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# INTEGRATING MONTESSORI, NEUROSCIENCE, AND ISLAMIC VALUES IN EARLY SCIENCE AND MATH LEARNING

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**ABSTRACT**
This paper explores the integration of the Montessori pedagogy and neuroscience principles in early childhood science and mathematics education through the lens of Islamic values. A key challenge in Indonesia is children's low interest in science and mathematics, often perceived as abstract and difficult, reflected in the nation's low global ranking. Neuroscience identifies early childhood a golden age for developing logical, critical, and exploratory thinking. The Montessori method, emphasizing concrete experiences and multisensory stimulation, enables children to construct abstract concepts through real-life activities (tarbiyah bil hal). Integrating with Islamic values further enriches the spiritual dimension, guided by Qur'anic principles encouraging humans to yatafakkar (reflect), yatadabbar (contemplate), ta'ammul (deep reflection), and yansur (observe) the order of Allah's creation. Moreover, this approach highlights the importance of education through lived example, so that children learn not only nurture intellect, emotion, and morality, allowing children to learn through heart, mind, and behavior. Using descriptive literature review of classical and contemporary sources of Montessori,-Neuroscience, and Islamic education. The findings indicate that a Montessori–Neuroscience–Islam integration stimulates cognitive development, while fostering spiritual awareness, it offers a holistic, integrative, and contextually relevant alternative for strengthening early childhood science and mathematics education in Indonesia.



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## 1. INTRODUCTION

Science and mathematics are fundamental pillars of early childhood cognitive development. These two fields not only equip children with basic numeracy and pattern-recognition skills, but also train logical, critical, and systematic thinking. However, results from the Programme for International Student Assessment (PISA) indicate that Indonesian children's literacy in science and mathematics remains low. Findings from PISA 2022 reveal that only 18% of Indonesian students reached the

minimum level of mathematics proficiency, compared to the OECD average of 69%. In science, only 34% achieved a similar level, far below the OECD average of 76% (OECD, 2023). This condition indicates a serious problem in foundational learning, which ideally should be strengthened from early childhood.

One contributing factor to these low achievements is the dominance of learning approaches that are overly abstract, rote-oriented, and lack connections to real-life experiences (OECD, 2023). As a result, science and mathematics are often perceived as difficult or even intimidating, especially when children are not provided with meaningful learning experiences. According to UNICEF, this issue can be addressed through learning through play (UNICEF, 2018), since early childhood is a golden age that determines the quality of cognitive development. The central challenge for early childhood education in Indonesia, therefore, is to identify approaches that can bridge abstract concepts with concrete experiences, making science and mathematics both enjoyable and meaningful (Lillard, 2005; Montessori, 2020).

The Montessori method offers a significant response to this challenge. Grounded in hands-on learning and multisensory stimulation, Montessori emphasizes that children learn best through activities involving their hands and senses rather than merely listening to verbal explanations. With the use of concrete materials such as number rods or golden beads, abstract mathematical concepts can be understood naturally (Montessori, 2007). Montessori also highlights the principle of auto-education, i.e. children's ability to educate themselves when provided with an appropriate learning environment (Montessori, 2021a). In this way, science and mathematics are no longer perceived as a burden, but rather as explorative activities aligned with children's natural curiosity.

Neuroscience provides scientific support for the effectiveness of this approach. Modern research shows that early childhood is a period of highest brain plasticity, when neural connections are formed rapidly (Knudsen, 2004; Kolb & Gibb, 2011; Shonkoff & Phillips, 2000). Appropriate stimulation during this phase strengthens memory, attention, and executive function. Sensorimotor activities such as counting objects, measuring liquids, or observing natural phenomena engage multiple brain regions, including the prefrontal cortex, which plays a role in logic and planning. Studies by Jensen (2005) and Sousa (2022) confirm that multisensory learning not only enhances understanding of abstract concepts but also improves memory retention. Thus, the Montessori approach is not only suitable for the learning needs of young children but also consistent with the natural mechanisms

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of brain development.

In the Indonesian context, integrating this approach cannot be separated from the Islamic values that shape children's environments. Education in Islamic early childhood institutions (PAUD Islam) aims not only to strengthen cognitive skills but also to nurture character, spirituality, and moral conduct (Purnama, 2021). Through Qur'anic verses that encourage humans to think and count, as well as the Prophet's ﷺ traditions on the importance of educating children from an early age, science and mathematics can be positioned not merely as rational knowledge but also as signs of God's greatness. Consequently, the integration of Montessori and neuroscience gains deeper relevance when practiced in Islamic educational settings: children learn to think logically while simultaneously developing spiritual awareness.

Based on this framework, this study seeks to address three key questions: (1) how to design early childhood science and mathematics learning using the Montessori approach, (2) how neuroscientific principles support the effectiveness of such learning, and (3) how Islamic values can be integrated to enhance its relevance in Indonesian early childhood education. In line with these questions, the purpose of this study is not to propose a new learning model but to examine and reaffirm that when Montessori, neuroscience, and Islam are combined, a more holistic, engaging, and contextually relevant approach to early childhood education can emerge.

While previous studies have examined Montessori pedagogy or neuroscience-informed early learning separately, few have systematically explored their integration within an Islamic educational framework. The novelty of this study lies in the integration of three key pillars that are rarely examined systematically in the literature: Montessori as a pedagogical methodology, neuroscience as a scientific foundation, and Islam as a moral and spiritual framework. This integrative approach has the potential not only to improve early childhood science and mathematics literacy but also to foster a generation that balances cognitive intelligence with spiritual depth. To answer these questions, this study adopts a literature review method, analyzing both classical and contemporary works on Montessori, neuroscience, and Islamic education.

## 1. METHOD

This study employs a qualitative approach using the library research method.

The primary sources of data consist of relevant primary and secondary literature, including classical works of (Montessori, 2021b), contemporary studies on the effectiveness of the Montessori method (Lillard, 2005), educational neuroscience research such as Jensen (2005) and Sousa (2022), as well as Islamic educational literature from both classical and modern scholars (e.g., Al-Ghazali, Ibn Khaldun, Abdullah Nashih Ulwan). Data were analyzed using a descriptive-analytical approach, examining the core concepts within each perspective and then integrating them to construct a conceptual framework for science and mathematics learning in early childhood. This framework is designed to be grounded in Montessori principles, reinforced by neuroscientific evidence, and contextualized within Islamic values. Through this approach, the study aims to provide a novel perspective on the integration of Montessori, neuroscience, and Islam in early childhood science and mathematics education.

## 2. RESULTS AND DISCUSSION

### 3.1. The Literacy Gap in Science and Mathematics

According to the PISA 2022 report, Indonesia's performance in science and mathematics literacy remains far below expectations. Only about 18% of Indonesian students achieved the minimum level of mathematical proficiency, while the OECD average reached 69%. A similar picture emerges in science, where Indonesia recorded 34%, compared to the OECD average of 76% (OECD, 2023). These figures signal that the majority of Indonesian children have yet to master critical and analytical thinking skills, which are the foundation of these two fields. As Trilling & Fadel (2009) argue, critical thinking, analytical reasoning, problem-solving, and creativity form the core of 21st-century competencies.

This condition is not new. Since the first waves of PISA assessments in 2018, Indonesia's scores have fluctuated with no significant breakthrough. Meanwhile, neighboring countries such as Singapore and Vietnam have soared to the top global ranks. Even Malaysia, historically facing similar educational challenges as Indonesia, has gradually moved ahead. This phenomenon creates a paradox: despite Indonesia's massive student population and steadily increasing education budget, the quality of basic literacy remains stagnant (Risza, 2025).

Why is this the case? One explanation lies in the way science and mathematics are treated in classrooms. They are often perceived as "formula memorization" or "test drills," rather than as tools to explore the real world (Boaler, 2016). From an early age, children are exposed to numbers and symbols that feel alien, without experiences that truly spark their curiosity (Bruner, 1961). It is unsurprising, then,

that many children grow up with anxiety and the belief that mathematics and science are difficult, intimidating, or reserved only for the so-called "smart kids" (OECD, 2019).

The consequences are long-term. Children who lack strong foundations in numeracy and science at an early age struggle to cope with advanced learning. Beyond the classroom, these weaknesses extend into the workforce, where problem-solving ability, logical reasoning, and technological literacy are essential (Trilling & Fadel, 2009). In the context of the Fourth Industrial Revolution, such conditions put Indonesia at risk of missing the demographic dividend, as its human capital may be unprepared to compete globally. This is particularly critical given Indonesia's aspiration for "Indonesia Emas 2045."

Therefore, the issue cannot be reduced to statistics alone. It calls for a re-examination of how early childhood learning experiences are designed so that science and mathematics are no longer intimidating but instead ignite children's curiosity. This is where the Montessori method offers a concrete, experience-based approach, strengthened by insights from neuroscience and framed within Islamic values, so that learning stimulates not only cognitive intelligence but also nurtures spiritual awareness.

In this context, addressing Indonesia's persistent literacy gap requires not just curriculum reform but a deeper pedagogical transformation, one that integrates scientific understanding, experiential learning, and moral-spiritual values. Such an integrative approach is essential to cultivate a generation that learns not only to think critically, but also to find meaning and purpose in knowledge itself.

### 3.2. Science and Mathematics as Exploration in Montessori

Unlike conventional teaching, which tends to introduce numbers through symbols and rote memorization, Montessori emphasizes that mathematics should begin with real-life experiences. For young children, abstract concepts such as "numbers," "tens," or "multiplication" are too distant if introduced solely through the blackboard. Montessori believed that children must first touch, feel, and manipulate objects before grasping the logic behind them. In this way, mathematics no longer appears as a rigid sequence of symbols but as an enjoyable activity of exploration.

A distinctive feature of this method is the use of concrete learning materials. For example, number rods help children understand numerical order by physically

handling rods of gradually increasing length. Golden beads introduce the concept of place value (units, tens, hundreds) through tangible beads that can be counted and combined. Even mathematical operations such as addition or division can be learned by "working with" these objects. This process enables abstract concepts to emerge naturally, without coercion, as if the child is discovering mathematical logic on their own. According to Namukasa & Aryee (2021), one of the central emphases of Montessori mathematics education is allowing children to independently reach conceptual understanding, rather than passively receiving teachers' explanations.

This approach is closely related to what Montessori called *the mathematical mind*, the natural tendency of children to think logically, orderly, and systematically. Montessori asserted: "Education is a natural process carried out by the child and is not acquired by listening to words but by experiences in the environment" (Montessori, 2021a). She also emphasized the role of the hand in cognitive development: "The hands help the development of the intellect" (Montessori, 2012). Lillard (2005) reinforces this view, showing that children in Montessori systems demonstrate stronger cognitive abilities, social skills, and self-regulation.

A key principle of this method is *auto* or *self-education*, the belief that children are capable of educating themselves when provided with the right environment. Teachers are no longer central lecturers but facilitators who prepare an environment conducive to exploration (Montessori, 2020). In this way, children develop confidence that mathematics is something they can understand in their own way. This positive disposition is crucial in shaping how they will face cognitive challenges in the future.

The Montessori method, developed by Maria Montessori, is grounded in the view that children are active learners with an innate drive to explore their environment. Its core principle is self-education or self-directed learning, the capacity of children to educate themselves when provided with an appropriate prepared environment. Montessori emphasizes the importance of concrete learning materials, freedom in choosing activities, and the teacher's role as a facilitator rather than a controller.

This exploratory approach also resonates with children's natural disposition as explorers of the world. Young children are inherently curious, and Montessori capitalizes on this instinct. When children pour water to learn about volume, or stack blocks to understand height and balance, they are in fact planting the seeds of mathematical thinking. At this point, mathematics is no longer something to be

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"studied as an obligation," but emerges naturally as a consequence of curiosity-driven daily activities (Isaacs, 2013).

In the Indonesian context, this approach directly addresses the major weaknesses of mathematics education, which is often overly abstract and intimidating. Montessori offers a middle ground: teaching mathematics from an early age without overwhelming children with symbols, but instead through concrete, multisensory, and exploratory experiences. In this way, mathematics is presented not as a source of fear, but as a natural language for understanding the world around the child. The contrast between Montessori and conventional approaches can be summarized as follows:

Table 1. Comparison between Montessori and Conventional Approaches in Early Childhood Science and Mathematics Learning

| Aspect | Montessori Approach | Conventional Approach |
|---|---|---|
| Learning Philosophy | Learning as self-directed exploration; children construct knowledge through experience. | Learning as teacher-directed instruction; children receive knowledge from adults. |
| Role of the Child | Active learner; free to explore materials and discover concepts independently. | Passive recipient; expected to follow teacher explanations and instructions. |
| Role of the Teacher | Facilitator and observer who prepares an enabling environment for exploration. | Central authority and primary source of knowledge. |
| Learning Materials | Concrete, multisensory materials (e.g., number rods, golden beads, sandpaper letters). | Abstract symbols and printed worksheets. |
| Concept Development | Abstract understanding grows naturally from hands-on, concrete experience. | Abstract concepts are introduced directly through verbal or written explanation. |
| Learning Environment | Prepared environment designed for autonomy, order, and sensory engagement. | Classroom dominated by blackboard, desks, and uniform tasks. |
| Learning Pace | Individualized; children progress at their own rhythm based on readiness. | Standardized; all students expected to follow the same pace and sequence. |
| Assessment | Continuous observation of progress and engagement. | Periodic testing and grades as main evaluation tools. |
| Emotional Climate | Encourages curiosity, confidence, and intrinsic motivation. | May induce anxiety and fear of failure, especially in mathematics. |

(Adapted from Montessori (2020, 2021), Lillard (2005), Isaacs (2013), and Namukasa & Aryee (2021)).

As shown above, Montessori transforms learning from a passive reception of symbols into an active process of discovery. This shift not only enhances conceptual understanding but also nurtures a lifelong sense of curiosity and confidence toward science and mathematics.

### 3.3 Why Focus on Science and Mathematics?

One may ask why special attention should be given to science and mathematics in early childhood education. The answer is simple yet fundamental: experts have long identified these two domains as the cognitive foundation of children's development. As Eshach (2006) emphasizes, science at an early stage is not about complex formulas or abstract theories, but rather simple activities that allow children to explore natural phenomena. Children learn through observation, classification, small experiments, and the discovery of patterns. Activities such as observing plant growth, mixing paint colors, or watching the phases of the moon are meaningful science experiences embedded in their everyday lives.

Similarly, mathematics in early childhood cannot be reduced to mere "number drills" on the blackboard. More broadly, mathematics involves number recognition, patterns, geometry, measurement, comparison, and estimation skills. The National Association for the Education of Young Children (NAEYC, 2020) highlights that mathematical experiences should be concrete, meaningful, and directly connected to children's real-life contexts. In other words, children should not only memorize numbers, but also construct understanding through objects, play, and daily activities.

Interestingly, science and mathematics are inherently interconnected. Scientific inquiry requires skills in counting and measuring, while mathematical concepts are often reinforced through scientific experimentation. Together, they foster the development of critical, logical, and systematic thinking from an early age (Gelman & Brenneman, 2004). Piaget (1952) reminds us that abstract concepts emerge from concrete experiences, while Vygotsky (1978) underscores the role of adult guidance in bridging children's real-world experiences with abstract ideas. At this point, the Montessori approach becomes particularly relevant, as its use of manipulatives allows children to grasp concepts through hands-on exploration.

Of course, emphasizing science and mathematics does not imply that other domains are less important. Literacy, for instance, plays a crucial role as the gateway for children to understand and express their world. In fact, literacy often

works hand in hand with science and mathematics. A child who observes plant growth may be encouraged to retell the experience, write it down, or name the changes observed. In this way, the three domains complement one another: science nurtures curiosity, mathematics cultivates logical thinking, and literacy enables the articulation of ideas.

Concrete experiences in science and mathematics do more than train children's logic and critical thinking. Behind simple activities, such as counting beads or observing plant growth, the child's brain is actively forming neural pathways that serve as the foundation for lifelong learning. Understanding these biological processes brings us to the field of neuroscience, which can help educators and parents become more attuned to the unique learning characteristics of each child. Hence, an integrative approach that combines Montessori's hands-on learning, neuroscience's cognitive foundation, and Islam's moral orientation can bridge this educational gap.

### 3.4 How Neuroscience Explains Learning and Behavior

Have we ever wondered why some children seem to grasp numerical concepts or patterns quickly, while others struggle despite repeated explanations? What actually happens in a child's brain when they observe leaves changing color, count marbles, or build with blocks? Such questions lead us to neuroscience, i.e. the study of how the brain functions during learning, and why this understanding is crucial for both teachers and parents who accompany children in their developmental journey.

The urgency of integrating neuroscience here is evident. Many teachers tend to judge children solely by their learning outcomes, whether they master numbers, patterns, or scientific concepts quickly or slowly, without considering the different rhythms of brain development. Neuroscience explains that every exploratory experience forms new neural pathways (neuroplasticity), and that differences in ability are not simply the result of laziness or lack of intelligence. By understanding how the brain works, teachers and parents can more effectively adjust stimulation, provide appropriate concrete experiences, and patiently support each child (Jensen, 2005; Sousa, 2022).

From a developmental psychology perspective, young children are in the preoperational stage (ages 2–7) according to Piaget (1952), where thinking remains egocentric but the capacity for symbolization and simple classification begins to

emerge. Vygotsky (1978) highlighted the Zone of Proximal Development (ZPD), the range of abilities that can be achieved with the guidance of adults or peers, underscoring the teacher's role in bridging abstract concepts through real-life experiences.

Neuroscience shows that 90% of brain development occurs within the first five years of life. Sensorimotor activities and experience-based learning, such as touching, handling, and counting objects, stimulate the prefrontal cortex, which supports executive functions like planning and decision-making, as well as the hippocampus, which is vital for long-term memory (Rushton et al., 2010). Hands-on learning (Jensen, 2005) strengthens neural connections, engages multiple senses, extends memory retention, and facilitates the understanding of abstract concepts (Sousa, 2022). Montessori is highly relevant here, as it provides manipulative tools and concrete experiences that align with how the brain naturally learns.

Furthermore, neuroscience helps teachers understand the unique learning profiles of each child. Not all children develop at the same pace; some may quickly grasp numerical patterns, while others may show greater strengths in language or the arts (Goswami, 2008). Recognizing this allows teachers to be more patient and strategic in providing stimulation, understanding that these differences are part of normal biological processes rather than signs of failure or lack of intelligence.

Each time a child observes, counts, or conducts a small experiment, billions of neurons communicate to form new networks. Simple activities such as measuring plant growth, pouring water, or stacking blocks actually train the child's brain, particularly executive functions, to think logically, critically, and systematically in the future (Ansari, 2008). At this point, the Montessori approach, through its use of manipulatives and concrete experiences, becomes especially relevant, as it directly corresponds with the brain's learning mechanisms (Lillard, 2005).

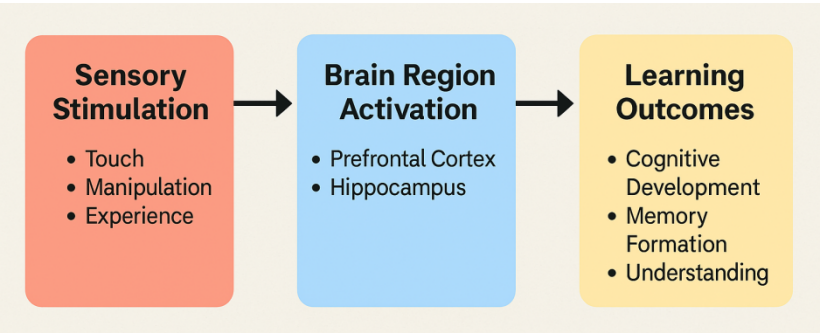


Figure 1. Sensory stimulation activates key brain regions (prefrontal cortex, hippocampus), leading to improved cognitive and memory-related learning outcomes.

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By understanding neuroscience, we see a clear connection between exploratory science and mathematics education, brain development, and even character formation. This provides a strong foundation for why concrete experiences in early childhood are indispensable. At the same time, it bridges us to Islamic values, where the Qur'an's injunctions to reflect, calculate, and observe nature resonate with the brain's design, enriched when children engage in authentic, hands-on exploration.

While neuroscience provides strong conceptual backing for Montessori's emphasis on sensory and experiential learning, this study does not conduct empirical or neurophysiological measurement. The discussion remains at the level of conceptual synthesis, integrating insights from neuroscience, Montessori pedagogy, and Islamic educational thought to illustrate their theoretical alignment.

### 3.5 Integrating Islam into Science and Mathematics Education

One may ask: is it sufficient for children to merely learn numbers, patterns, or natural phenomena without grasping the meaning behind them? Within the context of international approaches such as Montessori, it is important to note that this method, developed by Maria Montessori (1870–1952) in predominantly Christian Italy, was designed to be religiously neutral. The Montessori method emphasizes concrete experience, exploration, and self-education, without an explicit spiritual dimension. For Montessori, learning is a process of discovery through real-world experiences.

In Indonesia, however, a nation that upholds belief in God (*Ketuhanan Yang Maha Esa*) and whose population is predominantly Muslim, the integration of Islamic values into early childhood education is essential. The large presence of Islamic preschools and kindergartens (PAUD & TK Islam), as well as *Raudhatul Athfal* reflects this reality. Without a moral and spiritual dimension, the teaching of science and mathematics risks becoming flat and less meaningful. By embedding Islamic values, children not only grasp concepts but also learn to appreciate God's creation and develop character grounded in Islamic principles (*tarbiyah bil hal*).

This integration does not restrict children's freedom to explore; rather, it enriches their motivation and sense of purpose. For example, when children observe the growth of a plant, teachers can frame it as a manifestation of God's orderly creation, cultivating gratitude alongside scientific observation. Counting seeds or arranging patterns can be linked to Qur'anic verses that encourage reflection

(*ta'ammul*), observation, and contemplation of divine signs in the universe.

Through this approach, learning science and mathematics gains moral and spiritual depth. Simple Montessori activities, such as pouring water, measuring plant height, or mixing colors, not only develop scientific and numerical skills but also foster curiosity, patience, precision, and reverence for creation. Teachers remain facilitators, preparing manipulatives and experiential learning opportunities, while simultaneously connecting activities with relevant Islamic values.

From an Islamic perspective, scientific and mathematical thinking is integral to faith. The Qur'an presents science and mathematics as signs of divine order. For instance, *QS. Ar-Rahman [55]:5* states that the sun and moon move according to precise calculation (*hisab*). *QS. Al-Baqarah [2]:164*, *QS. Yunus [10]:101*, and *QS. Al-Mujadilah [58]:7* emphasize observation and careful reckoning. *QS. Al-Qamar [54]:49* asserts that all things are created in due measure (*qadar*). A hadith of the Prophet ﷺ further affirms: "*Indeed, Allah loves that when one of you does something, he does it with excellence (itqan)*" (HR. Thabrani).

Thus, learning science and mathematics aligns closely with Islamic teachings. The Qur'an repeatedly calls humans to *yatafakkar* (reflect), *yatadabbar* (contemplate), and *yansur* (observe). Commands to calculate (*hisab*, QS. Yunus:5) and to analyze natural phenomena such as the alternation of day and night highlight scientific activity as an intellectual form of worship. Consequently, attention to science and mathematics is not merely academic but also a reinforcement of human *fitrah* to think and seek truth (Al-Ghazzali, 2016; Khaldun, 2002).

Classical scholars further reinforce this view. Ibn Khaldun, in *al-Muqaddimah*, regarded arithmetic and geometry as the foundations of civilization (Khaldun, 2002). Al-Khawarizmi, the "father of algebra," authored *al-Jabr wa al-Muqabalah*, the cornerstone of modern mathematics (Berggren, 1986). Ibn al-Haytham's *Kitab al-Manazir* laid the groundwork for experimental scientific methods (Sabra, 1989). Contemporary scholars such as Yusuf al-Qaradhawi reject the dichotomy between religious and scientific knowledge, while Syed Naquib al-Attas emphasized that science education must ultimately serve *ta'dib* (formation of adab), not merely technical proficiency (Al-Attas, 1999; Al-Qaradhawi, 2022). Science and mathematics, therefore, cultivate both rationality and spirituality.

Imam al-Ghazali stressed that childhood is a decisive stage, likening the child's heart to unplanted soil ready to receive any seed. In *Ihya' 'Ulumuddin*, he wrote that children are entrusted to their parents, their pure hearts like uncarved jewels awaiting inscription (Al-Ghazzali, 2016). This view resonates with

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Montessori's concept of the sensitive period, a developmental window when a child's potential flourishes optimally with proper stimulation. The concept aligns with the Islamic principle of fitrah, as the Prophet ﷺ taught: "*Every child is born upon fitrah...*" (HR. Bukhari-Muslim). Hence, Montessori's method can be viewed as a tool for nurturing a child's *fitrah* within an Islamic framework.

Contemporary scholars such as Abdullah Nashih Ulwan (2015), in *Tarbiyatul Aulad fi al-Islam*, underscored parental responsibility in shaping a child's future, identifying five key dimensions of education: faith, morality, intellect, physical development, and socialization. Ibn Qayyim al-Jauziyyah (2021), in *Tuhfatul Maudud*, likewise stressed habituation from an early age, noting that a child raised in goodness will grow to embody it. These principles emphasize that moral and intellectual foundations must be instilled early to form a lasting character.

In practice, the integration of Islamic values within Montessori-based science and mathematics learning can be operationalized through purposeful lesson design and teacher narration. For instance, when children learn about measurement using water or sand, teachers may connect the activity to QS. Al-Mu'minun [23]:18, which describes how Allah measures rain with precision. Counting and sorting exercises using beads can be linked to QS. Al-Rahman [55]:7–9, which emphasizes balance and proportion in creation, reinforcing the concept of mathematical order as divine. When exploring plant growth or the life cycle, teachers can introduce QS. An-Nahl [16]:10–11, highlighting gratitude for the sustenance that Allah provides through nature. Likewise, simple observations of the moon's phases can be tied to QS. Yunus [10]:5 on calculation (hisab), showing how mathematics serves as a tool to understand time and the natural world. These linkages transform ordinary Montessori lessons into opportunities for *tazakkur* (remembrance) and *tafaqquh* (understanding), ensuring that learning remains both intellectually stimulating and spiritually grounded.

Ultimately, integrating Islamic values renders early childhood education holistic, combining concrete experiences, cognitive stimulation, character formation, and spiritual awareness. Such an approach enables children to see learning not only as mastery of numbers or experiments but also as a process of appreciating creation, cultivating critical and logical thinking, and developing ethical consciousness from the earliest years.

### 3.6 Montessori–Islam–Neuroscience: An Integrated Framework

Based on the theoretical review above, a conceptual framework can be formulated that integrates Montessori pedagogy, science and mathematics, neuroscience, and Islamic values in early childhood education. These four elements do not stand alone, but complement each other to form a holistic educational model. The conceptual relationship among these elements is illustrated in Figure 2 below.

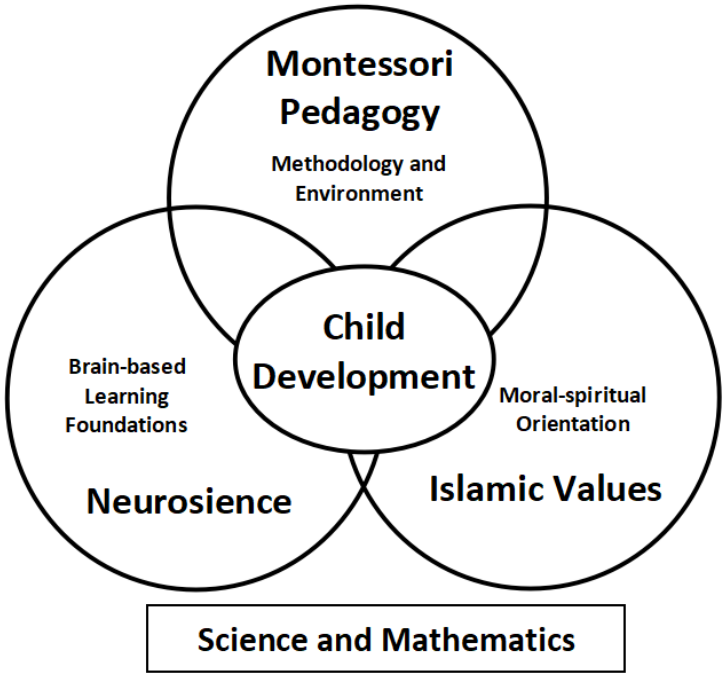


Figure 2. Conceptual model illustrating the integration of Montessori pedagogy, neuroscience, and Islamic values in early childhood science and mathematics learning. The model positions child development at the center, supported by methodological, neurobiological, and moral-spiritual foundations, with science and mathematics serving as the connecting cognitive content.

First, Montessori provides the methodological foundation by emphasizing hands-on learning, self-education, and a well-prepared environment. This principle allows children to develop their innate potential through concrete experiences aligned with their developmental stages.

Second, science and mathematics serve as core cognitive content, training children to observe, classify, count, recognize patterns, and understand the orderliness of natural phenomena. Jean Piaget (1952) emphasized that young children learn through concrete manipulation, while Lev Vygotsky (1978) highlighted the importance of teacher scaffolding in bridging abstract concepts. Thus, learning science and mathematics through Montessori is highly relevant to children's cognitive development.

Third, neuroscience provides a scientific justification that multisensory stimulation and concrete experiences during the golden age strengthen brain plasticity, memory, and executive functions. Research by Jensen (2005) and Sousa

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(2022) shows that learning involving multiple senses simultaneously enhances memory retention and conceptual understanding. This perspective resonates with Islamic teaching that hearing, sight, and heart are divine gifts to be optimized (Qur'an, An-Nahl [16]:78).

Fourth, Islamic values offer moral and spiritual orientation to ensure that children's freedom to explore remains guided by tawhid. The Qur'an encourages reflection on creation as signs of God's greatness (QS. Ali Imran [3]:190–191), while the Prophet ﷺ emphasized the importance of educating children from an early age. Scholars like Ibn Khaldun and Al-Ghazali underscored that education must embrace both intellect and character. Integrating Islamic values thus ensures that science and mathematics learning goes beyond rational mastery, directing children toward faith and ethical formation.

Taken together, these four elements produce a holistic and contextual model of learning. Montessori provides pedagogy, science and mathematics supply cognitive content, neuroscience explains the biological and psychological foundations of learning, and Islamic values frame it within moral and spiritual guidance. Altogether, this integration aims to nurture children who are intellectually capable, emotionally balanced, spiritually grounded, and aligned with their natural fitrah.

From this integrated model, several learning outcomes can be anticipated across multiple domains. Cognitively, children develop critical and analytical thinking, numerical reasoning, and scientific curiosity through multisensory, hands-on experiences. Emotionally, they cultivate self-confidence, intrinsic motivation, patience, and perseverance—attributes reinforced by Montessori's emphasis on autonomy and self-regulation. Socially and morally, they learn empathy, cooperation, and respect for order within a community of learners. Spiritually, they develop gratitude, humility, and awareness of divine order in creation, guided by Qur'anic reflection on nature (*ayat kauniyah*). Collectively, these outcomes embody the holistic aim of education in Islam—developing the whole child (*insan kamil*), whose intellect, emotion, and faith grow in harmony.

Contemporary perspectives reinforce this approach. The National Association for the Education of Young Children (NAEYC, 2020) stresses that early childhood education must be holistic, covering physical, cognitive, social-emotional, and moral development. This aligns with Islamic principles, which emphasize balance

between body and soul. Both classical and contemporary views therefore affirm the urgency of holistic early childhood education as the foundation for developing the whole person.

### 3.7 Challenges and Opportunities

The Montessori approach offers a strong foundation in early childhood education, particularly in introducing science and mathematics. This method emphasizes guided freedom, independence, and the use of concrete apparatus to help children grasp abstract concepts. In line with this, contemporary neuroscience shows that children learn most effectively through multisensory, interactive experiences that match the rhythm of their brain development. Thus, Montessori is not merely a pedagogical method, but one that resonates with the very way the human brain works.

From an Islamic perspective, freedom in learning does not mean directionless exploration, but a pathway to recognizing the order in God's creation. Through science and mathematics, children are invited to see signs of His greatness, so that knowledge does not stop at logic but also strengthens faith and shapes character. The Qur'an emphasizes the importance of reflecting on natural phenomena as a path to deepening faith. Within this frame, Montessori becomes more than just a teaching strategy, it evolves into a pathway for nurturing children who are both intelligent and virtuous.

Interestingly, Indonesia's national education policy is also moving in a parallel direction. The *Kurikulum Merdeka* and *Profil Pelajar Pancasila* emphasize holistic, contextual learning rooted in local wisdom (Aditomo et al., 2024). The *Deep Learning* Strategy campaign further promotes deep, interdisciplinary, and meaningful learning (Kemdikdasmen, 2025). All of this aligns with the Montessori spirit of granting learning freedom, enriched by Islamic values as a moral compass, and strengthened by neuroscience findings on the golden age of brain development.

Yet, no concept is flawless. In practice, implementing Montessori requires extra time and attention from teachers to support each child according to their unique developmental rhythm. Moreover, Montessori apparatus can be costly, posing a significant challenge for many educational institutions in Indonesia (Lillard, 2005). These barriers must be recognized early to ensure that Montessori implementation does not stop at jargon, but truly makes a tangible impact on children's learning quality.

Nevertheless, Indonesia is far from lacking in resources. Our socio-cultural context in fact offers abundant opportunities. Traditional games such as *congklak*,

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*engklek*, or *kelereng* are rich in concepts of numeracy, geometry, strategy, character, and social collaboration (Arvy, 2024; Karoso et al., 2025). When integrated, these games can serve as contextual learning media for science and mathematics, closely tied to children's everyday lives.

At the policy level, integration requires concrete support. Early childhood teachers, particularly in Islamic preschools and kindergartens, need training in the basics of neuroscience and Montessori pedagogy. The government, together with major Islamic organizations such as NU and Muhammadiyah, can play a crucial role in regulation and implementation support. In this way, early childhood education will not only prepare children with academic competencies but also nurture a generation that is critical, creative, spiritually grounded, and future-ready.

Ultimately, the integration of Montessori, neuroscience, and Islam, enriched by local wisdom and aligned with national policy directions, offers a new educational paradigm. It is not merely a method, but a worldview that bridges global best practices with local and spiritual roots. If carefully designed, this model can address Indonesia's low achievement in science and mathematics while shaping a generation that is intelligent, ethical, and grounded in enduring values.

## 3. CONCLUSION

This study highlights that integrating Montessori pedagogy, neuroscience, and Islamic values in early childhood science and mathematics education is not only possible but urgently needed. Montessori offers a methodological framework rooted in concrete experiences, neuroscience provides the biological basis for why multisensory stimulation is highly effective during the brain's golden age, and Islam supplies the moral and spiritual orientation to keep learning aligned with human nature (*fitrah*). Strengthened by local wisdom and national policy support, this integration holds the potential to nurture an Indonesian generation that is intellectually capable, ethically grounded, and spiritually rooted, fully prepared to face global challenges with a strong and authentic identity. Future research should focus on designing and testing classroom-based interventions that embody this integration, ensuring that neuroscience-informed Montessori education grounded in Islamic values can be effectively applied in diverse early childhood contexts across Indonesia.

## REFERENCES

Aditomo, A., Syahril, I., Yuliati, K., Suryani, N., Handayani, F., & Muhammad, H. (2024). *Kajian Akademik Kurikulum Merdeka*. Pusat Kurikulum dan Pembelajaran - Badan Standar, Kurikulum, dan Asesmen Pendidikan, Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Al-Attas, S. M. N. (1999). The Concept of Education in Islam: A Framework for an Islamic Philosophy of Education. In *The First World Conference on Muslim Education*. International Institute of Islamic Thought and Civilization.

Al-Ghazzali, I. (2016). *Ihya' Ulumuddin (Cetakan kedua)* (P. Purwanto (ed.)). Penerbit Marja.

Al-Jauziyyah, I. Q. (2021). *Newborn Baby Guide (Translation of Tuhfatu Al-Maudud bi Ahkami Al-Maulud*. Dar as-Sunnah Publishers.

Al-Qaradhawi, Y. (2022). *Terjemahan Al fiqh Al Islam Baina Al Ashalah Wali Al-Tajdid (Perkembangan Fiqh Antara Statis dan Dinamis)* (P. S. M. Yunus (ed.)). Cita Varia Kreativitas. https://repository.ar-raniry.ac.id/id/eprint/22003/1/Fiqh Yusuf Qaradhawi Terjemah.pdf

Ansari, D. (2008). Effects of Development and Enculturation on Number Representation in the Brain. *Nature Reviews Neuroscience*, *9*(4), 278–291. https://doi.org/10.1038/nrn2334

Arvy, B. R. (2024). Mengembangkan Numerasi Anak Usia Dini Melalui Permainan Tradisional. *Jurnal Ilmiah Pendidikan Dasar*, *09*(3), 482–492.

Berggren, J. L. (1986). *Episodes in the Mathematics of Medieval Islam*. Springer.

Boaler, J. (2016). Mathematical Mindsets: Unleashing Students' Potential through Creative Math. Jossey-Bass. In *Jossey-Bass*. Jossey-Bass A Willey Imprint.

Bruner, J. S. (1961). The Act of Discovery. *Harvard Educational Review*, *31*, 21–32.

Eshach, H. (2006). *Science Literacy in Primary Schools and Pre-Schools*. Springer Netherlands. https://doi.org/10.1007/1-4020-4674-x

Gelman, R., & Brenneman, K. (2004). Science Learning Pathways for Young Children. *Early Childhood Research Quarterly*, *19*(1), 150–158. https://doi.org/10.1016/j.ecresq.2004.01.009

Goswami, U. (2008). *Cognitive Development: The Learning Brain*. Psychology Press Taylor & Francis Group.

Isaacs, B. (2013). Understanding the Montessori Approach: Early Years Education in Practice. In *Understanding the Montessori Approach: Early Years Education in Practice*. https://doi.org/10.4324/9780203124802

Jensen, E. (2005). Teaching with the Brain in Mind (Revised version). In *Practising Wood in Architecture*. Association for Supervision and Curriculum Development. https://doi.org/10.4324/9781003428930-9

Karoso, S., Cahyono, B. T., Pujosusanto, A., & Handayani, E. W. (2025). Penanaman Nilai-Nilai Budaya dan Karakter melalui Permainan Anak Tradisional pada Pendidikan Anak Usia Dini. *Journal of Practice Learning and Educational Development*, *5*(2), 304–313. https://doi.org/10.58737/jpled.v5i2.423

Kemdikdasmen. (2025). *Pembelajaran Mendalam: Menuju Pendidikan Bermutu untuk Semua*. TPPM Puskurjar Kemendikdasmen. https://www.youtube.com/watch?v=sL9jFWXnfAs

Khaldun, I. (2002). *Mukaddimah*. Dewan Bahasa dan Pustaka.

Knudsen, E. I. (2004). Sensitive Periods in the Development of the Brain and Behavior. *Journal of Cognitive Neuroscience*, *16*(8), 1412–1425. https://doi.org/10.1162/0898929042304796

Kolb, B., & Gibb, R. (2011). Brain Plasticity and Behaviour in the Developing Brain. *Journal of the Canadian Academy of Child and Adolescent Psychiatry = Journal de l'Academie Canadienne de Psychiatrie de l'enfant et de* l'adolescent, 20(4), 265–276.

Lillard, A. S. (2005). *Montessori: the Science behind the Genius*. Oxford University Press. https://doi.org/10.5860/choice.43-5409

Montessori, M. (2007). *Education and Peace (The Montessori Series Volume 10)*. Montessori-Person Publishing Company.

Montessori, M. (2012). *The 1946 London Lectures*. Montessori-Pierson Publishing Company. http://www.montessori-pierson.com/.

Montessori, M. (2020). *The Discovery of the Child (The Montessori Method Volume 2)*. Montessori-Person Publishing Company.

Montessori, M. (2021a). *The Absorbent Mind (The Montessori Series Volume 1)*. Montessori-Person Publishing Company.

Montessori, M. (2021b). *The Secret of Childhood (The Montessori Series Volume 22)*. Montessori-Person Publishing Company.

NAEYC. (2020). Developmentally Appropriate Practice National Association for the Education of Young Children. *Naeyc.Org*, *April*, 1–43. https://www.naeyc.org/sites/default/files/globally-

shared/downloads/PDFs/resources/position-statements/dap-statement_0.pdf

Namukasa, I. K., & Aryee, K. L. (2021). Pedagogical Knowledge for Teaching Mathematics in Montessori Schools. *International Electronic Journal of Mathematics Education*, *16*(3), 1–20. https://doi.org/10.29333/iejme/11005

OECD. (2019). PISA 2018 Results (Volume I): What Students Know and Can Do. In *OECD Publishing: Vol. I*. https://www.oecd.org/pisa/publications/pisa-2018-results-volume-iii-acd78851-en.htm

OECD. (2023). *PISA PISA 2022 Results: Factsheets Indonesia*. https://www.oecd.org/publication/pisa-2022-results/country-notes/malaysia-1dbe2061/

Piaget, J. (1952). The Origins of Intelligence in Children. In M. C. (Translator) (Ed.), *Journal of Consulting Psychology*. W. W. Norton & Company. https://doi.org/10.1037/h0051916

Purnama, S. (2021). *Pemikiran & Praktik Pendidikan Islam Anak Usia Dini* (Jazariyah (ed.)). PPIAUD.

Risza, H. (2025). Meluruskan Kembali Implementasi Anggaran Pendidikan 20 Persen. *Detik Kolom*. https://news.detik.com/kolom/d-8048691/meluruskan-kembali-implementasi-anggaran-pendidikan-20-persen

Rushton, S., Juola-Rushton, A., & Larkin, E. (2010). Neuroscience, Play and Early Childhood Education: Connections, Implications and Assessment. *Early Childhood Education Journal*, *37*(5), 351–361. https://doi.org/10.1007/s10643-009-0359-3

Sabra, A. I. (1989). The Optics of Ibn Al-Haytham. In *Structure*. The Warburg Institute, University of London. https://monoskop.org/images/f/ff/The_Optics_of_Ibn_Al-Haytham_Books_I-III_On_Direct_Vision_Sabra_1989.pdf

Shonkoff, J. P., & Phillips, D. A. (2000). From Neurons to Neighborhoods: The Science of Early Childhood Development. In *From Neurons to Neighborhoods*. https://doi.org/10.17226/9824

Sousa, D. A. (2022). *How the Brain Learns (Sixth Ed)*. (CORWIN SAGE Publishing (ed.)).

Trilling, B., & Fadel, C. (2009). *21st Century Skills: Learning for Life in Our Times*. Jossey-Bass A Willey Imprint.

Ulwan, A. N. (2015). *Pendidikan Anak Dalam Islam (Terjemahan Tarbiyatul Aulad Fii Al-Islam)*. Khatulistiwa Press.

UNICEF. (2018). *Learning Through Play: Strengthening Learning Through Play*

*in Early Childhood Education Programmes* (p. 33). https://doi.org/10.1016/B978-0-08-044894-7.00499-1

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Mental Processes*. Harvard University Press.