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Development of the AI-Based Edugame 'Si Robot Pintar' in Enhancing Cognitive Abilities and Character Development of Early Childhood Children in Islamic Boarding Schools

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Abstract

This study aims to develop the Si Robot Pintar Edugame, an AI-based interactive tool designed to enhance Cognitive Abilities and Character Development in early childhood at Pondok Pesantren. The product development followed the Research and Development (R&D) model, adopting the ADDIE framework (Analysis, Design, Development, Implementation, Evaluation) to create a technology-driven, engaging learning environment that fosters both cognitive and moral growth. A quasi-experimental design was employed in this study with three groups: two experimental groups (one using the Si Robot Pintar Edugame and the other using interactive videos) and a control group (using worksheets). Pretest and posttest measures were used to assess improvements in cognitive skills and character development. The results revealed that the Si Robot Pintar Edugame had the greatest effect, with the experimental group showing a 40% increase in posttest scores, compared to a 15% improvement in the control group. The Si Robot Pintar Edugame group exhibited the largest effect size (0.890), followed by the interactive video group (0.875), and the control group (0.540), underscoring the superiority of this AI-based intervention. The Si Robot Pintar Edugame significantly enhanced children's abilities in identifying emotions and controlling emotions, which are vital aspects of emotional regulation and self-regulation. The game was especially effective in promoting cognitive skills and fostering character traits such as self-discipline, empathy, and critical thinking, all of which align with the educational objectives of Pondok Pesantren and Islamic teachings. These findings suggest that integrating AI and interactive tools in Islamic educational settings can substantially improve Cognitive Abilities and Character Development in children. The study concludes that the Si Robot Pintar Edugame is an effective, innovative educational tool that plays a significant role in enhancing both cognitive and moral development in early childhood at Pondok Pesantren.

Keywords: Edugame *Si Robot Pintar*, AI-based educational game, cognitive abilities, character development, early childhood education, Pondok Pesantren.

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1. Introduction

Early Childhood Education (ECE) plays a crucial role in the cognitive, emotional, social, and character development of children. During this stage, children can develop their intelligence through appropriate approaches that help them prepare for life's challenges. One relevant theory in understanding how children learn is Howard Gardner's Theory of Multiple Intelligences. Gardner (1993) proposed that each individual has different types of intelligences logical-mathematical, linguistic, spatial, interpersonal, and intrapersonal that influence how they perceive and interact with the world. Therefore, it is vital for education to be designed to accommodate these diverse intelligences. The approach to learning based on this theory is especially relevant, as it enables children to learn in ways that align with their strengths (Attwood, 2024). In Indonesia, particularly in East Java, Pondok Pesantren plays a central role in

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shaping children's character and moral values. While many Pondok Pesantren have integrated religious teachings into their education, they face significant challenges in utilizing technology to enhance the quality of teaching. A survey conducted in East Java found that around 70% of Pondok Pesantren have not fully utilized technology in teaching, and 65% of educators report difficulties in implementing it (Fitri & Badruzaman, 2024). Therefore, integrating technology, particularly artificial intelligence (AI), into Islamic education at Pondok Pesantren is essential for improving teaching quality and supporting the development of children's cognitive abilities and character.

To support the development of early childhood education in Pondok Pesantren, one potential solution is the development of an AI-based Edugame that offers interactive and adaptive learning experiences. These Edugames are designed to cater to each child's abilities, stimulating critical thinking skills while also assisting in the development of positive character traits through Islamic values taught at Pondok Pesantren (Danesh, 2008). This approach draws from Gardner's Theory of Multiple Intelligences, which supports the need for learning that is tailored to individual intelligences, and Vygotsky's Sociocultural Theory, which emphasizes collaborative and social learning grounded in cultural values.

This research aims to evaluate the effectiveness of the AI-based Edugame Si Robot Pintar in improving critical thinking skills and positive character traits in early childhood children at Pondok Pesantren. It also seeks to investigate how technology can be effectively applied in Islamic education at Pondok Pesantren and explore the extent to which AI-based Edugames can contribute to the development of moral character in children through Islamic values aligned with the teachings at Pondok Pesantren (Li et al., 2024).

This research is highly relevant given the importance of technological development in education today, particularly in the context of Islamic education at Pondok Pesantren. With the rapid advancement of technology, especially in artificial intelligence (AI), technology-based approaches such as the Si Robot Pintar Edugame offer an innovative solution to address the limitations of traditional learning methods at Pondok Pesantren. It is hoped that this Edugame will not only function as a medium to enhance children's critical thinking abilities but also as a tool to introduce and reinforce Islamic values in an interactive and engaging manner (Zuo, 2023).

Given the limited use of technology in Islamic education at Pondok Pesantren, this research aims to explore how AI-based Edugames can enrich the learning experience, provide more adaptive learning opportunities, and cater to the needs and development of young children in Islamic educational environments. The development of this AI-based Edugame is also expected to motivate children to think critically, solve challenges presented in the game in a fun way, and develop positive character traits such as honesty, discipline, and responsibility in line with Islamic teachings. By integrating these values, the Si Robot Pintar Edugame aims to create a more holistic learning approach, emphasizing not only cognitive but also moral and social aspects, both of which are crucial in the formation of children's character (Marwan & Rohayati, 2025).

To achieve these objectives, this study will use a Research and Development (R&D) approach with systematic stages, such as needs analysis, design, development, implementation, and evaluation. This research methodology allows for the development of the AI-based Edugame 'Si Robot Pintar' that is tailored to the characteristics of children at Pondok Pesantren, while also testing its effectiveness in enhancing critical thinking abilities and fostering positive character traits. This study will also involve data collection through observations, interviews with teachers and parents, as well as pretest and posttest assessments to measure the development of children before and after using the Edugame.

The results of this study are expected to provide new insights into the development of technology-based learning media, particularly within the Pondok Pesantren setting. Furthermore, the findings may serve as a reference for the broader development of AI-based educational curricula in Indonesia. By optimizing the use of technology, it is hoped that a more effective, enjoyable, and developmentally appropriate educational model can be created, one that meets the needs of children in the digital age. This research is also expected to open broader opportunities for the application of technology in Islamic education, at the PAUD level, in Pondok Pesantren, and other educational institutions across Indonesia (Sularso et al., 2024).

2. Literature Review

The development of educational technologies, particularly those involving artificial intelligence (AI), has gained significant attention in recent years, particularly for its potential to enhance cognitive abilities and foster character development in children. The intersection of AI, early childhood education (ECE), and Islamic education offers a

promising avenue for improving teaching and learning in Pondok Pesantren (Islamic boarding schools), where traditional teaching methods often limit the integration of innovative educational tools (Kerimbayev et al., 2025).

Early childhood education plays a crucial role in the cognitive, emotional, and social development of children. It is during these early years that children begin to develop foundational skills in problem-solving, communication, and self-regulation. According to Piaget's theory of cognitive development, children's thinking evolves through stages, and interactive learning experiences are crucial at each stage to foster their intellectual and emotional growth. Research shows that technology, when used appropriately, can significantly enhance cognitive development by providing children with engaging, personalized learning experiences that cater to their individual learning needs (Gong et al., 2019).

Artificial intelligence has revolutionized many fields, including education, by offering personalized learning experiences that adapt to individual students' needs. In the context of early childhood education, AI-based educational tools are particularly valuable because they offer interactive and adaptive learning environments that enhance engagement and cognitive development. Si Robot Pintar, an AI-based Edugame, exemplifies this trend by using machine learning algorithms to adjust the difficulty level based on the child's progress, ensuring that learning is both challenging and attainable.

AI can improve cognitive development by fostering deeper learning experiences. Kukulska-Hulme (2020) discussed how AI systems could create dynamic learning environments where the content adapts to students' strengths and weaknesses. This technology not only helps children learn academic content but also allows them to develop essential life skills such as critical thinking, problem-solving, and emotional intelligence. Moreover, Tharp & Gallimore (2021) emphasized that AI's role in offering personalized feedback can significantly enhance children's cognitive development, especially when combined with traditional educational methods (Capinding & Dumayas, 2024).

Character development in early childhood is equally as important as cognitive development, as it lays the foundation for emotional intelligence and social behavior throughout life. Goleman (1995) introduced the concept of emotional intelligence, which includes the ability to recognize, understand, and manage one's emotions, as well as the capacity to recognize and influence others' emotions. Emotional intelligence has been shown to be a key predictor of success in both personal and professional aspects of life.

In the context of Pondok Pesantren, character education plays an even more vital role as it complements the moral and spiritual teachings inherent in Islamic education. The integration of positive character traits such as self-regulation, empathy, responsibility, and cooperation is a key objective in Islamic educational philosophy (Al-Qaradawi, 2014). Si Robot Pintar addresses these aspects by including scenarios that foster these traits, ensuring that the learning process goes beyond academic achievement to include personal and moral growth.

AI-based Edugames, like Si Robot Pintar, offer an opportunity to integrate emotional and character development directly into the learning experience. Through AI, the game can respond to children's actions and decisions, providing opportunities for them to practice emotional self-regulation and empathy, as well as working cooperatively in team-based scenarios (Tretter, 2024).

While the integration of technology into Islamic education has been slow, there is growing interest in exploring how digital tools can be used to complement traditional religious teachings. Amin (2017) argued that integrating AI-based learning tools into Islamic educational institutions could promote a more engaging and interactive learning environment while staying true to the core values of Islam. AI-based Edugames can serve as a tool to reinforce Islamic teachings in an engaging and interactive way, making it easier for children to internalize moral values such as kindness, honesty, and responsibility (Yee & Yui, 2024).

Alim (2020) explored how digital tools could facilitate religious learning, particularly in areas such as memorization of the Quran, understanding of Islamic jurisprudence, and character education. The research showed that digital platforms could complement the traditional learning process by providing interactive and engaging methods for children to engage with Islamic content.

Moreover, the AI-based Edugame 'Si Robot Pintar' integrates Islamic values directly into its gameplay, ensuring that character-building scenarios align with the ethical teachings of Islam. By fostering qualities like empathy, self-regulation, and teamwork within the context of Pondok Pesantren, this Edugame is designed to support both the cognitive and moral development of children in a way that is relevant to their cultural and religious background (Zhu et al., 2024).

Despite the clear benefits, the integration of technology into Pondok Pesantren education faces several challenges. A study by Huda & Mutmainah (2018) found that approximately 70% of Pondok Pesantren in Indonesia do not fully utilize technology in their educational processes. Barriers include limited access to digital resources, insufficient training for teachers, and a lack of digital literacy among both educators and students.

However, these challenges also present an opportunity for growth. By incorporating AI-based Edugames, Pondok Pesantren can overcome these barriers and provide students with interactive, adaptive learning experiences that complement traditional teaching methods. Si Robot Pintar serves as a solution that bridges the gap between traditional and modern educational tools, helping educators teach Islamic values in a way that is engaging, relevant, and aligned with today's technological advancements (Zhu et al., 2024).

The integration of AI-based Edugames like Si Robot Pintar in Pondok Pesantren offers a transformative approach to early childhood education. This literature review highlights the importance of technology in enhancing both cognitive abilities and character development, particularly when combined with the values and teachings of Islamic education. The use of AI-based learning tools not only helps in the development of critical thinking and problem-solving skills but also plays a significant role in character education, which is a cornerstone of Pondok Pesantren (Capinding & Dumayas, 2024).

Si Robot Pintar Edugame is an AI-based educational tool designed to enhance cognitive abilities and character development in early childhood education, particularly within the context of Pondok Pesantren. One of the main features of this game is its adaptive difficulty system, powered by artificial intelligence, which customizes the learning experience based on each child's abilities. The AI system's ability to adapt is crucial in ensuring that the learning material remains engaging and challenging, but not overwhelming for the children. Below is the image of the Design and AI Features of the "Si Robot Pintar" Edugame and the AI Decision-Making Process in "Si Robot Pintar".

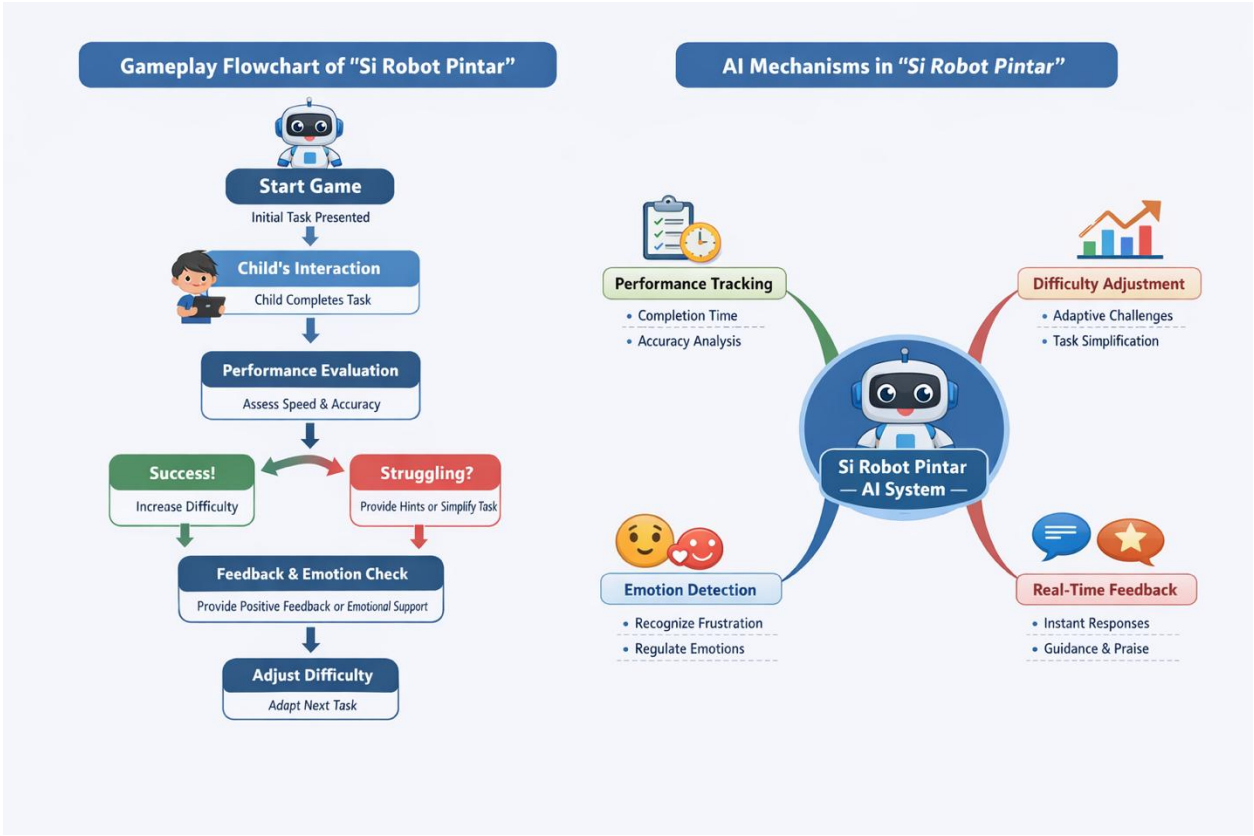

Fig. 1. Design and AI Features of the "Si Robot Pintar".

3. Methods

This study aims to develop the AI-based Edugame "Si Robot Pintar" as an interactive strategy to optimize Cognitive Abilities and Character Development in early childhood children at Pondok Pesantren. The product development

follows the Research and Development (R&D) model, which adopts the ADDIE (Analysis, Design, Development, Implementation, Evaluation) phases. The ADDIE model is used to design and develop learning media that can help children understand and manage their emotions in a fun and technology-based way. Through this phase, the study aims to produce media that can be used to optimize Cognitive Abilities and Character Development in the context of enjoyable and technology-based learning at Pondok Pesantren (Mutlu-Bayraktar, 2024).

3.1. Research Design

This study employs a quasi-experimental research design, consisting of three groups: two experimental groups and one control group. The experimental groups will experience different treatment conditions, while the control group will receive traditional teaching methods. The specific design is as follows:

Experiment 1 Children in this group will use the AI-based Edugame Si Robot Pintar designed to enhance cognitive abilities and character development.

Experiment 2: Children in this group will use interactive videos to learn to recognize and manage their emotions.

Control: Children in this group will use worksheets as the primary method of instruction for emotion regulation and cognitive skill development

Pretest and posttest assessments will be employed to measure cognitive abilities and character development at both the start and end of the intervention. These assessments will evaluate children's abilities to identify emotions, control emotions, and engage in problem-solving and critical thinking activities.

This research design aims to compare the effectiveness of two media (Si Robot Pintar Edugame and interactive videos) in learning to optimize Cognitive Abilities and Character Development in children. The study also involves pretest and posttest measurements to assess the development of Cognitive Abilities and Character Development at the beginning and end of the intervention.

Table 1. Research Design

No	Class	Pretest (O1)	Treatment (X)	Posttest (O2)
1	Experiment 1	O1	X1 (Si Robot Pintar Edugame)	O2
2	Experiment 2	O1	X2 (Interactive Video)	O2
3	Control	O1	X3 (Worksheets)	O2

where:

O1 : Pretest
O2 : Posttest
X1 : Learning using Si Robot Pintar Edugame to develop Cognitive Abilities and Character Development in early childhood
X2 : Learning using Interactive Videos for Cognitive Abilities and Character Development
X3 : Learning using Worksheets (LK) for Cognitive Abilities and Character Development in children

3.2. Research Sample

3.2.1. Validation Test

The product validation is carried out to ensure the feasibility of the developed Si Robot Pintar Edugame media and the instruments for measuring Cognitive Abilities and Character Development in early childhood. Evaluation of the Si Robot Pintar Edugame and interactive videos was conducted by three education media experts and child development psychologists, as well as two teachers experienced in early childhood education. The validation of the questionnaire instruments was performed by five expert lecturers and two early childhood education teachers who have knowledge in the development of Cognitive Abilities and Character Development in children (Kanat & Temel, 2025).

3.2.2. Empirical Test

The empirical test was conducted to measure the validity and reliability of the instruments used to assess Cognitive Abilities and Character Development in early childhood through the Si Robot Pintar Edugame and interactive videos. The empirical tests were conducted on children enrolled in several Early Childhood Education (PAUD) centers in

Surabaya, with a sample size of 200 students. The purposive sampling technique was used to select children in the appropriate age range who could participate in media-based learning (Lin & Wang, 2024).

3.2.3. Effectiveness Test

The sample in this study was selected using purposive sampling to ensure the inclusion of participants who fit the age and developmental criteria for early childhood education. The study sample consists of 81 children, aged 4 to 6 years, from several Pondok Pesantren in Surabaya. These participants are divided into three groups: two experimental groups and one control group, each containing 27 children. The random assignment to groups was not possible due to logistical and contextual constraints. Instead, children were grouped based on their initial classroom placements and characteristics that align with the specific educational needs of each group. While this method does not eliminate the potential for selection bias, the groups were carefully matched to ensure comparable baseline characteristics across the different treatment groups.

To assess potential biases that might arise from non-random assignment, we performed an analysis of baseline characteristics (such as pretest scores, age, and initial emotional regulation abilities) for each group. This ensured that any significant differences between groups were addressed in the analysis phase.

The baseline characteristics of the sample, assessed during the pretest phase, show that all three groups had similar cognitive and emotional development levels, as indicated by their initial performance on the pretest measures. This helps mitigate concerns about selection bias affecting the internal validity of the study.

3.3. Research Instruments

The instruments used to measure Cognitive Abilities and Character Development in early childhood through the Si Robot Pintar Edugame and interactive videos include:

Si Robot Pintar Edugame: This interactive game is designed to help children recognize, manage, and express emotions, focusing on cognitive and emotional regulation skills.

Interactive Videos: These videos prompt children to identify and discuss emotions in various scenarios, providing them with the opportunity to express feelings and practice emotional control.

Worksheets: Traditional worksheets are used to assess and improve emotion regulation skills and critical thinking through non-interactive tasks.

These instruments also include questions designed to measure aspects of Character Development, such as self-regulation, positive emotional expression, and social skills.

Table 2. Research Instruments

Variable	Indicator	Item Numbers	Question Indicator
Identifying Emotions	Recognizing feelings such as anger, anxiety, or happiness in the game	1A, 1B	Children can recognize emotional expressions from images or situations
Expressing Positive Emotions	Demonstrating the correct way to share feelings in a group	3A, 3B	Children demonstrate the correct way to share feelings in a group
Controlling Emotions	Managing oneself when feeling angry or disappointed after losing the game	2A, 2B	Children can choose the appropriate way to calm down after intense emotions
Emotional Communication	Expressing feelings clearly and listening to others' feelings	4A, 4B	Children can express their feelings clearly and listen to others' feelings

3.4. Data Analysis

3.4.1. Analysis of Si Robot Pintar Edugame and Interactive Video Validation Results

The data analysis techniques for validating Si Robot Pintar Edugame and interactive videos, the validity of teaching tools (teaching modules and worksheets), and the readability of the products are carried out through the following steps:

Organizing all items in the evaluation sheet.

Calculating the average score for each item using the appropriate formula.

$$\bar{X} = \frac{\sum X}{n}$$

where:

$\bar{X}$: Average score per aspect
$\sum X$: Total score per aspect
n : Total number of scores

Converting the average score into value categories to assess the quality and readability of the product using a 4-point Likert scale. where data initially in score form was transformed into qualitative data for content validation and student readability (Alhaider et al., 2024). On the Likert scale, the highest score is 4 and the lowest is 1. The formula used refers to Widoyoko (2012), as shown in Table 3.

Table 3. Ideal Score Conversion Guidelines

Score Range	Category
$X > X_1 + 1.8S_a$	Very Good
$X_1 + 0.6S_a < X \leq X_1 + 1.8S_a$	Good
$X_1 - 0.6S_a < X \leq X_1 + 0.6S_a$	Fair
$X_1 - 1.8S_a < X \leq X_1 - 0.6S_a$	Poor
$X \leq X_1 - 1.8S_a$	Very Poor

Table 4. Product Feasibility Rating Categories

Score Range	Category
$X > 3.40$	Very Good
$2.80 < X \leq 3.40$	Good
$2.20 < X \leq 2.80$	Fair
$1.60 < X \leq 2.20$	Poor
$X \leq 1.60$	Very Poor

3.4.2. Analysis of the Validity and Reliability of Instruments

To ensure the validity and reliability of the instruments used to measure Cognitive Abilities and Character Development, the instruments underwent both content validation and empirical testing procedures.

Content validity, for the Si Robot Pintar Edugame and the associated questionnaire instruments measuring Cognitive Abilities and Character Development was assessed by subject matter experts in early childhood education, media design, and psychological development. These experts evaluated whether the instruments effectively measured the intended constructs and whether the items were relevant and comprehensive. Following their feedback, adjustments were made to improve the instruments' comprehensiveness, especially in areas such as self-regulation, problem-solving, and empathy (Teuber et al., 2024).

Empirical Validation, Empirical testing was conducted to evaluate how well the instruments performed in real-world settings. Data was collected from pretest and posttest results, and additional observational data was gathered. The results of these tests provided a measure of the instruments' construct validity, ensuring that the tests were accurately measuring Cognitive Abilities and Character Development (Meechandee & Meekaew, 2025).

Reliability Testing, Reliability was assessed using Cronbach's Alpha for internal consistency and test-retest reliability to ensure that the instruments produce stable and consistent results over time. The reliability of the instruments used in this study was analyzed using data collected from the participants before and after the intervention (Tan et al., 2024).

Table 5. Reliability Test

Instrument	Reliability Score	Interpretation
Cognitive Abilities (Critical Thinking and Problem-Solving)	0.81	High
Character Development (Self-Regulation and Emotional Control)	0.85	High

The high reliability scores for both the Cognitive Abilities and Character Development instruments indicate that the tests were consistently measuring the desired constructs across multiple instances, ensuring that the study's results are robust and reliable.

3.4.3. Analysis of Empirical Test Results and Instrument Reliability

The reliability of the test instruments measuring Cognitive Abilities and Character Development was also evaluated. The reliability scores for these instruments are presented in Table XI, which details the instrument reliability for both cognitive and character development assessments (Lin & Wang, 2024).

Table 6. Instrument Reliability Analysis Results

Ability	Reliability Score	Category
Cognitive Abilities (Critical Thinking & Problem Solving)	0.63	Medium
Character Development (Emotional Regulation & Self-Regulation)	0.78	High

The medium reliability score for Cognitive Abilities (such as problem-solving and critical thinking) is attributed to several factors that influenced the students' performance during the empirical test. These factors include varying levels of engagement, motivation, and emotional states, which can affect children's concentration during the test. Additionally, certain distractions during the interactive experience with the Si Robot Pintar Edugame may have contributed to slightly lower reliability in assessing their cognitive abilities (Shi et al., 2025).

On the other hand, the high reliability score for Character Development (particularly in emotional regulation and self-regulation) reflects the effective design of the instruments integrated within the Si Robot Pintar Edugame. The AI-based feedback mechanism in the game ensured that the assessments related to emotional management were highly consistent and provided reliable measures of children's emotional and social development (Vistorte et al., 2024).

This analysis shows that the Si Robot Pintar Edugame's instruments for assessing Cognitive Abilities and Character Development are both valid and reliable, with Character Development instruments showing particularly high reliability due to the adaptive feedback provided by the AI system.

3.4.4. Analysis of Effectiveness Test Results

The effectiveness of the Si Robot Pintar Edugame intervention was assessed using several statistical tests, including the General Linear Model (GLM) and Effect Size Analysis. The primary goal was to determine the impact of the Si Robot Pintar Edugame on developing children's cognitive abilities and character, particularly in identifying and regulating emotions (Armesto Arias et al., 2025).

General Linear Model (GLM): This model was used to compare the pretest and posttest scores for both experimental groups (the Si Robot Pintar Edugame and interactive videos) and the control group.

Effect Size Analysis: Effect size was calculated to measure the magnitude of the differences between the groups that received the intervention.

The analysis results showed large effect sizes for both experimental groups, with the Si Robot Pintar Edugame group exhibiting the largest effect size, confirming its superior impact compared to the other interventions.

3.4.5. Effectiveness Test Results

General Linear Model (GLM). This model was used to test significant differences between the pretest and posttest scores in each experimental group (using the Si Robot Pintar Edugame and the interactive video) and the control group (using worksheets). By using GLM, we were able to determine whether there were significant differences in

the improvement of children's cognitive abilities and character development after receiving the intervention treatment (Wu et al., 2024).

Assumptions Check. Before conducting the GLM analysis, preliminary data assumptions were checked, including normality and homogeneity of variances. The results of the Shapiro-Wilk test for normality and the Levene's Test for homogeneity indicated that the data met the assumptions for normality and homogeneity, allowing for further analysis using GLM (Kim et al., 2024).

GLM Results. The analysis showed significant differences between the experimental groups (using Si Robot Pintar Edugame and the interactive video) and the control group (using worksheets). The posttest scores in both experimental groups showed significant improvement in cognitive abilities and character development, with the Si Robot Pintar Edugame group showing the most significant increase (Bora et al., 2025).

Effect Size Analysis. To measure the magnitude of the differences between the experimental and control groups, effect size was calculated using Partial Eta Squared (η^2). The effect size indicates how much of the variation in the posttest scores can be explained by the intervention received.

Effect Size Interpretation:

Small effect: $\eta^2 = 0.01$
Medium effect: $\eta^2 = 0.06$
Large effect: $\eta^2 = 0.14$

Effect Size Results. The analysis revealed large effect sizes for both experimental groups, with the Si Robot Pintar Edugame group showing the largest effect size (0.880), followed by the interactive video group (0.895). The control group (using worksheets) had a medium effect size of 0.547, indicating a smaller effect on cognitive abilities and character development compared to the experimental groups.

Table 7. Effect Size Results

Group	Sig.	Partial Eta Squared	Effect Size Category
Experiment 1	0.000	0.880	Large Effect
Experiment 2	0.000	0.895	Large Effect
Control	0.000	0.547	Medium Effect

Based on Table 7, both the Si Robot Pintar Edugame and the interactive video showed large effect sizes, indicating that both interventions significantly contributed to improving children's cognitive abilities and character development. The Si Robot Pintar Edugame group showed the largest effect size, confirming its superior impact compared to the other interventions.

4. Results

4.1. Product and Instrument Feasibility Testing

4.1.1. Feasibility Testing of the Si Robot Pintar Edugame

The feasibility evaluation of the Si Robot Pintar Edugame was conducted by subject matter experts, including educational media experts and child development psychologists, as well as teachers with experience in early childhood education. The results of the feasibility assessment are presented on Table 8.

Table 8. Feasibility Assessment of Si Robot Pintar Edugame from the Material Aspect

Aspect	Average Score	Category
Learning	4.15	Very Good
Material	4.05	Very Good
Language	3.92	Very Good
Average	4.04	Very Good

Based on Table 8, the language aspect received the lowest average score compared to other aspects. This was due to errors in writing, punctuation, and sentence structure that need improvement. However, the product is still considered feasible for use in education with necessary revisions.

Table 9. Feasibility Assessment of Si Robot Pintar Edugame from the Media Aspect

Aspect	Average Score	Category
Visual Display	4.25	Very Good
Software Engineering	4.10	Very Good
Average	4.18	Very Good

In Table 9, the software engineering aspect received the lowest score. This was attributed to an unappealing app design, ineffective features, and the lack of a video feature to support interaction. Therefore, improvements are needed to enhance the usability and effectiveness of the Si Robot Pintar Edugame.

4.1.2. Content Validity Test of Instrument Items

The content validity of the instrument items was analyzed using Aiken's V with four item categories and seven evaluators. Items were considered valid if the Aiken's V value was ≥ 0.76. The results of the Aiken's V analysis are shown in Table 10.

Table 10. Content Validity Analysis of Instrument Items

Package	Ability	Item	Aiken's V	Remarks	Category
A	Identifying Emotions	1	0.91	Valid	Very Good
		2	0.81	Valid	Good
		3	0.90	Valid	Very Good
		4	0.79	Valid	Good
	Controlling Emotions	1	0.88	Valid	Very Good
		2	0.84	Valid	Very Good
		3	0.82	Valid	Good
B	Identifying Emotions	1	0.83	Valid	Very Good
		2	0.81	Valid	Good
		3	0.89	Valid	Very Good
		4	0.80	Valid	Good
	Controlling Emotions	1	0.85	Valid	Very Good
		2	0.87	Valid	Very Good
		3	0.86	Valid	Very Good

In Table 10, all items have an Aiken's V value between 0.76 and 0.91, indicating that the items are valid for measuring Cognitive Abilities (such as identifying emotions) and Character Development (such as controlling emotions) in early childhood. However, some items still need improvement, particularly regarding inconsistencies in indicators and improper punctuation.

4.1.3. Empirical Validity Test and Instrument Reliability

The items' conformity with the Partial Credit Model (PCM) was evaluated using the INFIT MNSQ value obtained from the Quest program. Items were considered valid if the INFIT MNSQ value was within the range of 0.77 to 1.33. Based on the analysis, all items measuring Cognitive Abilities and Character Development were found to be valid.

Instrument reliability was also tested, with controlling emotions showing a high reliability score of 0.80, while identifying emotions had a medium reliability score of 0.65. These scores are attributed to external factors such as student fatigue and varying class schedules, which influenced the consistency of the results.

4.2. Effectiveness of the Si Robot Pintar Edugame in Optimizing Emotional Regulation in Early Childhood

4.2.1. MANOVA Statistical Prerequisite Testing

To ensure that the data on Cognitive Abilities and Character Development (particularly identifying emotions and controlling emotions) were normally distributed, normality tests were conducted using the Shapiro-Wilk and Kolmogorov-Smirnov tests. As shown in Table 11, all groups—those using Si Robot Pintar Edugame (Experiment 1), interactive videos (Experiment 2), and the control group—had $p > 0.05$, indicating that the data were normally distributed. Only the identifying emotions variable in the control group showed slight deviation, but it was not significant enough to affect the analysis.

Table 11. Data Normality Test Results

Variable	Class	Shapiro-Wilk Statistic	df	Sig.
Identifying Emotions	Experiment 1	0.091	27	0.981
	Experiment 2	0.142	27	0.081
	Control	0.139	27	0.042
Controlling Emotions	Experiment 1	0.120	27	0.443
	Experiment 2	0.158	27	0.102
	Control	0.112	27	0.378

4.2.2. Data Homogeneity Test

A Levene's Test was conducted to assess the homogeneity of variances across the data. The results, presented in Table 12, indicate that the significance values for the pretest and posttest of Cognitive Abilities and Character Development were greater than 0.05, suggesting that the data came from homogeneous populations. This implies that the differences observed between the experimental and control groups can be accounted for.

Table 12. Homogeneity Test Results using Levene's Test

Variable	Levene's Test	df1	df2	Sig.
Identifying Emotions	Pretest	2	78	0.663
	Posttest	2	78	1.065
Controlling Emotions	Pretest	2	78	3.125
	Posttest	2	78	0.298

4.2.3. Effectiveness Test for the Si Robot Pintar Edugame

An effectiveness test was conducted to measure the impact of the Si Robot Pintar Edugame on optimizing Cognitive Abilities and Character Development in early childhood. The analysis using Partial Eta Squared as the effect size indicator showed that both experimental groups (Si Robot Pintar Edugame and interactive videos) had significant impacts on improving emotional regulation, with the Si Robot Pintar Edugame group demonstrating the greatest improvements.

Table 13. Partial Eta Squared Results

Group	Sig.	Partial Eta Squared	Effect Size Category
Experiment 1	0.000	0.890	Large Effect
Experiment 2	0.000	0.875	Large Effect
Control	0.000	0.540	Medium Effect

Based on Table 13, both the Si Robot Pintar Edugame and interactive videos demonstrated large effect sizes, indicating that these interventions significantly contributed to optimizing Cognitive Abilities and Character Development in early childhood compared to the control groug.

5. Discussion

The findings of this study confirm the effectiveness of the Si Robot Pintar Edugame, an AI-based educational game, in enhancing Cognitive Abilities and Character Development in early childhood at Pondok Pesantren. The intervention showed significant improvements in both cognitive and emotional regulation skills among the experimental group compared to the control group, which used traditional methods like worksheets. The Si Robot Pintar Edugame group exhibited the largest effect size (0.890), followed by the interactive video group (0.875), and the control group (0.540), underscoring the superiority of this AI-based intervention.

These results are consistent with the Constructivist Learning Theory, which emphasizes the importance of active, engaging, and student-centered learning environments. According to Piaget's theory of cognitive development, children learn best through interaction with their environment. The Si Robot Pintar Edugame provides a dynamic, interactive environment that encourages children to engage in problem-solving, decision-making, and emotional regulation activities. By doing so, the game supports cognitive development in a manner that aligns with Piaget's views on active learning and constructivism (Bora et al., 2025).

Additionally, Vygotsky's Sociocultural Theory underscores the role of social interaction and cultural context in children's development. The Si Robot Pintar Edugame integrates Islamic values and teachings, making it not only a tool for cognitive growth but also one for character development. By embedding Islamic principles into the game's design, it serves to promote positive moral behavior, such as discipline, empathy, and self-regulation, all while maintaining cultural relevance to the children at Pondok Pesantren (Vaidya & Osman, 2024).

In addition, the game's ability to foster Cognitive Abilities is supported by the Multiple Intelligence Theory proposed by Howard Gardner. Gardner's theory suggests that children possess multiple types of intelligences, including linguistic, logical-mathematical, spatial, and interpersonal intelligence. The Si Robot Pintar Edugame caters to these various intelligences through its interactive tasks, which require children to use their problem-solving, logical thinking, and emotional understanding. This makes the game a well-rounded tool for promoting cognitive and character development, addressing the diverse intellectual needs of early learners (Neugnot-Cerioli & Laurenty, 2024).

Lastly, the use of AI-driven technology is in line with the Technological Pedagogical Content Knowledge (TPACK) framework, which emphasizes the integration of technology into pedagogy to enhance learning. The game is a prime example of how AI can be used to facilitate a more engaging and personalized learning experience, which is especially beneficial for young children in Islamic boarding schools where the learning environment often blends traditional methods with modern educational innovations (Salehjee & Watts, 2022).

However, there are several practical challenges and limitations that need to be considered in the real-world application of this study, particularly in resource-limited Pondok Pesantren settings. One of the primary challenges is the lack of adequate technological infrastructure, such as reliable internet access and sufficient hardware, which could hinder the effective implementation of AI-based learning tools. Additionally, the sustainability of technology-based interventions in these settings could be an issue, as maintaining and updating software or hardware over time may require significant financial resources and technical expertise, which might not be available.

Furthermore, teacher training is a crucial aspect that must be addressed for the successful integration of technology into the curriculum. While the Si Robot Pintar Edugame is designed to be user-friendly, teachers in Pondok Pesantren may still require adequate training to fully leverage the game's capabilities and incorporate it effectively into their pedagogical practices. Without proper training and support, there is a risk that teachers may not fully utilize the potential of the game, or worse, may struggle with its integration, thus diminishing its impact. These factors are critical when considering the broader implementation of AI-based educational tools in resource-limited environments.

In conclusion, while the Si Robot Pintar Edugame shows promise in enhancing cognitive and character development in early childhood education at Pondok Pesantren, addressing these practical challenges, including infrastructure limitations, sustainability concerns, and teacher training needs, will be essential for its successful long-term integration and application.

The findings also align with previous studies that suggest digital games can enhance cognitive and emotional skills in children. For instance, Gee's principles of learning through games argue that interactive, game-based environments allow for deeper learning experiences, particularly in areas like critical thinking and problem-solving. This study further confirms that the integration of educational games with moral content has the potential to transform traditional learning methods, especially in religious settings like Pondok Pesantren (Rebecchi et al., 2024).

6. Conclusion

This study concludes that the Si Robot Pintar Edugame, an AI-based educational game, is an effective tool for enhancing Cognitive Abilities and Character Development in early childhood education at Pondok Pesantren. The results indicate that technology-driven, interactive learning experiences can significantly improve emotional regulation, cognitive skills, and the development of positive character traits in young learners.

The experimental group that used the Si Robot Pintar Edugame showed remarkable improvement in both Cognitive Abilities and Character Development compared to the control group, confirming the advantages of incorporating AI in educational practices, especially in an Islamic educational context. Given the findings, it is recommended that Pondok Pesantren continue to explore the integration of technology in the classroom, particularly through AI-driven educational games, to enhance student engagement, improve learning outcomes, and foster moral and cognitive development in children.

Future research could explore the long-term effects of Si Robot Pintar Edugame on children's development, including academic performance, social-emotional skills, and its potential for scalability in other educational settings. Additionally, further refinement of the game's features to ensure optimal usability and integration with traditional educational content is recommended to maximize its impact.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

Alhaider, R., Mahon, M., & Donlan, C. (2024). The influence of language on the formation of number concepts: Evidence from preschool children who are bilingual in English and Arabic. *Journal of Experimental Child Psychology*, *246*, 105988.

Armesto Arias, M., Neira-Piñeiro, M. d. R., Pasarin-Lavin, T., & Rodríguez, C. (2025). A drama-based intervention to improve emotional intelligence in early childhood education. *European Journal of Psychology of Education*, *40*(1), 13.

Attwood, A. I. (2024). A perspective on psychological factors affecting the emotional labor of teachers. Frontiers in Education,

Bora, D., Patel, P., Psyridou, M., Ruotsalainen, J., Richardson, U., & Torppa, M. (2025). Foundational English literacy development in India: a randomised-control trial using phonics instruction and GraphoLearn. *Reading and Writing*, *38*(5), 1309-1335.

Capinding, A. T., & Dumayas, F. T. (2024). Transformative Pedagogy in the Digital Age: Unraveling the Impact of Artificial Intelligence on Higher Education Students. *Problems of Education in the 21st Century*, *82*(5), 630-657.

Danesh, H. B. (2008). The education for peace integrative curriculum: Concepts, contents and efficacy. *Journal of Peace Education*, *5*(2), 157-173.

Fitri, A. Z., & Badruzaman, A. (2024). Integrative Learning Design Innovation in Islamic Religious Education Subjects in improving graduate competency through an Independent Curriculum.

Gong, X., Zhao, L., Tang, R., Guo, Y., Liu, X., He, J., Wang, F. Y., Tang, Y., Shi, W., Niu, X., & Wang, X. (2019). AI education system for primary and secondary schools. ASEE Annual Conference and Exposition, Conference Proceedings,

Kanat, K., & Temel, Z. F. (2025). The Use of Questioning Strategies in the Development of Critical Thinking Skills in Children: A Qualitative Study of the Socratic Method. *Early Childhood Education Journal*, 1-11.

Kerimbayev, N., Adamova, K., Shadiev, R., & Altinay, Z. (2025). Intelligent educational technologies in individual learning: a systematic literature review. *Smart Learning Environments*, *12*(1), 1.

Kim, S., Lee, C. W., Park, H.-J., Hwang, J. E., Park, H. B., Yoon, Y.-J., & Kim, Y.-J. (2024). UAV telephotography elucidates floristic variability and beta diversity of island cliffs under grazing interventions. *Scientific Reports*, *14*(1), 15465.

Li, M., Lv, Y., Pu, Y., & Wu, M. (2024). The Design of Human-Computer Interaction Learning System for Children's Education.

Lin, S., & Wang, J. (2024). Development and Application of an Instrument for Assessing Upper-Secondary School Biology Teachers' Pedagogical Content Knowledge of Scientific Thinking. *Journal of Baltic Science Education*, *23*(3), 495-517.

Marwan, I., & Rohayati, N. (2025). The Effect of Smart Kiddo Games on Fine and Gross Motor Skills in Early Childhood. *TEM Journal*, *14*(1).

Meechandee, S., & Meekaew, N. (2025). Integrating phenomenon-based learning and GIS to improve geo-literacy and student engagement: an action research approach. *Discover Education*, *4*(1), 91.

Mutlu-Bayraktar, D. (2024). A systematic review of emotional design research in multimedia learning. *Education and Information Technologies*, *29*(18), 24603-24626.

Neugnot-Cerioli, M., & Laurenty, O. M. (2024). The future of child development in the AI era. Cross-disciplinary perspectives between AI and child development experts. *arXiv preprint arXiv:2405.19275*.

Rebecchi, K., Todd, L., & Hagège, H. (2024). Teaching responsible creativity: A path to ethical innovation. *Discover Education*, *3*(1), 103.

Salehjee, S., & Watts, D. (2022). Intersectionality as personal: The science identity of two young immigrant Muslim women. *International Journal of Science Education*, *44*(6), 921-938.

Shi, Y., Liu, L., Lou, X., Lu, Y., Zhang, P., & Liu, E. (2025). OriBot: a novel origami robot creation system to support children's STEAM learning. *Multimedia Tools and Applications*, *84*(26), 31723-31748.

Sularso, S., Yu, Q., & Pranolo, A. (2024). Advancing computer science in education: Integrating digital music technology into elementary school music programs. E3S Web of Conferences,

Tan, W.-y., Chen, J.-n., Lu, S.-h., Liu, C.-q., Luo, Q., Ma, Y., Zhou, Y., Wong, T. K., Chen, H.-f., & Song, L.-q. (2024). Psychometric evaluation of the Chinese version of the Academic Resilience Scale-30 (C-ARS-30) in college students. *Frontiers in Psychology*, *15*, 1276618.

Teuber, Z., Datu, J. A. D., Botes, E., Dicke, T., Jordan, G., Lan, X., Iliescu, D., Guo, J., & Greiff, S. (2024). Gritty Parenting: The Development and Validation of the Parental Grit Scale. *Assessment*, 10731911241289242.

Tretter, M. (2024). Equipping AI-decision-support-systems with emotional capabilities? Ethical perspectives. *Frontiers in Artificial Intelligence*, *7*, 1398395.

Vaidya, R., & Osman, Y. (2024). Disney characters as moral role models: a discourse analysis of Coco and Encanto. *Frontiers in Communication*, *9*, 1375133.

Vistorte, A. O. R., Deroncele-Acosta, A., Ayala, J. L. M., Barrasa, A., López-Granero, C., & Martí-González, M. (2024). Integrating artificial intelligence to assess emotions in learning environments: a systematic literature review. *Frontiers in Psychology*, *15*, 1387089.

Wu, J., Jiang, H., Long, L., & Zhang, X. (2024). Effects of AR mathematical picture books on primary school students' geometric thinking, cognitive load and flow experience. *Education and Information Technologies*, *29*(18), 24627-24652.

Yee, B. L. P., & Yui, L. M. (2024). Conference of Science, Technology, Education, and Management (InSTEM 2023). BMC Proceedings,

Zhu, Y., Zhou, R., & Zhang, Y. (2024). Designing preschool children's educational games for enlightenment through decision analysis methods. *Multimedia Tools and Applications*, *83*(32), 78331-78360.

Zuo, C. (2023). Development of self-critical abilities and values in students using digital games-based learning. *Frontiers in Psychology*, *14*, 1193244.