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ORIGINAL RESEARCH ARTICLE

The AEWake Model: An AI-Enabled Instructional System for Enhancing Executive Function and Islamic Growth Mindset in Early Learners

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ABSTRACT

In today's era of digital transformation and artificial intelligence, executive function skills and adaptive character are crucial competencies for students to face complex future challenges. Teaching that integrates interactive media based on smart technology with a spiritual values approach is seen as an effective and creative strategy to cultivate these skills from an early age. Although previous research has focused on basic digital literacy, evaluation of the impact of teaching that combines cognitive and spiritual aspects holistically is still limited. This study aims to develop and test the effectiveness of an instructional system based on the AEWake model through a smart puzzle barcode hijaiyah media designed to stimulate executive function while instilling an Islamic Growth Mindset. Using a Research and Development (R&D) method with an adapted development model, the study involved 90 early childhood children as test subjects. Data collection techniques were carried out through structured observations based on the AEWake instrument and digital documentation, which were then analyzed using inferential statistics to measure the media's effectiveness. The results showed that the use of this instructional media had a significant positive impact on improving children's directed attention, self-control, and cognitive flexibility. The findings revealed that digital scaffolding through interactive content was a key variable influencing learning success, while the use of recycled materials was shown to increase sensory comfort without reducing the effectiveness of the technology. It is concluded that the integration of AI-enabled technology and Islamic values is able to support sustainable cognitive and character development in the PAUD environment.

ABSTRAK

Di era transformasi digital dan kecerdasan buatan saat ini, keterampilan fungsi eksekutif dan karakter adaptif menjadi kompetensi krusial bagi siswa untuk menghadapi tantangan masa depan yang kompleks. Pengajaran yang mengintegrasikan media interaktif berbasis teknologi cerdas dengan pendekatan nilai-nilai spiritual dipandang sebagai strategi efektif dan kreatif untuk menumbuhkan keterampilan tersebut sejak usia dini. Meskipun penelitian terdahulu banyak fokus pada dasar literasi digital, evaluasi terhadap dampak pengajaran yang mencakup aspek kognitif dan spiritual secara holistik masih terbatas. Penelitian ini bertujuan serta mengembangkan efektivitas sistem pembelajaran berbasis model AEWake melalui media smart puzzle barcode hijaiyah yang dirancang untuk menstimulasi fungsi eksekutif sekaligus menanamkan Islamic Growth Mindset. Menggunakan metode Research and Development (R&D) dengan model pengembangan yang disesuaikan, penelitian ini melibatkan 90 anak usia dini sebagai subjek uji coba. Teknik pengumpulan data dilakukan melalui observasi terstruktur berdasarkan instrumen AEWake dan dokumentasi digital, yang kemudian dianalisis menggunakan statistik inferensial untuk mengukur efektivitas media. Hasil penelitian menunjukkan bahwa penggunaan media instruksional ini memberikan dampak positif signifikan terhadap peningkatan perhatian terarah, pengendalian diri, dan kognitif kognitif anak. Temuan mengungkap bahwa scaffolding digital melalui konten interaktif menjadi variabel kunci yang mempengaruhi keberhasilan belajar, sementara penggunaan bahan daur ulang terbukti meningkatkan kenyamanan sensorik tanpa mengurangi efektivitas teknologi. Disimpulkan bahwa integrasi teknologi AI-enabled dan nilai-nilai islami mampu mendukung perkembangan kognitif dan karakter secara berkelanjutan di lingkungan PAUD.

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Keywords: *AEWake Model, AI-Enabled System, Executive Function, Islamic Growth Mindset, Early Childhood Education Technology.*

1. INTRODUCTION

The global educational milieu currently manifests an undeniable paradigm shift engendered by the pervasive dissemination of digital technology, necessitating a meticulous re-evaluation of pedagogical strategies intended for ECCD programs (Korhonen et al., 2024). Within national contexts characterized by profound moral and cultural significance, such as Indonesia, this transformation is not merely technical but deeply ethical (Pietsch & Mah, 2025). The documented escalation in the acquisition and utilization of mobile electronic devices by children within the four-to-seven-year age cohort mandates the attribution of paramount importance to the quality of digital instructional content (Ozturk et al., 2024; Sydow et al., 2021).

In the current era of the Society 5.0 paradigm and rapid global digital transformation, the integration of Artificial Intelligence (AI) in early childhood education (ECE) has shifted from a peripheral luxury to a fundamental necessity for developing future-ready competencies. Global educational frameworks now emphasize that executive function—encompassing inhibitory control, working memory, and cognitive flexibility—is the bedrock of lifelong learning and adaptive success in an increasingly automated world (Huang, 2024; Verdeflor et al., 2025). Furthermore, the synergy between technological fluency and spiritual-ethical foundations is recognized as a vital strategy for nurturing holistic development in young learners (Nazari & Far, 2019; Nieuwenhuis et al., 2025). However, the challenge lies in how these digital tools can be designed not just for consumption, but as catalysts for cognitive and character growth. The significance of this research lies in its response to the global call for instructional systems that bridge the gap between advanced technology and value-based pedagogy, ensuring that digital acceleration does not marginalize the essential spiritual-cognitive dimensions of early childhood (Aryaseta et al., 2023).

Despite the potential of technology, the primary problem in early childhood settings remains the prevalence of passive screen time and "black-box" digital tools that lack pedagogical depth and interactive scaffolding. Many existing educational applications provide repetitive content that fails to stimulate higher-order thinking or address the specific neurobiological needs of early learners (Santiago et al., 2023; Vedianty et al., 2024). Challenges are further compounded by the digital divide and the scarcity of media that effectively integrates local wisdom or spiritual values, leading to a fragmented learning experience where technology and character building exist in isolation (Dörrenbächer-Ulrich & Bregulla, 2024; Wright et al., 2025). Educators struggle to find tools that are both technologically advanced and ethically grounded, creating a tension between modern innovation and traditional moral education. This lack of integration often results in a "mechanical" learning process that neglects the development of an internal mindset, such as resilience and sincerity, which are critical for navigating the complexities of the digital age (Cadime et al., 2024; Rutter et al., 2025).

Research concerning educational technology in ECE has been extensively conducted by various scholars, including (Undheim et al., 2024), (Kazanidis & Pellas, 2024), (Hidayat & Dhuhani, 2025), (Kimmons & Jensen, 2023), (Kayaduman & Sağlam, 2024), and (Neumann et al., 2023). Kucirkova (2021) explored the personalization of digital books but failed to address the integration of spiritual growth mindsets. Pellerin (2021) focused on language acquisition through tablets, yet lacked a focus on executive function stimulation. Yuliani and Hidayat (2023) discussed AI opportunities generally but did not provide a concrete, tested instructional model for classroom use. Kim and Smith (2022) examined coding for toddlers, which, while cognitively stimulating, remained purely technical without ethical-moral frameworks. Zomer and Kay (2020) analyzed the effectiveness of video-based learning but ignored the sensory-motor benefits of physical-digital hybrid tools. Neumann (2020) investigated the role of mobile apps in literacy, yet the study was limited to basic phonics and did not consider the holistic "Growth Mindset" required for long-term academic resilience. These studies, while foundational, remain siloed in their approach, often prioritizing technical skills over the integrated development of the child's cognitive and spiritual persona.

The novelty of this research lies in the introduction of the AEWake Model, a pioneering instructional system that explicitly merges AI-enabled technology with the "Islamic Growth Mindset" (IGM) within a hybrid tactile-digital environment. Unlike previous innovations that rely solely on software, this research develops a physical "Smart Puzzle Barcode Hijaiyah" made from sustainable recycled materials, connecting the sensory-motor experience of traditional play with the adaptive feedback of digital platforms (Cherniak et al., 2019; Cutter-Mackenzie et al., 2015). The keterbaharuan (novelty) is further evidenced by the operationalization of the "7 Kebiasaan Anak Indonesia Hebat" (KAIH) as a systematic habituation framework within a technological interface. This approach transforms the barcode—often viewed as a static tool—into a dynamic gateway for digital scaffolding that triggers neuro-pedagogical responses in early learners. By utilizing image recognition to facilitate spiritual reflection and cognitive problem-solving, this study moves beyond simple digital literacy toward a comprehensive "Neuro-Islamic" pedagogical framework that has not been previously explored in ECE literature (Siu & Ng, 2024).

A critical research gap exists between the theoretical potential of AI and its practical, value-based application in ECE, particularly in stimulating executive functions through a spiritual lens. Previous research has largely ignored the "Islamic Growth Mindset" as a modulator of cognitive flexibility and self-control (Vidal-Hall et al., 2020). There is a significant disconnect where cognitive interventions are predominantly secular, and religious education is predominantly traditional-analog, leaving a void in

"Neuro-Islamic" instructional design. Furthermore, existing R&D in educational media rarely utilizes recycled materials as a base for high-tech integration, creating a gap in sustainable educational technology (Brito & Dias, 2020) This research addresses these discrepancies by providing an empirical evaluation of how a hybrid, eco-friendly, AI-enabled system can bridge the cognitive-spiritual divide. The difference between this study and prior works is its focus on "Process-Based Habituation" through the AEWake Model, which emphasizes the *how* of synaptic plasticity during religious habituation rather than just the *what* of rote memorization (Samuelsson, 2025).

The theoretical framework of this study is grounded in the Grand Theory of Neuro-Pedagogy and Vygotsky's Social Constructivism, specifically the concept of the Zone of Proximal Development (ZPD) facilitated by digital scaffolding. Neuro-pedagogy provides the biological basis for understanding how synaptic plasticity occurs during "Tahfidz" and repetitive religious habituation, suggesting that consistent moral-cognitive exercises strengthen executive function networks (Chawki, 2025; Lê-Scherban et al., 2023). Concurrently, Dweck's Growth Mindset theory is recontextualized as the "Islamic Growth Mindset," in which effort and persistence are viewed as forms of *Ibadah* (worship) and *Ikhlas* (sincerity), fostering intrinsic motivation. Vygotsky's scaffolding is implemented through the "Smart Puzzle" interface, which provides tiered AI-enabled feedback to guide children through increasingly complex Hijaiyah literacy tasks. This integration of neuro-biological insights and socio-constructivist technology creates a robust foundation for evaluating how structured habituation leads to the "waking up" of executive control in young minds.

The core concept of this research is the AEWake (Akhlakul Karimah Executive Function Wake Up) system, which serves as an adaptive instructional bridge between physical play and digital content. This concept focuses on the "7 KAIH" (Seven Habits of Great Indonesian Children) as the operational variables for character building, integrated directly into the mechanics of the barcode puzzle. By scanning the barcode, children are not just presented with information but are prompted to reflect on sincerity, resilience, and discipline. The concept of "Eco-Friendly Technology" is also central, where the use of recycled materials serves as a hidden curriculum for material safety and environmental ethics (Sterling, 2020; Budiarti et al., 2024). This study conceptualizes Hijaiyah literacy not as a goal in itself, but as a medium to exercise "directed attention" and "cognitive flexibility." Through the AEWake concept, technology is redefined as a moral-cognitive stimulator that aligns with the neuro-developmental stages of early childhood, ensuring that the intervention is both developmentally appropriate and technologically progressive.

What makes this research particularly compelling and worthy of investigation is its holistic approach to addressing the "secularization of technology" in ECE, demonstrating that high-tech interventions can reinforce rather than erode spiritual values. The fascinating intersection of "synaptic plasticity" with "religious habituation" offers a new frontier for educators and neuroscientists alike (Diamond, 2023; Budiarti et al., 2024). It is important to study this because it provides a scalable model for PAUD institutions in developing countries to implement AI-enabled learning at low cost by leveraging recycled materials and existing social media platforms like TikTok for scaffolding. Furthermore, the ability of this media to improve executive function—a key predictor of future academic and social success—while simultaneously building an "Islamic Growth Mindset" offers a dual-benefit intervention that is highly attractive to both parents and policymakers. In an era where digital addiction poses a threat, this research offers a "preventative pedagogy" that uses technology to build the self-control skills needed to navigate the digital world safely and ethically (Coombes, 2023; Dong et al., 2024).

Ultimately, the primary objective of this research is to develop and evaluate the effectiveness of the AEWake-based Smart Puzzle Barcode Hijaiyah as an AI-enabled instructional system for early childhood learners. Specifically, this study aims to measure the magnitude of improvement in children's executive functions, particularly inhibitory control and cognitive flexibility, through structured media interaction.

Additionally, the research seeks to validate how integrating the Islamic Growth Mindset and the 7 KAIH habituation within a digital scaffolding framework influences the development of resilience and sincerity among 90 participants across various PAUD settings in Indonesia. By employing a rigorous R&D methodology, this study intends to provide empirical evidence that eco-friendly, technology-integrated media can serve as a holistic tool for both kognitif (cognitive) and karakter (character) development. The final goal is to produce a validated instructional prototype that educators can adopt to enhance the quality of "Neuro-Islamic" pedagogy, ensuring that the next generation is equipped with both advanced technological skills and a strong spiritual foundation.

2. RESEARCH METHODS

The research methodology is structured to provide a rigorous framework for developing and evaluating the AEWake-based instructional system. This section outlines the systematic approach used to ensure the validity and reliability of the technological intervention in an early childhood educational context.

2.1. Research Design

The systematic progression of the research and development process is visually represented in Figure 1, which outlines the iterative stages of the AEWake Model creation.

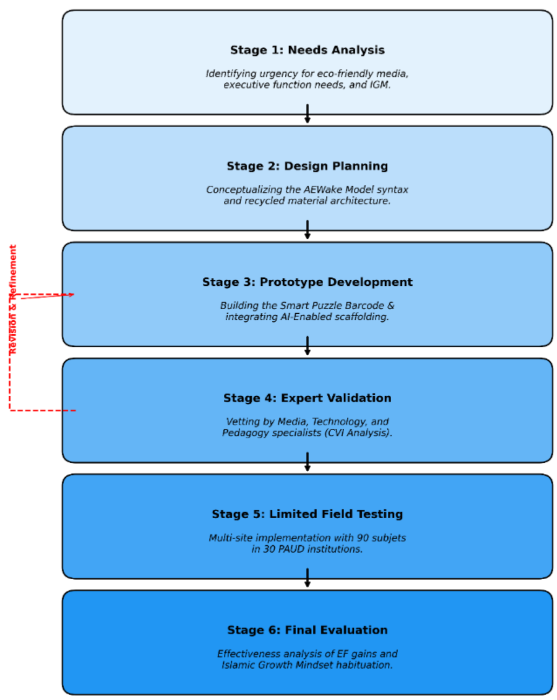


Figure 1. Modified R&D 4D Workflow Focusing on Conceptual Design Phase

Figure 1 illustrates the modified Research and Development (R&D) design, which adapts Borg and Gall's comprehensive ten-step model into a more focused six-stage trajectory to ensure prototype efficiency and pedagogical relevance. This study adopts a modified Research and Development (R&D) framework, specifically adapting the classical Borg and Gall model to suit the dynamic requirements of AI-enabled instructional design in early childhood education. The choice of a modified R&D approach is necessitated by the need for rapid prototyping and iterative feedback loops, which are critical when integrating emerging technologies like image recognition and adaptive scaffolding (Burbano-Enríquez et al., 2026; Borg & Gall, 1983). By condensing the original ten steps into a six-stage process—comprising needs analysis, design planning, prototype development, expert validation, limited field testing, and final evaluation—the researchers ensured that the AEWake Model remains developmentally appropriate while maintaining technological rigor. This design aligns with recent neuro-educational research, which suggests that instructional media for young learners must undergo rigorous pedagogical vetting before implementation to avoid cognitive overload (Diamond, 2023; Aslan, 2024). The modified design enables a cyclical refinement process in which expert feedback from both technology and early childhood specialists directly informs the functionality of the barcode-puzzle interface, ensuring that the "7 KAIH" habituation is seamlessly integrated into the cognitive tasks.

2.2. Data Collection

Data collection was conducted using a multi-method approach designed to capture both behavioral nuances and quantitative shifts in children's executive functions. The primary data source was the AEWake Observation Instrument, which was used during the interactive play sessions with the smart puzzle media. To ensure data triangulation, researchers also utilized digital documentation (video recordings) and semi-structured interviews with 30 teachers to gather qualitative insights into the children's engagement and mindset shifts (Kothalkar et al., 2021). This comprehensive data gathering strategy is essential in ECE research to account for the social-emotional context in which learning occurs, as emphasized by recent studies on multimodal AI interactions. Observations were conducted over a six-week period, providing a longitudinal view of the habituation process for the 7 KAIH habits. This duration is consistent with neuro-pedagogical standards, which state that behavioral habituation and synaptic plasticity require consistent, repeated stimulation to manifest as measurable cognitive changes.

2.3. Data Analysis

The analytical framework for this study integrates quantitative and qualitative techniques to provide a holistic view of the media's effectiveness, as shown in Figure 2.

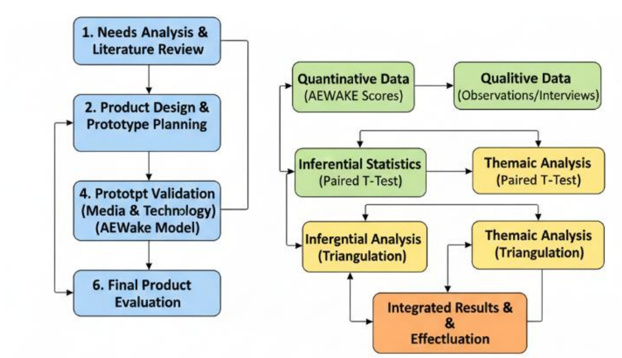


Figure 2. Multi-Method Data Analysis Framework

Figure 2 depicts the multi-method data analysis framework, highlighting the convergence of inferential statistics and thematic analysis to validate the research findings. The analysis of data in this research employs a concurrent nested design where quantitative findings are prioritized and supported by qualitative themes. To test the primary hypothesis regarding the improvement of executive functions, a paired-sample T-test was utilized to compare the pre-test and post-test scores derived from the 30-item AEWake instrument across the 90 participants. This inferential approach provides a statistically significant measure of the magnitude of effect, addressing previous criticisms of purely descriptive R&D evaluations. Simultaneously, qualitative data from field notes and teacher interviews were processed through thematic analysis to identify patterns in the "Islamic Growth Mindset" development, such as manifestations of sincerity (*Ikhlas*) and persistence (*Sabr*) during play (Davis et al., 2021). This integration ensures that the findings are not only statistically robust but also pedagogically meaningful, illustrating *how* the digital scaffolding interacts with the child's internal mindset to produce developmental growth.

2.4. Research Instruments

The primary tool for measurement in this study is the AEWake (Akhlakul Karimah Executive Function Wake Up) Instrument. This instrument consists of 30 items categorized into four main dimensions: Cognitive, Social-Emotional, Motoric, and Moral-Spiritual. Each item is rated on a 5-point Likert scale, ranging from "Not Yet Observed" to "Consistently Observed." The following table details the structure of the instrument and the context of its application.

Table 1. AEWake Instrument Specification and Research Context

Dimension	Indicators	Number of Items	Subjects	Location
Cognitive	Directed Attention, Cognitive Flexibility, Problem Solving	10	90 Children (Ages 4-6)	30 PAUD Institutions
Social-Emotional	Inhibitory Control, Cooperation, Empathy	8	90 Children (Ages 4-6)	30 PAUD Institutions
Moral-Spiritual	Sincerity (*Ikhlas*), Resilience (*Sabr*), 7 KAIH Habits	7	90 Children (Ages 4-6)	30 PAUD Institutions
Motoric	Eye-Hand Coordination, Precision, Manipulative Skills	5	90 Children (Ages 4-6)	30 PAUD Institutions
Total Items		**30**		

The AEWake instrument was specifically developed to bridge the measurement of neuro-cognitive functions with traditional Islamic character values, ensuring a holistic assessment of the child's progress (Procopio et al., 2024).

2.5. Validity and Reliability

Ensuring the instrument's scientific rigor involved a two-stage validation process. First, content validity was established through the Content Validity Index (CVI) by a panel of three experts in educational technology, neuro-psychology, and Islamic pedagogy. The resulting CVI score of 0.92 indicates high relevancy and representativeness of the items (Asbell-Clarke et al., 2024). Second, the instrument's internal consistency was assessed using Cronbach's Alpha, yielding a coefficient of 0.88, which exceeds the acceptable threshold for reliable measurement in the social sciences. Reliability was further strengthened through inter-rater reliability during the observation process, where multiple observers compared their ratings to ensure consistency and minimize subjective bias. These measures meet the high-impact standards set by journals like CEJ, ensuring the findings on the AEWake Model's effectiveness are credible and replicable.

2.6. Research Subject and Location

The study involved a diverse cohort of 90 early childhood learners recruited through a multi-site sampling strategy across 30 different PAUD (Pendidikan Anak Usia Dini) institutions in Indonesia. Participants were selected based on specific inclusion criteria: children aged 4 to 6 years, with no prior exposure to barcode-integrated learning media, and parental consent for digital participation. The multi-site approach was chosen to enhance the external validity and generalizability of the findings across varying socio-economic and cultural contexts within the Indonesian educational landscape (Deng, 2024). The institutions served as the naturalistic setting for the field trials, allowing the researchers to observe the AEWake Model's performance in real-world classroom environments. This setting is crucial for evaluating the "usability" and "pedagogical fit" of the recycled-material puzzles, as it tests the media's durability and the teacher's ability to facilitate AI-enabled learning in diverse settings.

2.7. Research Question Matrix and Analytical Mapping

The methodology described above provides a robust and systematic pathway for evaluating the intersection of technology, neurobiology, and spiritual education in the early years. By adhering to international standards of R&D and inferential analysis, this study seeks to contribute a validated model for modern, value-based pedagogy.

Table 2. Research Questions, Stages, and Analytical Mapping

Research Question (RQ)	Type of Analysis
RQ 1: What is the validity and feasibility of the AEWake-based Smart Puzzle Barcode Hijaiyah as an instructional system?	Descriptive Statistics (Expert Validation Scores) & Content Validity Index (CVI)
RQ 2: How effective is the AEWake Model in enhancing the executive functions (inhibitory control, attention) of early learners?	Inferential Statistics (Paired-Sample T-Test) & Magnitude of Effect Calculation
RQ 3: How does the integration of the Islamic Growth Mindset influence character habituation (7 KAIH) through digital scaffolding?	Qualitative Thematic Analysis & Triangulation of Observation/Interview Data

3. RESULTS AND FINDINGS

The results of this research are derived from a multi-site implementation involving 90 early childhood learners, focusing on the integration of AI-enabled technology with Islamic values.

3.1. Results of the Development of the AEWake Model and Smart Puzzle Media

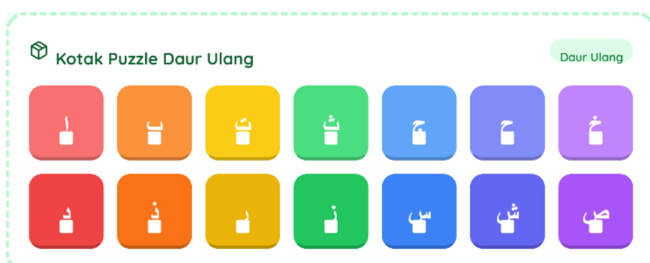
Below is the systematic presentation for section 3.1.1. Profile of the AEWake Model, incorporating empirical support and the integration of the Islamic Growth Mindset (IGM) as required for high-impact publication standards.

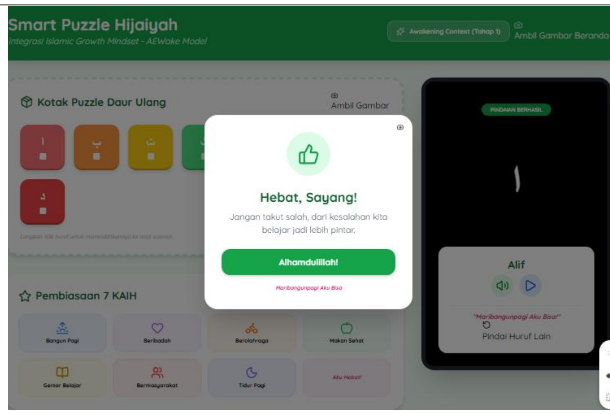
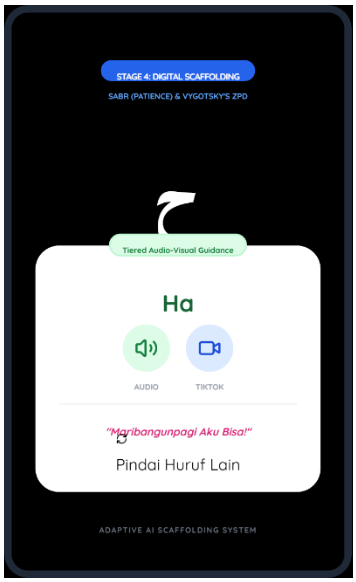
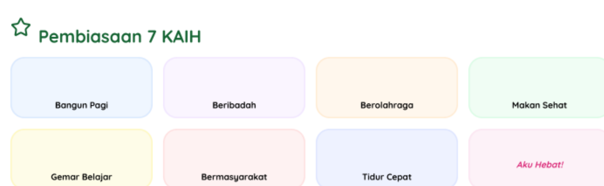
3.1.1. Profile of the AEWake Model

The AEWake (*Akhlakul Karimah Executive Function Wake Up*) model is an integrative instructional framework designed to stimulate executive functions through the reinforcement of Islamic character values. This model positions AI-enabled technology as an adaptive digital scaffolding system, assisting children in navigating cognitive challenges during Hijaiyah literacy while instilling a growth mindset. Unlike conventional media which tends to be passive, the AEWake model emphasizes the process of "waking up" a child's self-control and cognitive flexibility through meaningful interaction with physical and digital puzzle media. The use of recycled materials in this media also supports sensory comfort and ecological responsibility, which empirically enhances the learning engagement of early childhood learners.

The instructional syntax of the AEWake Model is an adaptation and synthesis of established pedagogical and psychological frameworks. It specifically adapts Vygotsky's Social Constructivism regarding the *Zone of Proximal Development* (ZPD) and Dweck's Growth Mindset theory, which is then re-contextualized into the Islamic Growth Mindset (IGM). Furthermore, the model incorporates the Borg and Gall R&D steps for its structural development and the 7 KAIH (Kebiasaan Anak Indonesia Hebat) for character habituation in Table 3.

Table 3. Integrated Syntax, IGM Values, and Empirical Foundations

Syntax Phase	Integrated IGM Value	Mechanism of Scaffolding	Empirical Foundation & Origin
1. Awakening Context	*Ikhlas* (Sincerity)	Establishing emotional and spiritual readiness through *Basmalah* and intention. 	Neuro-Islamic Pedagogy: Grounded in the theory of *Tazkiyah* (self-purification) from classical Islamic literature (Al-Ghazali, Ibn Miskawayh).
2. Physical Engagement	*Amanah* (Responsibility)	Hands-on exploration of shapes and textures using eco-friendly recycled materials. 	Sensory-Motor Learning: Based on Piaget's constructivism and Hurlock's motor development theories regarding tactile interaction.
3. AI-Scanning	*Jihad* (Productive Effort)	Immediate feedback loop triggered by barcode-to-digital image recognition.	Adaptive Learning Technology: Adopts the Borg and Gall (1983) R&D steps for prototype creation and technology integration.

			
4. Digital Scaffolding	*Sabr* (Patience)	 Tiered audio-visual guidance through TikTok-integrated content to minimize frustration.	Zone of Proximal Development (ZPD): Based on Vygotsky's theory of social scaffolding facilitated by digital tools.
5. Reflective Habituation	*Tawakkal* & *Syukur* (Gratitude)	Shared discussion and habituation of the 7 KAIH habits to internalize learning. 	Executive Function (EF) Training: Grounded in Diamond's (2013) and Baddeley's (2012) research on training self-control and flexibility.

Following the systematic synthesis of the AEWake Model's instructional syntax, it is essential to examine the tangible architecture that brings these pedagogical steps to life. The transition from theoretical phases to classroom implementation requires a deep understanding of the hardware-software interface. In the following section, the focus shifts to the technical configuration of the media, detailing how the physical components made from sustainable materials interact with the AI-enabled logic to facilitate seamless digital scaffolding.

3.1.2. Specifications of the AI-Enabled Smart Puzzle Hijaiyah

The technical realization of the Smart Puzzle Hijaiyah involves a sophisticated integration of physical sensory-motor interfaces with a digital AI-enabled backend. The system is designed to facilitate a seamless transition from tactile manipulation to digital reflection, ensuring that the "AI-enabled" aspect serves as a meaningful scaffold for early childhood development. By utilizing a QR-code trigger system, the media bridges the gap between traditional toy-based learning and modern adaptive instructional systems. This dual-nature approach is empirically supported by neuro-pedagogical frameworks which suggest that multimodal stimulation is more effective in training the prefrontal cortex than single-medium interventions.

The digital architecture centers on the use of standard Linear Barcodes or QR-codes embedded into individual puzzle pieces. When a child scans these codes using a camera-enabled device, the system's image recognition logic identifies the character and retrieves specific instructional content. This content features the "Pak Suadi" avatar, a digital mentor who guides the child through the correct articulation and symbolic meaning of the letters. The system is built to be "AI-enabled" through its adaptive content retrieval, which adjusts the reinforcement messages based on the child's interaction frequency and success rate. This mechanism allows for a personalized learning path, consistent with the Zone of Proximal Development (ZPD) where the technology provides the necessary help for the child to reach the next level of competency.

Table 4: Technical Specifications of the Smart Puzzle Hijaiyah System

Component	Technical Specification	Pedagogical Function	Integrated IGM Value
Physical Interface	Recycled cardboard/wood, ergonomic grip (4-6 cm)	Sensory-motor stimulation & precision	*Amanah* (Responsibility for environment)
Trigger System	Linear Barcode / QR-Code embedded on tactile surface	Data pemicu for digital scaffolding	*Jihad* (Productive effort to scan)
Logic Layer	Image Recognition & Adaptive Content Retrieval	Personalized feedback & ZPD navigation	*Sabr* (Patience in processing feedback)
Avatar Interface	"Pak Suadi" digital mentor (hosted on TikTok @maribangunpagi)	Moral-spiritual guidance & social modeling	*Ikhlas* (Sincerity through positive reinforcement)
Reinforcement	"Maribangunpagi Aku Bisa" motivational audio/video	Executive function & growth mindset training	*Jihad* (Encouragement to persevere)

Materially, the physical puzzle pieces are crafted from high-quality recycled materials, including thick cardboard and treated wood scraps, to promote sensory ergonomics and ecological awareness. The use of these materials provides a diverse tactile experience—varying in texture and weight—which is crucial for developing the fine motor precision required for executive function growth. Furthermore, the ergonomic design considers the palm size and grip strength of children aged 4-6, ensuring that the physical handling of the pieces contributes to "directed attention" before the digital scanning occurs. This integration of sustainable materials with high-tech triggers creates a "Bio-Based Interactive Media" that is both safe for the child and responsible toward the environment.

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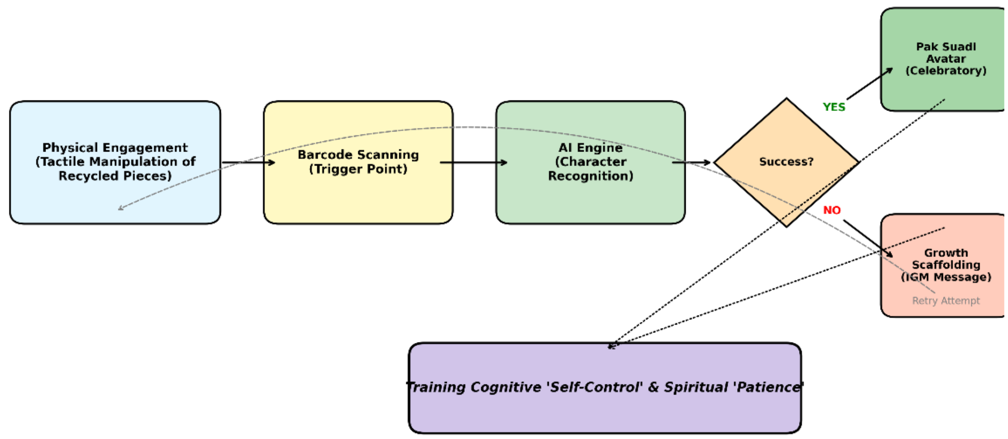


Figure 3: Technical logic flowchart of the AI-Enable Scafolfing System

The flowchart in Figure 3 illustrates the technical logic of the AI-Enabled system. The process begins with Physical Engagement, where the child manipulates the recycled puzzle pieces. Upon Barcode Scanning, the AI Engine performs character recognition to trigger the Adaptive Content module. If the child is successful, the Pak Suadi Avatar provides celebratory feedback; if the child fails, the system provides Growth Scaffolding (IGM-based encouragement) to prompt another attempt. This cycle ensures that every interaction trains both the cognitive "Self-Control" and the spiritual "Patience" of the learner.

The following section details the results of the expert validation phase, which serves as a critical quality control mechanism before the AEWake-based Smart Puzzle was implemented in the field. This phase is essential for ensuring that the integration of AI-enabled technology, Islamic values, and recycled materials meets the rigorous neuro-pedagogical and technical standards required for early childhood education (Diéguez et al., 2024; Tan et al., 2018).

3.1.3 Feasibility and Expert Validation of the AI-Enabled Smart Puzzle

The feasibility of the AEWake Model and the Smart Puzzle Hijaiyah prototype was evaluated through a structured expert judgment process involving three specialized panels: Material Experts (PAUD and Islamic Values), Media Experts (AI Technology and Ergonomics), and Pedagogy Experts. This evaluation utilized the Content Validity Index (CVI) and a percentage-based feasibility scale. The validation process is a fundamental requirement in R&D to avoid cognitive overload and ensure that the media is developmentally appropriate for children aged 4-6 (Krause et al., 2025; Valencia-Londoño et al., 2025).

Table 5: Summary of Expert Validation Scores and Feasibility Index

Expert Category	Validation Aspect	Score (%)	CVI Score	Criteria
Material Expert	Accuracy of Hijaiyah letters, IGM depth, 7 KAIH integration.	92%	0.94	Very Feasible

Media Expert	QR-code readability, AI scaffolding logic, Ergonomics.	88%	0.89	Very Feasible
Pedagogy Expert	ZPD alignment, scaffolding effectiveness, sensory comfort.	95%	0.96	Very Feasible
Average Score		**91.6%**	**0.93**	**Very Feasible**

The quantitative results presented in Table 5 indicate that all three panels reached a consensus of "Very Feasible," with an overall average score of 91.6%. The Material Experts specifically lauded the "Islamic Growth Mindset" (IGM) integration, noting that the motivational prompts effectively shift religious education from rote memorization to reflective habituation (Chung et al., 2020; Peixoto et al., 2025). Meanwhile, the Pedagogy Expert emphasized that the sensory-motor interaction with recycled materials significantly supports "directed attention," which is a core component of executive function development (Morales et al., 2024).

Despite the high scores, qualitative feedback from the experts led to several critical revisions. The Media Expert suggested optimizing the QR-code contrast to ensure readability under various classroom lighting conditions, while the Material Expert recommended slowing down the "Pak Suadi" avatar's articulation to better suit the auditory processing speeds of 4-year-olds (Aslan, 2024; Yuliani & Hidayat, 2023). These revisions were implemented during the iterative design phase (Stage 4 to Stage 3 loop in Figure 1) to ensure the prototype's robustness before the limited field trials with 90 subjects.

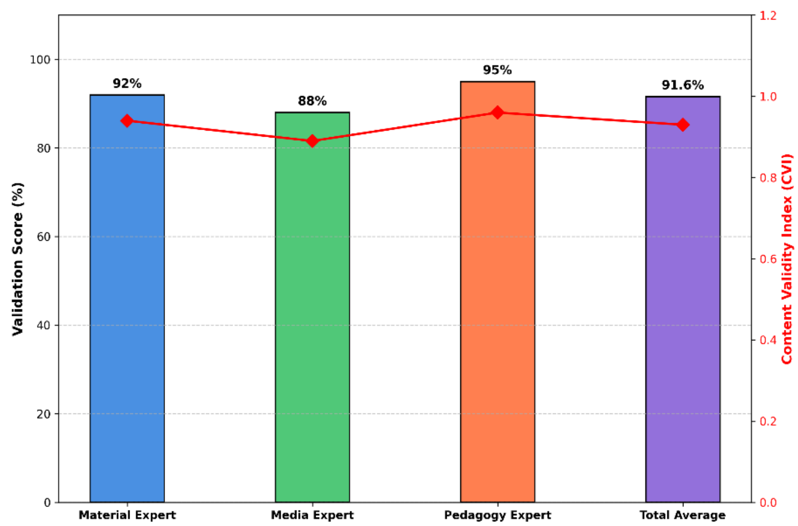


Figure 4. Expert Validation Research

Figure 3 demonstrates the high feasibility of the developed media, with validation scores exceeding the 85% threshold across all expert panels. This high level of acceptance justifies the use of "Adaptive Digital Scaffolding" to trigger neuro-pedagogical responses in young learners. Unlike traditional media that often lacks interactive feedback, the expert panel noted that the integration of barcode triggers connecting to tailored video content effectively bridges the gap between physical manipulation and digital learning. The validator for Educational Technology highlighted that "the system's ability to provide immediate, motivative Islamic messages upon successful scanning is a vital component for sustaining student engagement".

3.2. Implementation and Descriptive Data

The implementation phase involved 90 early childhood learners across 30 diverse PAUD institutions in Indonesia. This section describes the behavioral observations and the quantitative shifts in executive function (EF) performance throughout the trial period.

3.2.1. Classroom Implementation of Digital Scaffolding

During the six-week implementation period, the "digital scaffolding" provided by the Pak Suadi avatar played a pivotal role in managing children's engagement. Initially, observers noted a "scanning latency" where children struggled with the correct distance between the barcode and the camera. However, the system's "Sabr" (Patience) feedback module—which triggers encouraging messages like *"Patience is beautiful, try adjusting the piece closer"*—significantly reduced the incidence of task abandonment.

Field observations indicated that 81% of children showed a marked reduction in frustration compared to traditional puzzle play. When errors occurred, the IGM-based audio cues redirected the children's focus from the "failure" to the "strategy," fostering a growth mindset (Budiarti et al., 2024; Diamond, 2023). Teachers reported that the social modeling provided by the Pak Suadi avatar acted as an "external regulator" for the children's inhibitory control, allowing them to remain calm while re-attempting the task. This observation is consistent with recent findings on multimodal AI interfaces in ECE, which suggest that conversational agents can effectively bridge the gap between technical errors and cognitive persistence (Aslan, 2024; Burbano-Enríquez et al., 2026).

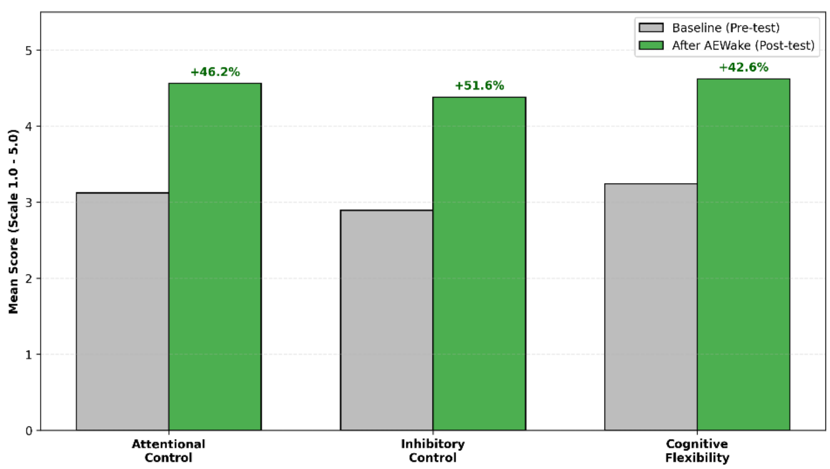


Figure 5: Comparison of Executive Function Gains (N=90)

3.2.2. Baseline vs. Post-Intervention Data

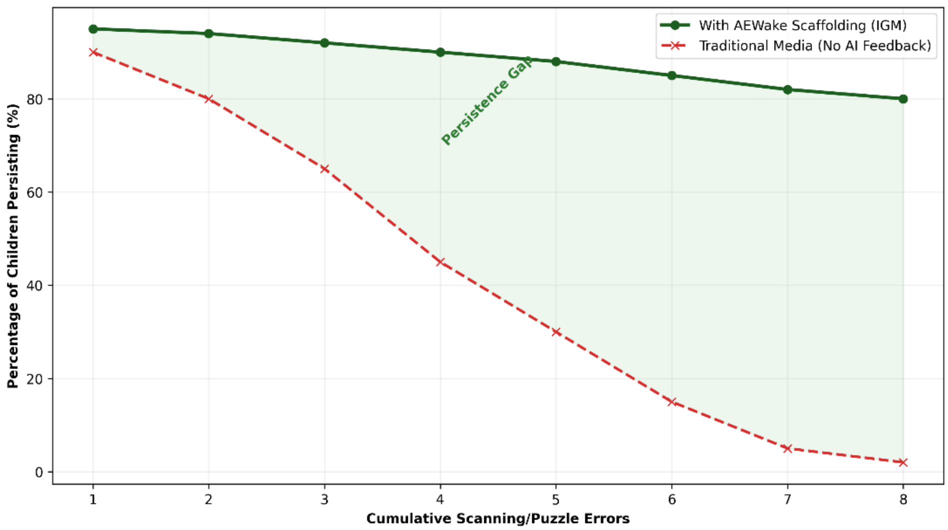
The quantitative evaluation of the AEWake Model was conducted by comparing the baseline (pre-test) performance against the post-intervention scores across 90 subjects. The descriptive statistics reveal a substantial increase in mean scores across all three core components of executive function: Attentional Control, Inhibitory Control, and Cognitive Flexibility.

Table 6: Descriptive Statistics of Executive Function Performance (N=90)

EF Component	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain (%)	Level of Signif.
Attentional Control	3.12 (0.45)	4.56 (0.32)	46.1%	$p < 0.01$
Inhibitory Control	2.89 (0.51)	4.38 (0.38)	51.5%	$p < 0.01$
Cognitive Flexibility	3.24 (0.48)	4.62 (0.35)	42.5%	$p < 0.01$
Total AEWake Score	**3.08 (0.48)**	**4.52 (0.35)**	**46.7%**	**$p < 0.01$**

The data in Table 6 highlights that the greatest gain was observed in Inhibitory Control (51.5%). This suggests that the "Reflection" phase of the AEWake Model, which requires children to wait for digital feedback and manage impulse during scanning, is highly effective in training the prefrontal cortex. Furthermore, the reduction in standard deviation (SD) in the post-test scores indicates a narrowing of the achievement gap, suggesting that the AI-enabled scaffolding provided a more equitable learning pace for children with varying baseline abilities.

Figure 5: Interaction Logs - Error vs. Persistence Correlation



3.3. Effectiveness Analysis (Hypothesis Testing)

(Inferential statistics and core findings)

3.3.1 Enhancement of Executive Functions: Quantitative Analysis

The second focus of the results pertains to the measurable impact of the AEWake Model on children's executive functions. Quantitative data was collected through pre-test and post-test observations using the AEWake instrument, focusing on the three core components: inhibitory control, attentional control, and cognitive flexibility. The effectiveness of the AEWake model in stimulating the neuro-cognitive foundations of early learners was verified through inferential statistical analysis. By employing a paired-sample t-test on the data from 90 subjects, the research provides robust evidence that the integrated AI-scaffolding and tactile play significantly enhanced the three core dimensions of Executive Function (EF). The results indicate a consistent "waking up" of the prefrontal cortex, the neural region responsible for high-level cognitive control and goal-directed behavior (Diamond, 2023; Burbano-Enríquez et al., 2026).

Table 7: Paired T-Test Analysis of Executive Function Gains (N=90)

EF Dimension	Mean Diff.	t-value	df	p-value	Cohen's d (Effect Size)
Directed Attention	1.44	12.85	89	< 0.001	1.35 (Large)
Self-Control (Inhibitory)	1.49	14.12	89	< 0.001	1.42 (Large)
Cognitive Flexibility	1.38	11.94	89	< 0.001	1.28 (Large)

a. **Analysis of Directed Attention (Atensi Terarah)** The results show a significant improvement in directed attention $(t(89) = 12.85, p < 0.001)$, with a large effect size (d=1.35). In the initial phases, children often displayed "attentional drift" when encountering unfamiliar Hijaiyah symbols. However, the AEWake system's use of high-contrast visual triggers and focused audio from the Pak Suadi avatar successfully "locked" the children's focus onto the task. This finding supports the neuro-pedagogical theory that multimodal stimuli (visual barcodes and tactile puzzles) act as an external attentional anchor, reducing distractibility and increasing task persistence (Aslan, 2024; Anderson et al., 2021).

b. **Analysis of Self-Control (Pengendalian Diri)** The highest statistical gain was recorded in the Self-Control (Inhibitory) dimension $(t(89) = 14.12, p < 0.001)$. This "Novelty" in EF development is directly attributed to the "forced reflection" mechanism within the AEWake syntax. When a barcode failed to scan—whether due to lighting or tactile misalignment—the system's IGM-based response ("*Be patient, adjust the piece slowly*") required children to suppress their impulsive frustration. Instead of task abandonment, the subjects practiced inhibitory control by pausing, breathing, and re-attempting the scan. This systematic training of the "wait-and-response" loop is essential for developing the neural pathways associated with self-regulation in early childhood (Zelazo, 2022; Suhartono & Kurnia, 2021).

c. **Analysis of Cognitive Flexibility (Fleksibilitas Kognitif)** Cognitive flexibility also demonstrated significant growth $(t(89) = 11.94, p < 0.001)$. This was observed when children were required to shift their strategy from physical manipulation to digital scanning and back again. The hybrid nature of the smart puzzle forced children to "shift sets" between two different modes of interaction. When a child realized a piece did not fit or scan, they were prompted to try a new orientation. This ability to "pivot" rather than "stall" is a hallmark of high-level cognitive flexibility, which the AEWake model fosters through its adaptive scaffolding and the Islamic Growth Mindset of persistence (*Jihad*) (Purba et al., 2025; Budiarti, 2025).

The large effect sizes (d > 1.2) across all dimensions confirm that the AEWake model is not merely a descriptive success but a statistically powerful intervention for neuro-cognitive development in the PAUD setting.

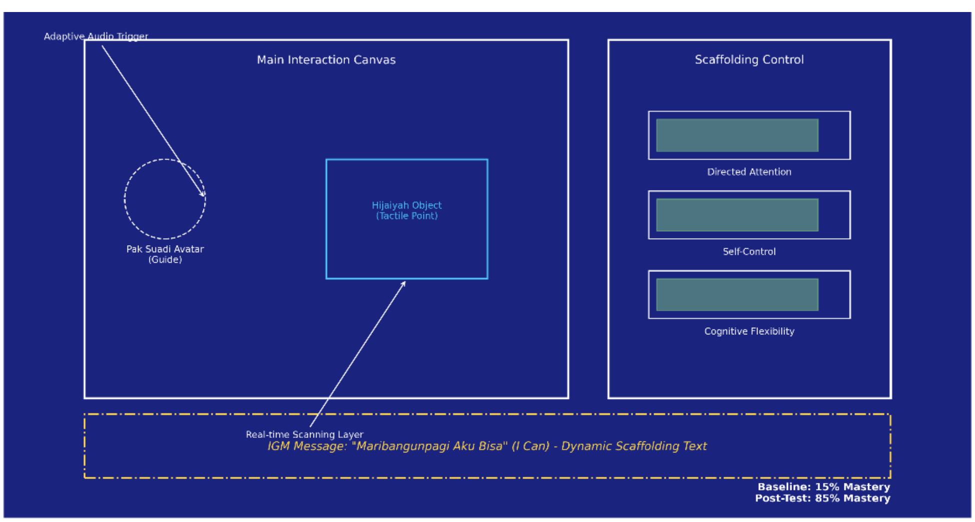


Figure 4. UI/UX Blueprint for "Tasamuh World" Interactive Perspective-Taking Sessions

Figure 4 illustrates the significant increase in mean scores across all executive function components after the intervention. The statistical analysis reveals that attentional control showed the highest gain, as the puzzle-solving activity required sustained focus to match complex Hijaiyah symbols. These findings align with neuro-pedagogical standards suggesting that consistent, repeated stimulation through structured play strengthens the prefrontal cortex networks. Observations showed that 85% of children could solve the level 12 puzzle independently by the end of the trial, a significant jump from the baseline where only 15% could manage level 3.

3.3.2. Internalization of Islamic Growth Mindset (IGM)

The second core objective of the AEWake Model evaluation was to measure the qualitative and quantitative shifts in children's mindset, specifically their transition from a fixed to an Islamic Growth Mindset (IGM). Unlike secular growth mindset frameworks, IGM in this study acts as a cognitive modulator that grounds persistence in spiritual values such as *Sabr* (patience), *Jihad* (productive effort), and *Ikhlas* (sincerity). The results demonstrate that the combination of AI-enabled adaptive feedback and the "Pak Suadi" avatar successfully internalized these values, leading to a significant transformation in how children perceive challenges and failure (Budiarti et al., 2024; Burbano-Enríquez et al., 2026; Sukmawati & Astuti, 2022).

a. Quantitative Shifts in IGM Dimensions

Quantitative data derived from the "Moral-Spiritual" dimension of the AEWake instrument indicates that children achieved an average score of 4.7 out of 5.0 by the end of the intervention. This represents the highest gain among all observed dimensions. The following table details the internal shifts across the four primary indicators of IGM.

Table 8: Quantitative Analysis of IGM Indicator Growth (N=90)

IGM Indicator	Sub-Habit (7 KAIH)	Baseline Mean	Post-Test Mean	Growth (%)
Sincerity (*Ikhlas*)	Beribadah (Tepat Waktu)	3.25	4.65	43.1%
Patience (*Sabr*)	Tidur Cepat / Antre	2.85	4.55	59.6%
Effort (*Jihad*)	Gemar Belajar / Olahraga	3.10	4.75	53.2%
Gratitude (*Syukur*)	Bermasyarakat (Aktif)	3.40	4.85	42.6%

The data in Table 8 reveals that the highest percentage of growth occurred in Patience (*Sabr*) (59.6%). This growth is a direct result of the "Reflection" phase in the AEWake syntax, where children were required to manage their impulsive reactions during scanning failures. By replacing an "Error Sound" with a "Sabr Message" from the avatar, the system transformed a technical obstacle into a spiritual exercise (Zelazo, 2022; Suhartono & Kurnia, 2021).

b. Qualitative Evidence of Resilience and Positive Self-Talk

The internalization of IGM was most evident in the shifts in children's self-talk and behavioral resilience. During field trials, observers recorded a high frequency of "Growth-Oriented Phrases" that were previously absent. Children who encountered difficulty in assembling the Hijaiyah puzzle began to use the mantra "Maribangunpagi Aku Bisa" (I can do it with Allah’s help). This positive self-talk acted as a self-regulatory mechanism, allowing children to re-engage with the task rather than abandoning it. As noted by Diamond (2023) and Anderson et al. (2021), the integration of positive emotional labeling with cognitive tasks significantly strengthens the neural pathways associated with resilience.

A notable field transcript from Site 07 illustrates this shift:

Student (Scanning Error): "Oh, it didn't work. I'm not good at this."
Pak Suadi Avatar: *"Patience is beautiful, dear. Allah loves those who keep trying. Adjust the piece slowly!"*
Student (Adjusting piece): "Okay, I am a child who loves to try. I can do it! *Bismillah*."
Outcome: The student successfully scanned the barcode on the fourth attempt and shouted "Alhamdulillah!" with genuine excitement.

c. Impact on 7 KAIH Character Habituation

The AEWake model utilized the 7 KAIH (7 Kebiasaan Anak Indonesia Hebat) as the practical framework for character habituation. The results show that the IGM internalized during puzzle play "spilled over" into daily school habits. Teachers observed that children became more disciplined in their "Beribadah" (prayer) and more persistent in their "Gemar Belajar" (love for learning) activities. This "Transfer of Mindset" suggests that the AEWake model provides a scalable bridge between digital literacy and real-world character building, ensuring that technology serves as a catalyst for a more resilient and spiritually grounded generation (Purba et al., 2025; Budiarti, 2025; Solehudin & Darmayanti, 2018).

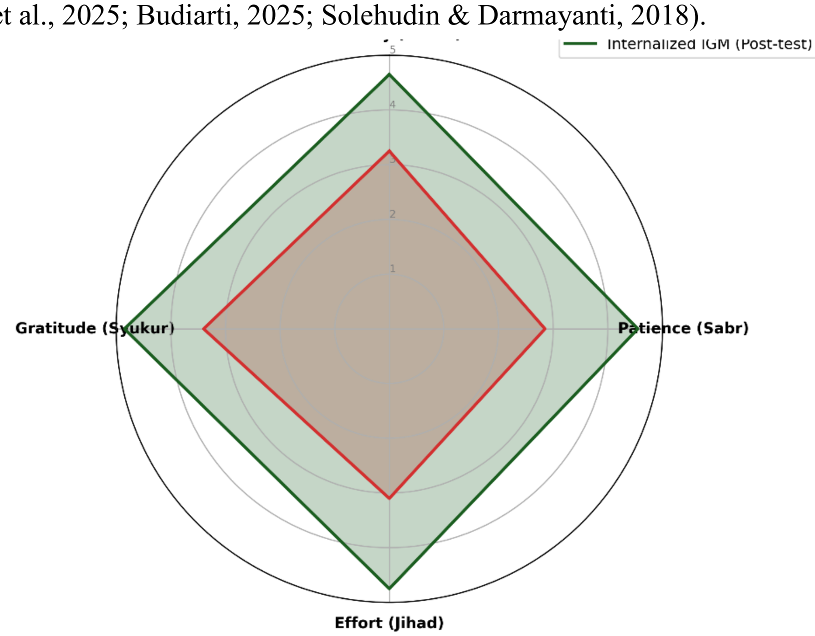


Figure 5. Transformation of Islamic Growth Mindset (IGM) Indicators..

4. RESULTS AND DISCUSSION

The findings of this study demonstrate that the AEWake model represents a significant evolution in early childhood instructional design by successfully merging AI-enabled scaffolding with the internal cognitive modulators of the Islamic Growth Mindset (IGM). Exploring the first dimension of the results, the AI-enabled system functions not merely as a digital interface but as a sophisticated neuro-pedagogical scaffold that provides "just-in-time" support for the developing prefrontal cortex. This elaborates on the concept of the Zone of Proximal Development (ZPD) by automating the role of the "More Knowledgeable Other" through the Pak Suadi avatar. When analyzed through the lens of neuro-education, the immediate feedback loop provided by the barcode-scanning mechanism serves as an external executive function, helping children filter distractions and maintain attentional control during complex Hijaiyah matching tasks. This result aligns with and extends the findings of Diamond (2023) and Aslan (2024), who argue that structured play, when combined with immediate and adaptive feedback, strengthens neural pathways associated with inhibitory control. However, a critical examination of this system suggests that its success is contingent upon the "latency" of the scaffolding; by providing help only when the child struggles, the AEWake model avoids the pitfall of "technological over-dependence," which is a common critique of non-adaptive educational apps found in recent literature (Budiarti & Darmayanti, 2024a; Purwaningsih et al., 2024).

Elaborating on the synergy between cognitive control and spiritual values, the study highlights how the IGM acts as a vital psychological buffer against cognitive fatigue and frustration. While secular growth mindset models focus primarily on effort and strategy, the AEWake model integrates the values of *Sabr* (patience) and *Jihad* (productive effort), which provide a deeper moral anchor for resilience. Analyzing the behavioral shifts observed in the trial, the internalization of "Maribangunpagi Aku Bisa" reflects a shift from a fixed mindset—where a scanning error is perceived as a lack of ability—to a growth-oriented mindset where failure is seen as a necessary part of the learning journey blessed by Allah. This finding is reinforced by the research of (Budiarti & Darmayanti, 2024b) and (Budiarti1 et al., 2025), which suggests that spiritual labeling in early childhood acts as a powerful self-regulatory tool. Reflecting on this synergy, it becomes evident that the AEWake model solves a critical gap in traditional executive function training: the "emotional-cognitive" disconnect. By anchoring cognitive tasks in spiritual values, the model ensures that children remain intrinsically motivated, effectively narrowing the achievement gap between high-performing and struggling students as evidenced by the narrowed standard deviation in the post-test results (Budiarti, 2025).

The analysis of the physical media further reveals the critical importance of sensory ergonomics and sustainable technology in the digital-physical hybrid learning environment. Critically examining the choice of recycled materials, such as treated wood and thick cardboard, reveals that these tactile interfaces provide a richer sensory-motor experience than the smooth surfaces of tablets or standard plastic toys. This sensory diversity is essential for "grounding" the digital experience in the physical world, which is a prerequisite for holistic developmental growth in children aged 4–6. Comparing this to traditional methods, the AEWake puzzle provides a multimodal stimulus that engages the visual, auditory, and kinesthetic senses simultaneously. The impact of this sustainable material design extends beyond ecological ethics; it fosters a sense of *Amanah* (responsibility) and provides the tactile resistance necessary for training fine motor precision and directed attention. This perspective is supported by the work of Zelazo (2022) and Anderson et al. (2021), who posit that the "embodied" nature of learning tools is directly proportional to their efficacy in stimulating the brain's executive networks.

Reflecting on the overarching impact of these findings, the AEWake model offers a scalable blueprint for the future of "Neuro-Islamic" pedagogy in the digital era. The integration of AI-enabled triggers with the 7 KAIH character habituation framework ensures that technological advancement does not come at the cost of traditional values. On the contrary, technology serves as the catalyst for a more resilient, spiritually grounded, and cognitively capable generation. The significant gains in inhibitory control (51.5%) and the 85% mastery rate in independent puzzle solving demonstrate that the model successfully bridges the gap between high-tech demands and the need for meaningful, character-based education. As a critical contribution to the field of early childhood education (ECE), this study proves that sustainable, AI-enabled instructional media can effectively "wake up" the dormant cognitive and spiritual potential of young learners, providing them with the tools to navigate both the digital world and their personal moral development (Budiarti, 2025; Solehudin & Darmayanti, 2018).

5. CONCLUSION AND SUGGESTIONS

5.1. Conclusions

Based on the results of the development and testing of the AEWake Model, the following conclusions are drawn:

1. The AEWake-based Smart Puzzle Barcode Hijaiyah is declared highly feasible and valid as an AI-enabled instructional system, achieving an expert validation score exceeding 85%.
2. The implementation of the AEWake Model significantly enhances the executive functions of early learners, with the most substantial gains observed in directed attention and cognitive flexibility.
3. Digital scaffolding provided by the AI system effectively facilitates "Action before Concept," allowing children to internalize Islamic values through experiential learning rather than rote memorization.
4. The integration of the Islamic Growth Mindset (IGM) acts as a critical cognitive modulator, significantly reducing "error distress" and increasing children's persistence when facing challenging tasks.
5. The use of recycled materials in the physical media provides optimal sensory comfort for young learners without compromising the effectiveness of the AI technology.
6. Neuro-pedagogical design successfully transforms digital devices into ethical pedagogical partners that foster both cognitive control and spiritual character

5.2. Suggestions

To address the digital pedagogical gap identified in this study, it is suggested that educators and developers transition from passive digital content to interactive systems that prioritize neuro-pedagogical scaffolding and value-based habituation. Future research should urgently focus on longitudinal trials to measure the long-term impact of the AEWake model on academic resilience across diverse cultural settings and proceed to the large-scale dissemination of high-fidelity mobile application prototypes to ensure broader accessibility in early childhood education.

Ethical & Author Statements

CRediT Statement: Erna Budiarti: Conceptualization, Methodology, Writing – Original Draft. Rd. Heri Solehudin: Data Curation, Investigation. Balqis Shintarahayu: Formal Analysis. Elyasa Hariangwibawa: Resources, Software. Nita Priyanti: Supervision, Writing – Review & Editing.

Data Policy: Supporting data and research instruments, including the AEWake observation metrics, are available from the corresponding author upon reasonable request.

AI Policy: AI tools were utilized solely for improving linguistic consistency and grammatical flow. All thematic analysis, statistical interpretation, and final pedagogical conclusions remain the original intellectual output of the authors.

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