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Construction of Early Childhood Learning Experiences in Intelligent Digital Environments and Their Impact on Learning Independence

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A B S T R A C T

This study examines the construction of early childhood learning experiences in intelligent digital environments and their impact on children's learning independence. Using a mixed methods sequential explanatory design, the research was conducted in 12 Early Childhood Education (PAUD) units in Surabaya, Malang, and Sidoarjo, involving 96 children aged 4–6 years and 18 educators. Quantitative data indicate a 26.8% increase in children's learning independence, with the highest gains in learning initiative (29.7%) and self-regulation (25.4), categorized as moderate to high. Qualitative findings show that interactive, exploratory digital activities with direct feedback enhance children's intrinsic motivation and independence. The study concludes that well-designed pedagogical use of intelligent digital environments significantly strengthens early childhood learning independence.

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INTRODUCTION

Digital transformation in the education sector has brought fundamental changes to the way learning experiences are designed, implemented, and interpreted, including at the early childhood education (PAUD) level. The development of digital technology that is increasingly intelligent, adaptive, and interactive encourages the birth of a new learning environment that not only functions as a medium for delivering materials, but also as a learning ecosystem that is able to respond to the needs, interests, and characteristics of children's development in a more personalized manner (Luckin et al., 2022; OECD, 2021). In this context, the smart digital environment is one of the innovative approaches that has the potential to meaningfully enrich early childhood learning experiences.

Early childhood education has unique characteristics that place learning experiences as the main foundation for children's cognitive, social-emotional, and independent development. Learning independence in early childhood is understood as the ability of children to show initiative, regulate learning behaviors, make simple decisions, and maintain involvement in learning activities according to their developmental stage (Whitebread & Basilio, 2020). Strengthening learning independence from an early age is crucial because it is positively correlated with self-regulation skills, long-term learning readiness, and academic success at the next stage of education (Zimmerman, 2021).

As the use of digital technology in early childhood education increases, academic attention has begun to shift from just the issue of access and use of technology to the quality of pedagogical construction of digital learning experiences. Recent research shows that the use of digital technology in early childhood does not automatically have a positive impact, but rather depends heavily on how the learning experience is designed and mediated pedagogically (Edwards, 2021; Hirsh-Pasek et al., 2022). A smartly designed digital environment, with adaptive content, direct feedback, and exploratory activities can function as a digital scaffolding that supports the development of children's independent learning if it is aligned with the principles of early childhood development.

On the other hand, a number of studies have also identified challenges in the use of digital technology in early childhood education, such as the tendency to use it passively, the dominance of one-way instruction, and children's dependence on educators or digital devices themselves (Dong et al., 2020; Neumann, 2023). This condition shows that the existence of digital technology alone is not enough; It is necessary to construct a learning experience that places children as active subjects and educators as facilitators who are able to mediate children's interaction with the digital environment in a meaningful and contextual way.

In the Indonesian context, especially in urban areas, the use of digital learning media and applications in early childhood education is beginning to show an increase in line with the push for digital transformation of education and learning experiences during and after the COVID-19 pandemic (Ministry of Education, Culture, Research, and Technology, 2022). However, empirical

studies that specifically examine how early childhood learning experiences are constructed in a smart digital environment and its impact on children's learning independence are still relatively limited, especially at the level of pedagogical practice in early childhood education units.

Based on these gaps, this research is relevant and important to be conducted. This study focuses on the analysis of the construction of early childhood learning experiences in a smart digital environment and its impact on children's learning independence in PAUD units in several cities in East Java. By using a mixed methods approach, this study is expected to be able to provide a comprehensive overview of the effectiveness of the use of smart digital environments in supporting early childhood learning independence, as well as enriching the treasures of digital pedagogy studies based on the local context of Indonesia. The findings of this study are expected to be a reference for educators, early childhood education managers, and policy makers in designing and implementing digital learning that is pedagogical, sustainable, and development-oriented for children.

LITERATURE REVIEW

Smart Digital Environment in Early Childhood Education

An intelligent digital environment in education refers to a technology-based learning ecosystem that utilizes interactive, adaptive, and responsive systems to support the learning process of students. In the context of early childhood education, the smart digital environment not only serves as a medium for delivering content, but also as a means that is able to adapt the learning experience to the needs of children's development, interests, and abilities (Kucirkova & Sakr, 2020). This approach places technology as part of a pedagogically designed learning environment, not just an instructional tool.

Recent research shows that the use of digital technology in early childhood has positive potential if it is designed based on active interaction, exploration, and meaningful play. Digital learning environments that are adaptive allow children to learn through repetitive experiences, direct feedback, and opportunities to make simple decisions in the learning process (Papadakis, 2021). Thus, the quality of pedagogical design is a key factor in determining the effectiveness of the digital environment on child development.

Construction of Digital-Based Early Childhood Learning Experience

Early childhood learning experiences are built through interaction between children, educators, the environment, and learning media. In digital-based learning, the construction of the learning experience is inseparable from how activities are designed to encourage the child's active participation, curiosity, and emotional engagement (Bird & Edwards, 2022). Digital activities that are interactive and exploratory have proven to be more effective than the use of technology that is passive and oriented towards content consumption alone.

Recent studies confirm that meaningful digital learning experiences in early childhood must integrate the principles of play, guided exploration, and social support from educators and peers (Marsh et al., 2023; Anggraini et al., 2026). This

approach is in line with the theory of constructivism which emphasizes that children build knowledge through direct experience and reflection on the activities carried out. Therefore, digital technology needs to be positioned as a medium that enriches the learning experience, not replaces it.

Learning Independence in Early Childhood

Learning independence in early childhood includes the ability of children to show initiative, regulate learning behavior, persevere in completing tasks, and manage emotions during the learning process. This independence develops gradually and is strongly influenced by the learning environment that provides space for children to explore and make decisions (Pino-Pasternak & Whitebread, 2020). A learning environment that is too structured and dominated by educator instruction has the potential to hinder the development of children's learning independence.

Cutting-edge research shows that digital technology, when used appropriately, can support the strengthening of early childhood learning independence. Learning apps that provide activity options, graded difficulty levels, and immediate feedback can help children develop self-regulation and confidence in learning (Zhang et al., 2022). However, this effectiveness is highly dependent on the assistance of educators who are able to mediate children's interaction with technology in a reflective and developmental manner.

The Role of Educators in Digital Learning Mediation

Although the smart digital environment offers a wide range of potential, the role of educators remains a determining factor in the success of digital learning in early childhood. Educators play the role of facilitators who direct, accompany, and reflect on children's learning experiences in a digital environment (Fleer, 2021). Without proper pedagogical mediation, the use of digital technology risks lowering the quality of social interaction and shifting the focus of learning away from meaningful learning experiences.

Several studies confirm that the digital pedagogy competence of early childhood educators has a significant effect on the quality of children's learning experiences in a digital environment (Sundqvist et al., 2020). Educators who are able to integrate technology reflectively tend to create learning experiences that encourage children's independence, creativity, and active engagement. This shows that the development of a smart digital environment must go hand in hand with strengthening the capacity of educators.

Research Gaps

Although the study of digital technology in early childhood education continues to develop, most of the research still focuses on aspects of technology use or the perception of educators and parents. Empirical studies that specifically analyze the construction of early childhood learning experiences in an intelligent digital environment and their impact on children's learning independence, especially in the context of early childhood education units in Indonesia, are still limited. Therefore, this study seeks to fill these gaps by presenting quantitative

and qualitative data-based analysis that is contextual and relevant to early childhood education practices.

METHODOLOGY

The research method used in this study is a mixed methods approach with a sequential explanatory design, namely the collection and analysis of quantitative data at the initial stage which is then followed by the collection and analysis of qualitative data to deepen and explain the quantitative findings obtained. The selection of this design is based on the need to comprehensively understand the impact of the smart digital environment on early childhood learning independence while examining in depth the construction of learning experiences that take place in the context of digital learning (Creswell & Plano Clark, 2023; Tashakkori et al., 2021).

The research was carried out in 12 Early Childhood Education (PAUD) units located in the city of Surabaya, Malang City, and Sidoarjo Regency, East Java. The research location was chosen purposively with the criteria of early childhood education units that have utilized digital learning media and applications in learning activities. The research subjects consisted of 96 children aged 4–6 years old as the main subjects and 18 PAUD educators as supporting informants. Early childhood is chosen because it is in the early stages of independent learning development, while educators play an important role in mediating children's interaction with the digital environment and providing contextual information about applied pedagogical practices (Neumann & Neumann, 2022).

Quantitative data was collected using an early childhood learning independence assessment instrument developed based on three main indicators, namely self-regulation, learning initiative, and perseverance. The instrument is in the form of an observational assessment scale that is used during the learning process and filled in by researchers and educators. The observational approach was chosen because it was in accordance with the characteristics of early childhood who were not able to provide self-reports independently. The validity of the instrument was tested through expert judgment, while the internal reliability was tested using Cronbach's alpha coefficient to ensure measurement consistency (Howard et al., 2021).

Qualitative data was obtained through learning observation and semi-structured in-depth interviews with PAUD educators. Observations are focused on the construction pattern of digital learning experiences, the form of children's interaction with digital media and applications, and the role of educators in facilitating learning. The interview was conducted to explore educators' perceptions of changes in children's independent learning behavior, pedagogical strategies used, and challenges in utilizing the smart digital environment. A qualitative approach is used to capture meanings, processes, and contexts of learning that cannot be fully explained through quantitative data (Braun & Clarke, 2021).

Quantitative data analysis was carried out using descriptive and inferential statistics to identify changes in children's learning independence levels before

and after the use of an intelligent digital environment. The results of the analysis are presented in the form of a percentage increase in each aspect of learning independence and are categorized into low, medium, and high levels. Qualitative data were analyzed using thematic analysis through the stages of coding, theme grouping, and interpretation of meaning to identify patterns of learning experience construction and pedagogical factors that contribute to strengthening children's learning independence (Braun & Clarke, 2021). The integration of quantitative and qualitative data is carried out at the interpretation stage to produce findings that complement each other according to the principle of explanatory sequential design.

The validity of quantitative data is maintained through the validity and reliability test of the instrument, while the validity of qualitative data is guaranteed through triangulation of sources and techniques as well as member checking with educators as informants. This research was carried out by paying attention to the ethical principles of early childhood education research, including approval from early childhood education institutions and children's parents, protection of the confidentiality of the subject's identity, and the implementation of research that prioritizes the best interests of children (BERA, 2021; Lincoln & Guba, 2021).

RESEARCH RESULT

Increasing Early Childhood Learning Independence

The results of quantitative data analysis show that the use of a smart digital environment in early childhood learning has a positive impact on increasing children's learning independence. Measurements taken before and after the implementation of media-based learning and digital applications showed an increase in the average learning independence of children by 26.8%, which was in the medium to high category. This improvement indicates that children are starting to show better ability to manage their learning process independently, including initiating activities, maintaining engagement, and completing learning tasks. Increasing children's learning independence in detail in each aspect is presented in Table 1.

Table 1. Increasing Early Childhood Learning Independence

Aspects of Learning Independence	Initial Score (Mean)	Final Score (Mean)	Increase (%)	Categories
Self-regulation	2.31	2.90	25.4	Medium
Learning initiatives	2.18	2.83	29.7	Height
Perseverance in learning	2.25	2.80	24.3	Medium
Overall average	**2.25**	**2.85**	**26.8**	Medium–High

Source: Primary data of the study (processed by the author)

In detail, the highest increase was found in the aspect of learning initiatives with a percentage increase of 29.7%. Children are more likely to start learning activities without direct direction from educators, show interest in

exploring digital learning features, and choose activities according to their interests. The aspect of self-regulation also experienced a significant increase of 25.4%, shown through the child's ability to follow the flow of learning activities, manage attention focus, and control distractions during the learning process. Meanwhile, the aspect of learning persistence increased by 24.3%, which is reflected in the child's ability to survive completing tasks and try again when experiencing difficulties. These findings show that the smart digital environment contributes to strengthening various dimensions of early childhood learning independence.

Comparison of Increased Learning Independence by Location

Comparative analysis based on the location of PAUD units showed that there was a variation in increasing children's learning independence between research areas. Early childhood education units in the city of Surabaya showed an average increase in learning independence by 30.1%, being in the high category, while the early childhood education units in Malang City increased by 27.6% with the medium to high category. The PAUD unit in Sidoarjo Regency showed an increase of 22.4%, which is still in the medium category. This difference indicates that the quality of the use of the smart digital environment and the pedagogical strategies applied in each PAUD unit affect the level of strengthening children's learning independence. The difference in increasing learning independence between regions can be seen in Table 2.

Table 2. Comparison of Increased Learning Independence by Location

Early Childhood Education Location	Number of Children	Average Increase (%)	Categories
Surabaya	36	30.1	Height
Malang	32	27.6	Medium–High
Sidoarjo	28	22.4	Medium

Source: Primary data of the study (processed by the author)

The results of observations show that PAUD units with higher increases tend to implement digital activities that are more interactive and exploratory, as well as provide a wider space for children to make decisions during the learning process. On the other hand, PAUD units with lower increases showed a tendency to use digital media that was still instructional and limited to material delivery. These findings emphasize that the quality of digital learning experience construction is a key factor in increasing children's learning independence.

The Relationship Between Aspects of Learning Independence

The results of the correlational analysis showed a strong positive relationship between learning initiative and self-regulation ($r = 0.62$), as well as a moderate positive relationship between self-regulation and learning perseverance ($r = 0.54$). In addition, the relationship between learning initiative

and perseverance was also in the moderate category (r = 0.58). These findings show that the increase in learning independence in early childhood is multidimensional and interrelated between its aspects. Children who show high learning initiative tend to have better self-regulation and perseverance in completing learning activities.

Table 3. Correlation Between Aspects of Learning Independence

Variable	Self-Regulation	Learning Initiative	Perseverance
Self-regulation	1.00	0.62	0.54
Learning initiatives	0.62	1.00	0.58
Perseverance in learning	0.54	0.58	1.00

Source: Primary data of the study (processed by the author)

Remark: r > 0.50 indicates moderate to strong relationship.

This inter-aspect relationship indicates that the intelligent digital environment not only affects one dimension of learning independence separately, but contributes to the holistic development of children's learning independence. In other words, strengthening one aspect of learning independence through the right digital experience has the potential to encourage the development of other aspects simultaneously.

Qualitative Findings on the Construction of Digital Learning Experiences

The results of qualitative data analysis show that children's learning experiences in an intelligent digital environment are constructed through interactive, exploratory, and game-based learning activities, with the support of direct feedback from digital media. Children are actively involved in trying out various learning features, exploring activity options, and reflecting on the results obtained through the responses provided by the learning application. This learning pattern encourages children to play an active role in the learning process and strengthens confidence in completing tasks independently. An educator said that "*now children are more daring to try on their own and are not afraid of making mistakes because they immediately get a response from the application*" (G-Sby-03).

Changes in children's learning behavior are also clearly seen in the child's ability to make simple decisions during the digital learning process, such as choosing a sequence of activities, determining the level of difficulty, and setting the learning tempo according to his ability. Children tend to try to complete activities independently before asking for help from educators. This is reinforced by the statement of educators who reveal that "*children do not immediately ask the teacher, but try first, then ask for help if they really have difficulties*" (G-Mlg-02). These findings suggest that the construction of an adaptive digital learning experience provides space for children to develop initiative and self-regulation gradually.

In addition, the results of the interviews showed a decrease in children's dependence on direct verbal instruction from educators. Children become more independent in understanding the flow of digital learning activities and completing tasks without intensive assistance. An educator from Sidoarjo

Regency stated that "*the children already understand the steps of the activity, so we don't need to give instructions repeatedly*" (G-Sda-01). Nonetheless, educators emphasized that their role remains crucial in ensuring the quality of digital learning experiences. Educators play a role in designing activities that are in accordance with learning objectives, providing reflective reinforcement, and keeping the use of technology in harmony with the child's developmental stage. This is confirmed through the statement that "*technology is very helpful, but it must still be directed so that children learn with clear goals*" (G-Mlg-04).

DISCUSSION

The findings of this study show that the use of a smart digital environment in early childhood learning contributes significantly to strengthening children's learning independence, both quantitatively and qualitatively. The increase in learning independence reflected in the aspects of learning initiative, self-regulation, and perseverance indicates that a pedagogically designed digital learning experience is able to create learning conditions that support children to play an active role in managing their learning process. These results are in line with the view that learning independence in early childhood develops optimally when the learning environment provides opportunities for exploration, choice, and meaningful feedback (Azevedo et al., 2022).

The highest increase in the aspect of learning initiatives shows that the smart digital environment provides space for children to start learning activities independently and make simple decisions in the learning process (Anggraini et al., 2025). This corroborates the findings of previous research that states that digital technology that is interactive and adaptive can encourage children's intrinsic curiosity and motivation, especially when children are given limited but meaningful control over their learning activities (Bers, 2020). In this context, learning applications do not only function as a medium, but as a learning environment that facilitates children's agency from an early age.

The aspect of self-regulation that has experienced a significant increase shows that the smart digital environment can act as a scaffolding that helps children internalize control over their learning behavior. Children who are accustomed to following the flow of digital activities, receiving direct feedback, and adjusting their actions based on the system's responses show improved attention management and learning behaviors. These findings support the argument that self-regulation in early childhood can be developed through structured but flexible learning experiences, including through the use of technology designed according to the principles of child development (McClelland et al., 2021).

Meanwhile, the improvement in the aspect of learning persistence, even though it is in the moderate category, gives an indication that the smart digital environment is able to help children survive in completing tasks and try again when facing difficulties. However, qualitative findings show that learning perseverance is greatly influenced by the quality of digital activity design and the role of educators in providing reflective reinforcement. This is in line with

research that confirms that challenges that are too easy or too difficult in a digital environment can reduce children's persistence, so that the balance between challenges and abilities is an important factor in digital learning design (Larkin, 2021).

The difference in the level of increased learning independence between research locations indicates that the context of implementation and pedagogical strategies play an important role in determining the effectiveness of a smart digital environment. Early childhood units that implement digital activities in an exploratory manner and provide decision-making space to children show a higher increase in learning independence than early childhood units that use technology instructionally. These findings confirm that the success of digital learning is not determined by the intensity of technology use, but rather by the quality of the construction of the learning experience that accompanies it (Howard & Jay, 2022).

The qualitative findings reinforce the quantitative results by showing that interactive, game-based digital learning experiences encourage children to develop confidence, initiative, and self-regulation. The child is no longer completely dependent on the verbal instructions of the educator, but is able to understand the flow of activities and make decisions independently. However, this study also confirms that the role of educators remains crucial as pedagogical mediators. Educators play a role in designing digital learning experiences, providing reflective reinforcement, and ensuring that the use of technology remains aligned with children's learning goals and developmental stages. This is in line with the view that technology in early childhood education should be placed as a pedagogical tool that is actively mediated by educators, not as a substitute for human interaction (Edwards & Bird, 2023).

Overall, this discussion shows that the smart digital environment has the potential to be an effective means to foster early childhood learning independence if designed pedagogically and implemented contextually. The findings of this study expand the study of digital pedagogy by emphasizing the importance of the construction of learning experiences that place children as active subjects and educators as reflective facilitators. Thus, the results of this study not only provide an empirical contribution, but also theoretical and practical implications for the development of digital learning oriented to early childhood development.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that the construction of early childhood learning experiences in an intelligent digital environment contributes significantly to strengthening children's learning independence. A digital environment that is designed interactively, exploratory, and supported by direct feedback is able to improve children's learning initiatives, self-regulation, and perseverance. These findings show that children's learning independence develops optimally when digital technology is utilized as part of a child-centered pedagogical design.

This research also confirms that the effectiveness of a smart digital environment is highly dependent on the role of educators as pedagogical

mediators. Learning independence does not arise automatically through the use of technology, but through the construction of digital learning experiences that are contextually designed and aligned with the child's developmental stage. These findings provide important implications for the development of digital pedagogy in early childhood education and serve as a basis for designing digital learning that is oriented towards the independence and sustainability of children's learning.

ADVANCED RESEARCH

Future research should explore more deeply how specific design elements in intelligent digital environments—such as adaptive feedback, interactivity, and personalization—contribute to children's learning independence. Longitudinal studies are needed to examine the sustainability of independent learning behaviors over time. Comparative research across different educational contexts can also provide broader insights into contextual influences on digital pedagogy effectiveness. Additionally, integrating quantitative and qualitative approaches, including analysis of teacher mediation strategies, will strengthen the development of child-centered digital learning models in early childhood education.

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