in early childhood education settings.

Keywords: fine motor skills, early childhood education, digital learning, coloring activities, visual-motor integration, preschool development.

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INTRODUCTION

Fine motor development represents a critical aspect of early childhood development, encompassing the coordination of small muscle movements that enable children to perform precise tasks such as writing, drawing, and manipulating small objects (Jumiyati et al., 2023; Roseli et al., 2024). These skills are fundamental to a child's academic readiness and daily functioning, serving as building blocks for more complex skills required in formal education settings (Rymanowicz, 2023) . The development of fine motor skills in early childhood is particularly crucial as it coincides with significant neurological development and establishes foundational abilities that influence later academic achievement.

Traditional approaches to fostering fine motor development have predominantly relied on paper-based activities such as drawing, coloring, and cutting. Coloring activities, in particular, have been widely recognized as effective tools for developing fine motor skills in young children (Marhaeni et al., 2022). These activities foster artistic expression while simultaneously developing the precise muscle control needed for writing and other academic tasks (Astawa & Astuti, 2020). Through coloring, children learn to coordinate visual perception with hand movements, control writing implements, and develop appropriate pressure and precision.
In recent years, the landscape of early childhood education has been transformed by the integration of digital technologies (Navas-Bonilla et al., 2025). Touch screen devices, in particular, have become increasingly prevalent in educational settings, raising questions about their potential impact on children's development (Martin et al., 2022; Muppalla et al., 2023). Research examining the relationship between touch screen use and fine motor development has yielded mixed results. Some studies suggest that touchscreen use may be linked to stronger fine motor abilities in young children, with research by Price and colleagues indicating that tablet use was associated with improvements in the speed and consistency of drawing movements (Semmelmann et al., 2016; Souto et al., 2019). Conversely, concerns have been raised about whether digital tools provide the same sensory and motor experiences as traditional materials.

Despite the growing body of research on technology in early childhood education, there remains a significant gap in understanding how digitally-integrated coloring tasks specifically affect fine motor development. Most existing studies have examined general touchscreen use rather than focused interventions using specific applications designed to target fine motor skills.

Additionally, few studies have directly compared the efficacy of digital and traditional approaches within the same skill domain, such as coloring activities.

The present study addresses these gaps by implementing a controlled comparison of digitally-integrated and traditional coloring tasks in early childhood education settings. By focusing specifically on coloring activities across both mediums, this research aims to isolate the impact of the digital interface while maintaining consistency in the underlying task. This approach allows for a more nuanced understanding of how the medium affects fine motor development, rather than comparing fundamentally different activities.

The primary objectives of this study are to: 1.Compare the effects of digitally-integrated and traditional coloring tasks on fine motor development in preschool children; 2.Identify specific components of fine motor skills (grasping, visual-motor integration) that may be differentially affected by digital versus traditional coloring activities; 3.Evaluate the potential of digital coloring applications as supplements to traditional fine motor development activities in early childhood education settings

By addressing these objectives, this study aims to provide evidence-based guidance for early childhood educators seeking to integrate digital tools effectively while supporting children's fine motor development

MATERIALS AND METHODS

Participants

This study was conducted in four early childhood education centers (Pendidikan Anak Usia Dini) located in Kabupaten Kampar, Riau, Indonesia. Participants were preschool children aged 4 to 5 years, selected using purposive sampling based on the following inclusion criteria: no known developmental delays, parental consent, and regular attendance. The final sample consisted of 60 children who were randomly assigned to either the experimental group (n=30) or the control group (n=30). Demographic characteristics of the participants were collected, including age, gender, and parental education level, to ensure comparability between groups.

Study Organization

This quasi-experimental study was conducted over an 8-week period in four early childhood education centers. The experimental group engaged in digitally-integrated coloring tasks using tablet devices, while the control group performed traditional paper-based coloring tasks. All coloring activities were conducted during regular class hours, under the supervision of the classroom teacher and a trained research assistant. Both groups received equal instructional time and coloring frequency (three sessions per week, 30 minutes per session).

The intervention materials for the digital group consisted of age-appropriate coloring applications that incorporated tactile interaction, pinch-and-zoom features, and stylus use to mimic fine motor demands. The applications were selected based on their alignment with developmental appropriateness, user interface simplicity, and incorporation of features that promote fine motor skill development. The control group used conventional coloring materials including crayons, colored pencils, and printed coloring sheets with similar content and complexity as those available in the digital applications.

Prior to the intervention, all teachers received training on the implementation protocols to ensure consistency across sites. Weekly monitoring visits were conducted to maintain intervention fidelity and address any implementation challenges.

Test and Measurement Procedures

To evaluate fine motor proficiency, the study employed two standardized instruments:

Table 1. Description of Fine Motor Assessment Instruments Used in the Study

Assessment Tool	*Subtests / Components*	*Target Age*	*Purpose / Skills Assessed*	*Administration*
Peabody Developmental Motor Scales–Second Edition (PDMS-2)	Grasping, Visual-Motor Integration	Birth to 5 years	- **Grasping**: Assesses hand use ability - **Visual-Motor Integration**: Assesses coordination between visual perception and hand/finger movements	Administered by trained examiners blinded to group assignment; conducted 1 week before (pre-test) and within 1 week after (post-test) the intervention following standardized protocols
Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery VMI), 6th Ed.	Visual-Motor Integration	Typically 2 years and older (varies by edition)	Measures ability to integrate visual and motor skills; relevant for tasks like coloring and drawing	Same administration procedures as PDMS-2 (pre- and post-intervention, by blinded trained examiners, standardized protocol)

These assessments were administered by trained examiners who were blinded to group assignment. Assessments were conducted one week before the intervention began (pre-test) and within one week after the intervention concluded (post-test). All testing procedures followed standardized protocols as outlined in the respective test manuals.

Statistical Analysis

Data were analyzed using SPSS version 26. Descriptive statistics (mean ± SD) were calculated for each variable. Normality was assessed using the Shapiro–Wilk test. Pre- and post-test comparisons within groups were conducted using paired t-tests for normally distributed data or Wilcoxon signed-rank tests for non-parametric data. Between-group differences were analyzed

using independent t-tests or Mann–Whitney U tests, depending on data distribution.
Effect sizes (Cohen's d) were computed to determine the magnitude of the intervention effect, with values interpreted as small (0.2), medium (0.5), and large (0.8). Statistical significance was set at $p < 0.05$. Additionally, an analysis of covariance (ANCOVA) was performed to control for potential differences in baseline scores and demographic variables.

RESULTS

Demographic Characteristics

Table 2. presents the demographic characteristics of the study participants. There were no significant differences between the experimental and control groups in terms of age, gender distribution, or parental education levels, indicating successful randomization.

Table 2. Demographic Characteristics of Study Participants

Characteristic	*Experimental Group (n=30)*	*Control Group (n=30)*	*p-value*
Age (months)	54.3 ± 6.2	55.1 ± 5.8	0.61
Gender			0.79
Male	16 (53.3%)	15 (50.0%)	
Female	14 (46.7%)	15 (50.0%)	
Parental Education			0.68
High school	12 (40.0%)	14 (46.7%)	
College	18 (60.0%)	16 (53.3%)	

Pre-test and Post-test Comparisons

Table 3. Pre-test and Post-test Scores on Fine Motor Assessments

Assessment	*Group*	*Pre-test (Mean ± SD)*	*Post-test (Mean ± SD)*	*Mean Difference*	*p-value*	*Effect Size (d)*
PDMS-2 Grasping	Experimental	42.3 ± 5.1	48.7 ± 4.8	6.4	<0.001	1.28
	Control	43.1 ± 4.9	45.9 ± 5.2	2.8	0.003	0.55
PDMS-2 Visual-Motor Integration	Experimental	135.6 ± 12.3	148.9 ± 11.7	13.3	<0.001	1.10
	Control	136.2 ± 11.8	142.1 ± 12.4	5.9	0.002	0.49
Beery VMI	Experimental	89.4 ± 8.7	97.8 ± 7.9	8.4	<0.001	1.01
	Control	90.1 ± 8.3	93.5 ± 8.5	3.4	0.008	0.41

Between-Group Comparisons

To examine the differential effects of the interventions, between-group comparisons were conducted using independent t-tests on the change scores (post-test minus pre-test). The results are presented in Table 4.

Table 4. Between-Group Comparisons of Change Scores

Assessment	*Experimental Group Change (Mean ± SD)*	*Control Group Change (Mean ± SD)*	*Mean Difference*	*p-value*	*Effect Size (d)*
PDMS-2 Grasping	6.4 ± 2.1	2.8 ± 1.9	3.6	<0.001	1.79
PDMS-2 Visual-Motor Integration	13.3 ± 4.7	5.9 ± 3.8	7.4	<0.001	1.72
Beery VMI	8.4 ± 3.2	3.4 ± 2.5	5.0	<0.001	1.73

The experimental group showed significantly greater improvements than the control group across all measures ($p<0.001$). The effect sizes for these between-group differences were large ($d>1.7$), indicating a substantial impact of the digitally-integrated coloring tasks on fine motor development.

ANCOVA Results

ANCOVA analyses controlling for baseline scores confirmed the significant effect of the intervention on all outcome measures ($p<0.001$). These results remained significant after controlling for demographic variables, suggesting that the observed effects were attributable to the intervention rather than to other factors.

DISCUSSION

This study investigated the impact of digitally-integrated coloring tasks compared to traditional paper-based coloring activities on the development of fine motor skills in preschool children. The findings revealed that while both approaches led to improvements in fine motor proficiency, the digitally-integrated coloring tasks resulted in significantly greater gains across all measured domains of fine motor development (Harsismanto et al., 2021).

The superior performance of the experimental group in the grasping subtest of the PDMS-2 suggests that the digital interface, particularly when used with a stylus, may provide unique opportunities for developing precision grip and finger control. This finding aligns with research by Lin et al., who found positive effects of tablet use on fine motor development in children aged 4-6 years (Lin et al., 2017). The requirement to manipulate the stylus with appropriate pressure and precision on the tablet surface appears to facilitate the development of grasping skills in ways that complement traditional coloring activities (Kirkorian et al., 2019).

The experimental group also demonstrated more substantial improvements in visual-motor integration, as measured by

both the PDMS-2 and Beery VMI assessments. This finding is particularly noteworthy as visual-motor integration represents a complex interplay between visual perception and motor execution, skills that are fundamental to academic tasks such as writing and drawing. The digital interface may enhance visual-motor integration through features such as pinch-and-zoom functionality, which requires children to coordinate visual attention with fine motor movements in novel ways (Fitzgibbons, 2022; John & Renumol, 2018). Additionally, the immediate visual feedback provided by digital applications may facilitate the refinement of motor planning and execution.

These results contribute to the ongoing discourse regarding the role of technology in early childhood education. While concerns have been raised about excessive screen time and the potential displacement of hands-on learning experiences, this study suggests that thoughtfully designed digital activities can effectively support specific developmental domains. Rather than viewing digital and traditional approaches as mutually exclusive, educators may benefit from considering how these tools can be integrated to provide complementary learning experiences (Liu & Moeller, 2019; Näykki et al., 2019).

The findings of this study are consistent with the research of Price and colleagues, who found that tablet use was associated with improvements in the speed and consistency of drawing movements (Guelman et al., 2009; Price et al., 2015). However, the current study extends this work by specifically examining the effects of a structured intervention using digitally-integrated coloring tasks, rather than general tablet use. This distinction is important, as it suggests that the benefits observed may be attributable to specific features of the digital coloring applications rather than to tablet use in general (Axford et al., 2018).

It is worth noting that while the experimental group showed greater improvements, the control group also demonstrated significant gains in fine motor skills (Stembridge, 2024). This finding underscores the value of traditional coloring activities in supporting fine motor development, consistent with established practices in early childhood education (Palomino et al., 2025). The continued effectiveness of traditional approaches suggests that digital tools should be viewed as supplements to, rather than replacements for, hands-on learning experiences.

Several limitations of this study should be acknowledged. First, the intervention period of 8 weeks, while sufficient to detect significant effects, may not capture the long-term impact of digitally-integrated coloring tasks on fine motor development. Future research should consider longer intervention periods and follow-up assessments to examine the sustainability of the observed effects. Second, the study focused specifically on coloring activities and may not generalize to other fine motor tasks or digital applications. Additional research is needed to explore how different types of digital activities affect various aspects of fine motor development.

Furthermore, the study did not examine potential moderating factors such as prior experience with digital devices or individual differences in learning styles. These factors may influence how children respond to digitally-integrated learning experiences and should be considered in future research. Finally, while the study controlled for demographic variables, other factors such as home environment and parental involvement in fine motor activities were not assessed and may have influenced the results.

CONCLUSION

This study provides evidence that digitally-integrated coloring tasks can effectively enhance fine motor proficiencies in early childhood education settings, with particular benefits for visual-motor integration and grasping skills. The findings suggest that digital tools, when thoughtfully implemented, can serve as valuable supplements to traditional approaches in supporting children's fine motor development.

The significantly greater improvements observed in the experimental group highlight the potential of digital interfaces to provide unique opportunities for developing specific aspects of fine motor control. Features such as stylus use, pinch-and-zoom functionality, and immediate visual feedback may contribute to these enhanced outcomes by engaging children in novel forms of fine motor practice.

These results have important implications for early childhood education practice. Rather than viewing digital and traditional approaches as competing alternatives, educators may benefit from integrating both modalities to provide a comprehensive approach to fine motor development. By leveraging the strengths of each approach, educators can create learning environments that support diverse learning needs and prepare children for both traditional and digital literacy demands.

Future research should explore the long-term effects of digitally-integrated fine motor activities, examine potential moderating factors such as prior digital experience, and investigate how specific features of digital applications contribute to fine motor development. Additionally, research examining how digital and traditional approaches can be optimally integrated within early childhood curricula would provide valuable guidance for educational practice.

In conclusion, this study contributes to our understanding of how digital technologies can support early childhood development when implemented with clear developmental goals and appropriate pedagogical approaches. As digital tools continue to evolve and become more prevalent in educational settings, research-based guidance on their effective integration will be increasingly important for supporting children's holistic development.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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