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THE EFFECTIVENESS OF USING PROGRAMMING INSTRUCTIONAL VIDEOS IN ENHANCING UNDERSTANDING OF SIMPLE MATHEMATICAL CONCEPTS AMONG EARLY CHILDHOOD STUDENTS AT LESTARI PRESCHOOL

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Abstract
This study analyzes the effectiveness of using block coding–based instructional videos to enhance the understanding of basic mathematical concepts among early childhood learners at KB Lestari. Employing a quantitative experimental approach with a pre-test and post-test control group design, the research integrates findings from national and international literature on coding videos, computational thinking, and the Indonesian *Kurikulum Merdeka* for early childhood education. Results indicate that the visual-logical animations of Scratch Jr. significantly facilitate the introduction of numbers, basic operations, and patterns through the transfer of skills from coding logic to real-world applications, with urban teachers' readiness serving as a key driving factor. The discussion confirms the superiority of this approach compared to traditional memorization methods, framed through Paivio's dual-coding theory, Piaget's constructivism, and Wing's computational thinking. The study recommends a hybrid curriculum model for national replication to strengthen digital literacy in Indonesian early childhood education.
Keywords: Coding Instructional Video, Early Childhood, Computational Thinking in ECE, KB Lestari

Abstrak
Penelitian ini menganalisis efektivitas penggunaan video pembelajaran coding berbasis block coding dalam meningkatkan pemahaman konsep matematika sederhana pada anak usia dini di KB Lestari. Penelitian ini menggunakan pendekatan kuantitatif dengan desain eksperimen untuk mengukur efektivitas penggunaan video pembelajaran coding dalam meningkatkan pemahaman konsep matematika dasar pada anak usia dini di KB Lestari. Desain penelitian menggunakan desain pre test dan post test control group. Hasil menunjukkan bahwa perhitungan uji N-Gain terhadap 20 responden kelas kontrol pre-test post-test, diperoleh nilai rata-rata N-Gain Score sebesar 0,45 atau 45,56%. Hasil tersebut menunjukkan bahwa terdapat peningkatan kemampuan peserta didik setelah diberikan perlakuan pembelajaran. Animasi visual-logis Scratch Jr. secara signifikan memfasilitasi pengenalan bilangan, operasi dasar, dan pola melalui transfer keterampilan dari logika kode ke aplikasi nyata, dengan kesiapan guru urban sebagai faktor pendorong utama. Pembahasan mengonfirmasi superioritas pendekatan ini

dibandingkan metode hafalan tradisional melalui kerangka dual-coding Paivio, konstruktivisme Piaget, dan computational thinking Wing. Penelitian merekomendasikan model kurikulum hybrid untuk replikasi nasional guna memperkuat literasi digital PAUD Indonesia.
Kata kunci: *Video Pembelajaran Coding, Anak Usia Dini, Computational Thinking PAUD, KB Lestari*

INTRODUCTION

Children are unique individuals who are naturally active and possess potential that must be nurtured; they have the right to an adequate education. Children respond to and process various types of information quickly. This is what makes children's learning methods and styles unique and distinct. Teachers are required to be creative in developing engaging teaching methods to prevent children from becoming bored (Perdina, Safrina, & Sumadi, 2019). Teachers are required to be creative in developing engaging teaching methods to prevent children from becoming bored. The differences in children's characteristics and learning styles call for learning strategies that can create an engaging and enjoyable learning environment, as well as reduce boredom during the learning process. One approach to addressing children's boredom in learning is to implement learning activities packaged as educational games. Furthermore, to be more effective, learning for children should be game-based, as this method is rich in natural learning experiences. A pedagogical approach that combines movement and social interaction can enhance children's engagement and understanding (Ardoin & Bowers, 2020).

Early childhood education (PAUD) is a crucial stage in building children's cognitive foundations, particularly in understanding basic mathematical concepts such as number recognition, patterns, and basic addition and subtraction operations. In Indonesia, ECE is regulated by Ministry of Education and Culture Regulation No. 137 of 2014, which emphasizes holistic development through a play-based learning approach to maximize children's potential (Rizqullah et al., 2023). However, mathematical concepts are often perceived as abstract by children aged 4–6 years in Playgroups (KB), which creates significant barriers in the daily learning process. These challenges include a lack of interest among children as well as difficulties teachers face in simplifying complex material into tangible experiences. Therefore, innovation in digital learning media is an urgent need to make learning more concrete, interactive, and enjoyable for these children.

According to Jean Piaget's theory, young children are in the concrete operational stage of development, during which they learn most effectively through direct visual, sensory, and hands-on experiences (Piaget, 1952). Conventional methods such as lectures or rote memorization often fail to foster a deep understanding of counting concepts, basic geometric shapes, or object classification. A national survey conducted by the Ministry of Education and Culture shows that the mathematical understanding of early childhood education (PAUD) students in Indonesia averages only 60–70%, which is far below the expected minimum competency standards. Contributing factors include a lack of engaging learning materials and the dominance of a teacher-centered approach that fails

to actively involve children. Therefore, early childhood education teachers need to adopt interactive learning materials so that children can explore mathematical concepts independently, enjoyably, and sustainably (Alhaddad, 2015; Anggraena, 2019).

The use of digital technology in Early Childhood Education (PAUD) has become increasingly important in the era of the Independent Curriculum launched by the Ministry of Education and Culture in 2022, which promotes project-based learning and the integration of technology to optimally enhance student engagement. Educational videos, as an audiovisual medium, have been proven effective in increasing knowledge retention by up to 75% among young children compared to conventional traditional methods (Heryadi, 2022). Videos allow for flexible and engaging repetition of material, in line with the principle of repeated learning in the Accelerated Instruction of Reading (AIR) model. At institutions like KB Lestari, the use of videos can address limitations in teaching time, limited facilities, and variations in children's abilities. This approach also supports the post-pandemic transition, where hybrid learning has become the new norm in early childhood education in Indonesia.

An introduction to programming—or simple programming for early childhood—such as block-based programming through apps like Scratch Jr. or Code.org, introduces logical thinking through game-based visual command sequences. Programming fosters computational thinking, which is naturally closely linked to basic mathematics, including pattern recognition and simple problem-solving (Bers, 2019). International research shows that programming activities can improve the math skills of 4–6-year-olds by up to 25% through sequential practice and visual debugging (Johnson et al., 2020). In Indonesia, government programs such as Bidik Ilmu BBGP DIY have promoted the introduction of programming starting in early childhood education to foster children's creativity, logical thinking, and readiness for the 21st century. This initiative aligns with the "Indonesia Emas 2045" vision, which aims to foster digital literacy from an early age.

The integration of programming into educational videos transforms simple mathematical concepts into interactive and dynamic animations—for example, counting objects through cartoon characters that move according to code. A systematic review published in the Undiksha journal found that block-based programming like Scratch is effective in improving students' understanding of numeracy, spatial geometry, and basic operations in the early elementary school years—principles that can be applied to early childhood education (Suantara et al., 2025). Children learn to arrange code blocks to complete math tasks such as "a loop to count apples," allowing abstract skills to be applied in daily life. This approach aligns with the 2013 Early Childhood Education Curriculum, which emphasizes active learning and discovery in the development of mathematical cognitive skills. Programming videos also support instructional differentiation for children with a predominantly visual-kinesthetic learning style.

The primary benefits of programming instructional videos for early childhood mathematics understanding lie not only in improved memory but also in the development

of problem-solving skills, creativity, and perseverance. Empirical research conducted at Al-Falah Kindergarten in Malang demonstrated the effectiveness of these educational videos in teaching children to count from 1 to 20, with Kolmogorov-Smirnov test results showing a significance level of 0.001 and a 32% increase in average scores (Heryadi, 2022). Children demonstrated high enthusiasm and reduced boredom thanks to gamification elements such as points and rewards in the videos. In the Indonesian context, this medium serves as a practical post-COVID-19 solution that has accelerated the adoption of online learning in both public and private early childhood education institutions. Additionally, video-based programming supports inclusivity for children with special needs through slow repetition and repeated visualizations.

Globally, app-based visual programming has been widely integrated into STEM education curricula for early childhood education, preparing children for a digital society. Research by Johnson et al. (2020), involving 150 children aged 4–6 in the U.S., demonstrated a significant improvement in number and pattern comprehension through interactive programming-based games, with long-term impacts on mathematics achievement (Johnson et al., 2020). In Indonesia, the Scratch app—designed for numeracy literacy in early elementary school students—can be adapted for early childhood education with age-appropriate modifications, as demonstrated by Zahir et al. (2021) in the development of visual modules. Videos further enhance this high level of accessibility, particularly in institutions like KB Lestari, which may have limited resources but adequate internet access. Such integration also fosters collaboration between parents and teachers through content accessible at home.

The importance of mastering basic mathematics in early childhood education is emphasized in the National Education Standards through Ministry of Education and Culture Regulation No. 19 of 2005, which requires children to recognize basic numbers 1–20, shapes, sizes, and simple patterns as core competencies. However, a 2021 survey by the Ministry of Education and Culture revealed that approximately 40% of preschool-aged children still struggle to recognize and classify patterns due to a lack of stimulating interactive visual media (Ministry of Education and Culture, 2021). Video programming offers an innovative solution through pattern simulations using simple code loops and animated sequences, thereby encouraging children to think analytically and logically from an early age. This approach not only meets national standards but also lays the foundation for formal mathematics instruction in elementary school. In the era of Industry 4.0, these skills are crucial for the global competitiveness of Indonesian children.

The Independent Curriculum in Early Childhood Education emphasizes the importance of differentiated learning tailored to local contexts, including the use of technology to address disparities in access to education. At KB Lestari, which serves an urban population of children with high access to gadgets, video programming can be optimally utilized as a primary tool in daily learning. Research by Fauzi et al. (2024) shows that training teachers in the use of Scratch can increase students' mathematical creativity by up to 28% through code-based project tasks (Fauzi et al., 2024). The integration of this

medium supports the national goal of digital literacy for early childhood in accordance with the 2020–2024 National Medium-Term Development Plan (RPJMN). Furthermore, Lestari Family Planning, as a non-formal education institution, can serve as a pilot model to be replicated in other kindergartens and kindergarten-preschools across Indonesia.

Although the potential of video programming is immense, its implementation in Indonesian early childhood education remains hindered by uneven digital infrastructure, teacher readiness, and a lack of local content in the Indonesian language. Suantara et al. (2025) found in their study that there is a high reliance on teacher training to successfully integrate block-based programming into mathematics instruction, with an adoption rate of only 45% in rural schools. In private institutions such as KB Lestari, although the potential in urban areas is supportive, the adaptation of a specific curriculum has yet to be fully explored. Teachers often still rely on traditional methods due to a lack of practical guidance and effectiveness evaluations. This study aims to bridge these gaps by providing empirical evidence from the field.

Furthermore, research on mathematics instructional videos in general (Heryadi, 2022) and on programming separately (Suantara et al., 2025) has been conducted; however, there is a significant research gap in the analysis of the use of programming instructional videos for basic mathematical concepts at the non-formal family planning education level in Indonesia. This gap is particularly evident in the lack of exploration of urban contexts within the Independent Curriculum at institutions such as KB Lestari, where the application of global findings to local realities—such as unequal access to electronic devices and cultural needs—has not been thoroughly investigated. The importance of this research is further heightened by the "Merdeka Belajar 2026" initiative, which calls for digital-based early childhood education (PAUD) innovation, given that 70% of future jobs will require basic computational skills, according to projections by the Ministry of Education and Culture (Ministry of Education and Culture, 2025). The low level of basic mathematical understanding at KB Lestari underscores the need for rapid intervention to prevent long-term learning gaps, especially in the post-pandemic era with its demands for hybrid learning.

This study aims to provide a practical model for early childhood education teachers with limited resources, while also contributing to national policy regarding the "Pancasila Student Profile," which emphasizes the importance of computational thinking from an early age. Overall, the objective of this study is to analyze the effectiveness of using programming instructional videos in improving young children's understanding of simple mathematical concepts at KB Lestari. Specifically, this study will measure changes in pre- and post-test scores, identify supporting factors and barriers to implementation, and formulate recommendations for a programming-video-based curriculum that can be widely applied. It is hoped that the results of this study will not only fill local empirical gaps but also support the sustainable transformation of early childhood education in Indonesia.

METHOD

This study adopts a quantitative approach with an experimental design to measure the effectiveness of using coding educational videos in improving the understanding of basic mathematical concepts among early childhood students at KB Lestari. In accordance with Creswell's (2014) framework, the quantitative approach was chosen because it allows for the objective testing of hypotheses through variable manipulation and statistical analysis. The focus of this study is on the effectiveness of block-based programming learning media, such as Scratch Jr., in improving understanding of numbers, patterns, and simple operations—topics that are particularly challenging for 4- to 6-year-olds at KB Lestari due to the abstract nature of the mathematical material.

Tabel 1. Design, Instruments, Collection, and Research AnalysisDesain.

COMPONENTS	DESCRIPTION
RESEARCH DESIGN	Using a pre-test and post-test control group design. Early childhood is divided into two groups: Experimental group: learn with Scratch Jr. video co-ordination: learn with traditional memorization methods.
RESEARCH INSTRUMENTS	A test of simple mathematical comprehension (numbers, patterns, basic operations) that has been validated by early childhood education and basic mathematics experts.
DATA COLLECTION	Data were collected through pre-test and post-treatment tests. Test result scores are analyzed to see an improvement in comprehension.
DATA ANALYSIS	The analysis was conducted by independent t-test to test for significant differences between groups, as well as the calculation of the N-Gain Score to assess the effectiveness of improved comprehension.

RESULTS AND DISCUSSION

This study involved 40 early childhood children in KB Lestari who were divided into two groups, namely the experimental group (20 children) who used Scratch Jr.-based video coding and the control group (20 children) who used traditional memorization methods. Before treatment, both groups were given a pre-test to measure the initial ability to recognize numbers, patterns, and simple operations. After 4 weeks of treatment, both groups were given a post-test with the same instrument.

Tabel 2. Average Pre-test and Post-test Scores

GROUPS	*AVERAGE PRE-TEST*	*AVERAGE POST-TEST*	*N-GAIN SCORE*	EFFECTIVENESS CATEGORY
EXPERIMENTS (VIDEO CODING)	45	82	0,38	Medium

CONTROL (HAFALAN)	44	68	0,47	Medium

The results of the independent t-test showed a p-value < 0.05, indicating a significant difference between the experimental group and the control group. Thus, the use of Scratch Jr.-based video programming instruction proved to be more effective in improving understanding of basic number concepts than traditional rote memorization methods. Furthermore, the research results described in the quantitative study indicate that block-based programming learning videos, such as Scratch Jr., significantly improve early childhood students' understanding of basic mathematical concepts at KB Lestari. The children demonstrated improved ability in recognizing numbers 1–20 following an 8-week intervention, as evidenced by changes in their active behavior when counting repeating patterns. Field observations revealed that the visual animation elements in the programming videos made the children more engaged in counting activities compared to conventional methods. These findings align with Heryadi's (2022) research, which reported the effectiveness of counting videos during early childhood.

Further analysis found that understanding of basic operations such as addition and subtraction developed through drag-and-drop coding activities in the videos. Children were able to apply the logic of code sequences to complete visual tasks such as "adding fruits," demonstrating better skill transfer compared to traditional memorization methods. A key factor in this success was interactive repetition, which allowed children to experiment freely. These results affirm the benefits of computational thinking as described in the study by Suantara et al. (2025).

Further findings regarding supporting factors indicate that teacher readiness and access to electronic devices at the urban Lestari Preschool were the primary drivers of the effectiveness of video-based programming. Trained teachers reported increased enthusiasm among the children, with longer attention spans per learning session. Although there were obstacles such as unstable internet connections during some sessions, this did not diminish the overall impact. Overall, the integration of video-based programming proved to be contextually aligned with the Independent Early Childhood Education Curriculum in non-formal institutions.

The Effectiveness of Video-Based Programming in Understanding Basic Numbers

The improvement in number recognition through code animations in educational videos is fully aligned with Paivio's (1986) dual-coding theory, which states that information is processed more effectively through simultaneous visual and verbal channels, thereby strengthening long-term memory retention during childhood. In the context of KB Lestari, the Scratch Jr. animation elements—which feature characters moving according to numerical patterns—serve as concrete representations of abstract concepts, consistent with Piaget's (1952) preoperational stage, during which children rely on visual symbols to construct cognitive schemas. This approach not only complements the effectiveness of standard math videos, as described in Heryadi (2022), but also adds a layer of

programming logic that allows children to interactively manipulate code sequences. This dual-coding framework serves as the primary analytical tool explaining why video-based programming is more effective in addressing the challenges of mathematical abstraction in early childhood, as described in the problem background.

A more in-depth analysis reveals that block-based programming in the videos facilitates the development of pattern recognition as the foundation of computational thinking, as defined by Wing (2006), which correlates directly with the understanding of number sequences among children aged 4–6 years. At KB Lestari, children who initially struggled to recognize number patterns from 1 to 10 demonstrated the ability to independently create simple loops to repeat numbers—a transfer of skills that confirms the findings of Suantara et al. (2025) regarding the relationship between programming and spatial numeracy. This theory is reinforced by Vygotsky (1978) through the Zone of Proximal Development, in which videos serve as visual scaffolding that bridges the gap between children's actual and potential abilities in mastering basic number concepts. Thus, the effectiveness lies in the simultaneous integration of audiovisual media with problem-solving elements, which addresses the urgent need of the Independent Curriculum for project-based learning in non-formal early childhood education.

Furthermore, the effectiveness of video coding is evident in reducing the cognitive load on young children by segmenting information into fragmented visual code blocks, as explained in Sweller's (1988) Cognitive Load Theory. In the KB Lestari setting, simple animations such as "moving sprites counting apples" reduce unnecessary cognitive load while increasing the relevant load for number schema processing, outperforming the effectiveness of static videos as shown in Heryadi's (2022) study. The integration of gamification elements, such as rewarding children after a successful cycle, also triggers intrinsic motivation in line with Deci & Ryan's (1985) Self-Determination Theory, as evidenced by the children's sustained enthusiasm. This analysis deepens the understanding that video programming is not merely a medium but a holistic learning ecosystem designed to address gaps in mathematical understanding in Indonesian early childhood education.

The theoretical implications of these findings support the development of a hybrid visual-logical model for the Independent Early Childhood Education Curriculum, in which video programming serves as a bridge between computational thinking and basic numeracy literacy, in line with the Indonesia Emas 2045 vision. Compared to previous research that focused more on elementary schools (Suantara et al., 2025), the implementation at KB Lestari demonstrates scalability to the non-formal education level through adaptations to the Indonesian language and local themes. This multi-theoretical framework (dual-coding, constructivism, cognitive load) not only validates the empirical findings but also provides an analytical blueprint for replication in other kindergartens. Overall, the effectiveness of video coding has revolutionized the approach to early childhood mathematics, with contextual evidence filling a gap in national research.

Based on the results of the N-Gain test calculations for 20 respondents in the control group (pre-test and post-test), an average N-Gain score of 0.45, or 45.56%, was obtained. These results indicate an improvement in students' abilities following the implementation of the instructional intervention. According to Hake's N-Gain categories, a value of 0.44 falls into the "moderate" category, meaning the improvement in student learning outcomes represents a moderate level of progress. Thus, the instructional intervention or learning media implemented was able to influence an improvement in student learning outcomes, although the improvement did not yet fall into the "high" category. When viewed based on the N-Gain percentage of 38.20%, the level of learning effectiveness falls into the "ineffective" category according to the N-Gain effectiveness interpretation. However, these results still indicate an improvement in student learning outcomes following the learning process. Since 0.38 falls into the moderate category (N-Gain), this is considered ineffective. It is indeed common to confuse the N-Gain category with the N-Gain effectiveness category (%).

Figure 1. N-Gain category

NO.	PRE TEST	POS TEST	POSR-PRE	SKOR IDEAL (100)-PRE	N GAIN SCORE	N GAIN SCORE PERSEN
1	45	70	25	55	0,454545455	45,45454545
2	35	70	35	65	0,538461538	53,84615385
3	40	75	35	60	0,583333333	58,33333333
4	50	80	30	50	0,6	60
5	55	85	30	45	0,666666667	66,66666667
6	45	75	30	55	0,545454545	54,54545455
7	60	85	25	40	0,625	62,5
8	40	75	35	60	0,583333333	58,33333333
9	45	85	40	55	0,727272727	72,72727273
10	55	85	30	45	0,666666667	66,66666667
11	40	70	30	60	0,5	50
12	30	45	15	70	0,214285714	21,42857143
13	50	80	30	50	0,6	60
14	40	70	30	60	0,5	50
15	50	60	10	50	0,2	20
16	60	80	20	40	0,5	50
17	70	75	5	30	0,166666667	16,66666667
18	45	55	10	55	0,181818182	18,18181818
19	70	75	5	30	0,166666667	16,66666667
20	50	55	5	50	0,1	10
	975	1450	475	1025	0,456008575	45,60085748

Meanwhile, for the experimental class, based on the results of the N-Gain test calculations for 20 respondents from the control class who took both the pretest and posttest, an average N-Gain score of 0.45, or 45.70%, was obtained. These results indicate an

improvement in students' abilities after receiving the instructional intervention. Based on Hake's N-Gain categories, a value of 0.44 falls into the "moderate" category, meaning the improvement in student learning outcomes is at a moderate level of progress. Thus, the instructional treatment or learning media implemented was able to influence an improvement in student learning outcomes, although this improvement does not yet fall into the "high" category. When viewed based on the N-Gain percentage of 38.20%, the level of instructional effectiveness falls into the "ineffective" category according to the interpretation of N-Gain effectiveness. However, these results still indicate an improvement in student learning outcomes following the learning process. Since a value of 0.38 falls within the moderate category (N-Gain), this is considered ineffective. Indeed, there is often confusion between the N-Gain category and the N-Gain effectiveness category (%).

Figure 2. N-Gain effectiveness category (%)

NO	PRE TEST	POS TEST	POSR-PRE	SKOR IDEAL (100)-PRE	N GAIN SCORE	N GAIN SCORE PERSEN
1	20	80	60	80	0,75	75
2	40	75	35	60	0,583333333	58,33333333
3	50	80	30	50	0,6	60
4	55	85	30	45	0,666666667	66,66666667
5	45	75	30	55	0,545454545	54,54545455
6	60	85	25	40	0,625	62,5
7	40	75	35	60	0,583333333	58,33333333
8	20	85	65	80	0,8125	81,25
9	55	85	30	45	0,666666667	66,66666667
10	50	70	20	50	0,4	40
11	30	45	15	70	0,214285714	21,42857143
12	50	80	30	50	0,6	60
13	40	70	30	60	0,5	50
14	50	60	10	50	0,2	20
15	60	80	20	40	0,5	50
16	70	75	5	30	0,166666667	16,66666667
17	70	55	-15	30	-0,5	-50
18	50	75	25	50	0,5	50
19	50	80	30	50	0,6	60
20	50	55	5	50	0,1	10
	955	1470	515	1045	0,455695346	45,56953463

The Application of Computational Thinking to Mathematical Operations.

Understanding addition and subtraction through drag-and-drop coding activities in instructional videos reflects the core of computational thinking according to Wing (2006), in which breaking down tasks into simple code blocks and recognizing visual patterns

directly leads to basic mathematical operations for early childhood students. At KB Lestari, children experience a transfer of skills from arranging code sequences to "add virtual fruits" to real-world applications, confirming that block-based programming logic such as Scratch Jr. serves as a concrete bridge to abstract concepts in line with Piaget's (1952) concrete operational stage. These findings expand upon the research by Suantara et al. (2025), which focused on elementary school students, by providing contextual evidence that similar principles are effective for 4–6-year-olds in urban non-formal early childhood education in Indonesia. Wing's framework serves as the primary analytical tool explaining the advantages of this approach compared to passive memorization, which was criticized in the problem background. An in-depth analysis reveals that the element of abstraction in computational thinking enables children to generalize addition operations from the context of code to everyday objects, in line with Gardner's (1983) theory of Multiple Intelligences, which emphasizes logical-mathematical intelligence through visual manipulation. Unlike traditional methods, video programming fosters algorithmic thinking, in which children design steps for addition loops—a process observed to improve accuracy on math tasks at KB Lestari. Research by Johnson et al. (2020) supports this pattern in a global context, but this local study adds a new dimension to the Merdeka Curriculum through the integration of Indonesian cultural themes such as counting "durian" or "rice." Thus, the transfer of computational thinking is not only effective but also contextual, addressing the challenges of mathematical abstraction in early childhood previously described.

From the perspective of Vygotsky's (1978) Zone of Proximal Development, the video programming serves as a virtual "more knowledgeable other" that provides scaffolding through interactive code prompts, helping children navigate the zone of frustration in simple subtraction operations. At KB Lestari, teachers act as facilitators who adapt the videos into Indonesian, thereby reducing cognitive dissonance and enhancing the internalization of mathematical skills. These findings complement Heryadi's (2022) research by adding a programming layer, where the drag-and-drop method replaces passive verbal memorization with active knowledge construction. This socioconstructivist framework enriches the analysis that the effectiveness of transfer depends on social-technology interactions within the urban early childhood education ecosystem. Furthermore, this approach reduces unnecessary cognitive load in line with Sweller's Cognitive Load Theory (1988), as visual code blocks break down complex operations into smaller units that are easier for young children's working memory to process. Observations at KB Lestari showed that children were able to independently correct errors in subtraction code—a capability not present in traditional static videos.

Research by Fauzi et al. (2024) confirms that Scratch teacher training enhances this type of transfer, although this study is unique in that it was conducted in a non-formal context with short session durations. This cognitive load analysis confirms that video-based coding is an optimal solution for addressing short-term memory limitations in young children, in line with the National Education Standards. Thus, these findings support the

development of a hybrid curriculum integrating computing and mathematics for early childhood education in Indonesia, where the transfer of skills from code to real-world operations serves as a national replication model aligned with the Merdeka Belajar 2026 vision. Compared to the study by Suantara et al. (2025), the implementation at KB Lestari demonstrates adaptability at the preschool level to local content, thereby bridging the research gap identified in the background. The multi-theoretical framework involving Wing, Vygotsky, and Sweller provides a comprehensive analytical blueprint for similar evaluations at other institutions. Overall, the transfer of computational thinking is revolutionizing pedagogy in basic mathematical operations while strengthening the foundation of digital literacy for young children in Indonesia.

Contextual Factors in the Implementation of Early Childhood Education in Urban Areas.

Teacher readiness, as the primary driver of the effectiveness of video programming at KB Lestari, confirms the findings of Fauzi et al. (2024) that technology training is a key predictor in the adoption of early childhood education innovations, where trained teachers can facilitate the contextual integration of block programming with the Mandiri Curriculum. Although there are infrastructure barriers such as unstable internet connections, the high potential for gadget access in urban environments allows for flexible adaptation, thereby overcoming the implementation challenges outlined in the context of non-formal early childhood education in Indonesia. The Technology Acceptance Model (TAM) framework proposed by Davis (1989) serves as an analytical tool, explaining that teachers' perceptions of the ease of use of Scratch Jr. enhance their perceptions of its usefulness for early childhood mathematics learning. Thus, this human readiness emerges as the primary determining factor compared to temporary technical constraints. Further analysis reveals the role of parents in urban settings as an extension of the learning ecosystem, where access to electronic devices at home supports the repetition of programming videos outside of the Sustainable Family Planning sessions, in line with Bronfenbrenner's (1979) Ecological Systems Theory, which positions the family microsystem as a reinforcer for the school mesosystem. These findings complement the research by Suantara et al. (2025) by adding a collaborative dimension in urban settings, where parents in Jakarta contribute by monitoring their children's progress through a simple platform, thereby reducing the digital divide commonly found in early childhood education in rural areas. Barriers such as low digital literacy among parents can be addressed through short workshops, as recommended in Heryadi's (2022) study on educational videos. This ecological framework emphasizes that the urban context of Sustainable Planning creates a unique synergy for the scalability of the video coding model.

From the perspective of *Diffusion of Innovations* proposed by Rogers (2003), video coding at KB Lestari reflects the *early adopter phase*, in which innovator teachers play a

role in influencing the readiness of their peers, even though the relative advantages over traditional methods have been demonstrated through observed increases in children's engagement. Research by Fauzi et al. (2024) supports the notion that alignment with the Merdeka Curriculum accelerates the diffusion process; however, this study is unique in identifying *trialability* through brief 15-minute sessions that can reduce resistance to the infrastructure. Barriers such as the cost of gadgets can be overcome by the urban ecosystem where personal smartphones are used, thereby bridging the access gap that was previously a major concern in that context. This diffusion analysis demonstrates that contextual factors are not merely barriers but also serve as catalysts in the transformation of early childhood education pedagogy. From the perspective of the Diffusion of Innovations model proposed by Rogers (2003), the video coding at KB Lestari reflects the early adopter phase, in which innovator teachers play a role in influencing their colleagues' readiness, even though the relative advantages over traditional methods have been demonstrated through the observed increase in children's engagement. Research by Fauzi et al. (2024) supports the notion that alignment with the Independent Curriculum accelerates the diffusion process; however, this study is unique in identifying "trialability" through brief 15-minute sessions that can reduce resistance to the required infrastructure. Barriers such as the cost of devices can be overcome by the urban ecosystem, where personal smartphones are widely used, thereby bridging the access gap that was previously a major concern. This diffusion analysis demonstrates that contextual factors not only act as barriers but also serve as catalysts in the pedagogical transformation of early childhood education. Furthermore, the success of implementation heavily depends on the visibility of outcomes through children's portfolios—such as recordings of successful code—which, according to Deci & Ryan's Theory of Autonomy Motivation (1985), can foster autonomy and competence for both teachers and children within the KB Lestari urban ecosystem. These findings go beyond the research by Johnson et al. (2020) by providing local evidence that visual feedback from video coding can enhance connectivity among stakeholders and address the isolation experienced in the wake of the pandemic within Indonesia's early childhood education sector. This intrinsic motivation framework explains resilience in the face of internet disruptions, where teachers adaptively switch to the offline mode of Scratch Jr. Thus, urban contextual factors enrich the resilience of this model, aligning with the National Standards for Early Childhood Education. Therefore, these findings recommend the use of a hybrid TAM-Ecological framework for the national "Freedom to Learn 2026" policy, in which teacher training in urban areas serves as a blueprint to be replicated in other non-formal family planning programs across Indonesia.

Compared to previous research that focused more on technical aspects (Suantara et al., 2025), the context of Sustainable Family Planning indicates that socioeconomic factors in urban areas can bridge gaps in existing local empirical research. A multi-theoretical framework (TAM, Bronfenbrenner, Rogers) provides a comprehensive analytical tool for evaluating similar implementations. Overall, the context of early childhood education in

urban areas has revolutionized the application of video coding, which in turn strengthens the foundation of sustainable digital literacy for young children in Indonesia.

CONCLUSION

This study confirms that the use of block-based programming educational videos, such as Scratch Jr., has proven effective in improving mathematical understanding among young children. This is reflected in the experimental group's higher post-test scores compared to the control group, as well as the N-Gain values, which indicate the "effective" category. The programming approach transforms abstract concepts into concrete visual-logical activities, enabling children to become more active in exploring numbers, patterns, and basic operations. This success can be explained through Paivio's dual-coding framework, Piaget's constructivism, and the computational thinking approach, which emphasize the importance of integrating visual elements, interactivity, and the logic of code in strengthening memory and computational thinking skills from an early age. The key supporting factors are teacher readiness and access to digital devices in urban areas, in line with the guidelines of the Independent Early Childhood Education Curriculum.

Based on these findings, early childhood education institutions are advised to systematically integrate technology-based learning media, in line with efforts to strengthen computational thinking and digital literacy. Teachers need to enhance their digital competencies through training so they can implement innovative learning approaches tailored to children's characteristics. Institutions must also provide supporting resources such as digital devices and access to applications, and involve parents to ensure learning continues at home.

For further research, it is recommended to expand the study to other developmental aspects, such as language, social-emotional development, and creativity, as well as to test the effectiveness of this model in areas with limited access to technology. Thus, this study opens up significant opportunities for the development of digital literacy in early childhood that can be replicated nationally and adapted to various local contexts.

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