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Analyzing the design of montessori-based media to introduce letters and numbers

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Abstract. This research analyzes the design aspects of Montessori-based educational tools, such as sandpaper letters, sandpaper numbers, and moving alphabet; employed in early childhood education to introduce letters and numbers. The study aims to evaluate functionality, safety, usability, aesthetic appeal, construction quality, developmental impact, and compliance with standards. Utilizing qualitative analysis and interviews with educators and parents, the data were analyzed using thematic analysis, where interview transcriptions were coded and grouped into categories to identify key themes. The interviews were semi-structured, allowing flexibility for respondents to share their perspectives and experiences in depth. The research examines these tools' effectiveness in facilitating learning among young children. Results reveal varying levels of functionality, safety, and usability across the tools. Sandpaper letters and numbers offer moderate functionality and safety, emphasizing tactile learning, while moving alphabet presents higher functionality and interactive engagement. Usability is limited in static tools but heightened in the interactive moving alphabet. Aesthetic appeal varies, with all media focusing on engaging visual and tactile elements. Compliance with standards remains partial. The research underscores the significance of diverse design approaches in early childhood education and recommends iterative enhancements in usability, safety, and compliance for optimized learning experiences. These findings have implications for educators, suggesting the integration of interactive elements to bolster early childhood education's efficacy.

Keywords: design aspects, Montessori education, early childhood learning

Introduction

Early childhood education plays an important role in forming the basis of holistic learning and development in the early stages of life. One of the critical points in early childhood education is the recognition of letters and numbers, which become the basis for the future development of reading, writing, and numeracy skills (Deluca et al., 2019). Appropriate learning media design plays an important role in facilitating early childhood development (Sari & Jannah, 2023). In particular, the Montessori method has been shown to be effective in supporting critical stages of child development at this age. Letter and number recognition is one of the main focuses in the Montessori curriculum to stimulate children's cognition naturally. With learning media such as sandpaper letters, sandpaper numbers, and moving alphabets, Montessori creates a learning environment that stimulates and supports the absorption of information in early childhood (Widjaja, 2017). These media provide sensory experiences that enrich children's understanding of letters and numbers, facilitate recognition, and strengthen connections between concepts and real objects in the learning process (Cahnia & Zulfahmi, 2024).

To improve the quality of learning in early childhood, the Montessori approach has emerged as a highly effective method with an emphasis on learning through sensory and

exploratory experiences (Primayanti & Esser, 2023). Sandpaper letter, sandpaper number and moving alphabet are important components in the Montessori method for introducing letters and numbers to early childhood (Montessori, 2016). In addition, all three types of educational tou also serve to stimulate early childhood sensory abilities through the recognition of sequences of letters and numbers, involving the fingers in following the sand lines on letters helps develop fine motor skills needed to write well. With Moving Alphabet, children can string letters into simple words, so that it can help in enriching children's vocabulary, improving their ability to speak and understand language (Lillard, 2005).

In the context of early childhood education, design principles play a critical role in enhancing the learning experience and supporting developmental goals. The user-centered design (UCD) approach, often used in educational tool development, emphasizes creating materials and tools that cater to the needs, abilities, and interests of young children. This design philosophy is rooted in understanding the child as the "user" and ensuring that learning materials are accessible, engaging, and developmentally appropriate. According to Norman (2013), effective designs for young children should prioritize simplicity, tactile engagement, and an intuitive interface that allows children to interact with the tools independently. When designing Montessori-based materials like sandpaper letters and moving alphabets, the emphasis is on fostering sensory engagement and encouraging self-directed learning, which aligns well with user-centered principles. Principles of design for children emphasize the importance of materials that are not only visually appealing but also promote cognitive and motor development through active interaction. Harrington & Thomas (2018) suggest that educational tools should be designed to offer sensory feedback, ensuring that the child can explore concepts in a multi-sensory way, engaging both their touch and visual senses. These principles are evident in the Montessori method, where materials like sandpaper letters encourage tactile learning, while moving alphabets offer interactive learning experiences. This design philosophy supports both the cognitive development and fine motor skills of young children, ensuring that learning is both effective and enjoyable.

Graha Ananda Kindergarten is one of the early childhood education institutions located in West Bandung Regency, since its establishment until now Graha Ananda Kindergarten has made several curriculum adjustments, the last of which is the application of the central method in the curriculum and daily learning process. However, along with the times, Graha Ananda Kindergarten has now begun to switch slowly and apply the Montessori method, where to introduce letters and numbers to early childhood in the Montessori method using Sandpaper Letter, Sandpaper Number and Moving Alphabet. In the transition period of the curriculum at Graha Ananda Kindergarten, the introduction of letters and numbers through a Montessori approach with the use of Sandpaper Letters, Sandpaper Numbers, and Moving Alphabet has a high urgency. This approach not only provides an effective learning method in introducing letters and numbers to early childhood, but also provides an immersive sensory and interactive experience, and can better facilitate concept recognition. Under conditions of curriculum transition adjustment, the Montessori approach provides stability and continuity in teaching while supporting children's cognitive, motor, and language skills development, and encouraging creativity and learning independence amid the changing educational challenges faced.

To establish the research gap for this study, it is important to review previous research in the field of early childhood education, particularly focusing on the use of Montessori methods and sensory learning media. Previous studies have highlighted the effectiveness of Montessori's sensory materials, such as sandpaper letters, sandpaper numbers, and moving alphabets, in promoting cognitive, motor, and language development in young children (Lillard, 2005; Sari & Jannah, 2023). Research has shown that these tools provide hands-on, multisensory learning experiences that engage children in active learning and improve their recognition of letters and numbers (Widjaja, 2017). Furthermore, studies have explored the role of Montessori materials

in enhancing fine motor skills and vocabulary development by allowing children to physically interact with the materials, which helps strengthen their understanding of basic concepts (Cahnia & Zulfahmi, 2024). Some studies also suggest that the Montessori method supports individualized learning and fosters creativity, independence, and problem-solving abilities among children (Azhar et al., 2023). However, despite these findings, there is a lack of research focusing on the implementation and impact of Montessori-based learning media in early childhood education centers undergoing curriculum transitions, such as Graha Ananda Kindergarten in West Bandung Regency.

The importance of proper learning media design in a Montessori context does not only lie in teaching letters and numbers. More than just introducing basic concepts, the use of carefully designed learning media in the Montessori method encourages creativity, problem-solving, and the development of fine motor skills in early childhood (Kara & Cagiltay, 2020). By aligning learning media according to the child's developmental stage, Montessori creates an environment that allows children to learn independently and progressively (Azhar et al., 2023). Thus, the application of appropriate learning media design in the Montessori curriculum is key in supporting the holistic growth of early childhood (Hassinger-Das et al., 2021). The importance of sandpaper letters, sandpaper numbers, and moving alphabet design is one important aspect that cannot be overlooked to build a solid and holistic educational foundation for early childhood. Montessori methods implemented through such tools provide several significant benefits that support optimal development of children in various aspects of learning (Noor & Widayati, 2014).The use of sandpaper letters, sandpaper numbers, and moving alphabet provides an approach that focuses on sensory experience and overall skill development. Therefore, in this study, an analysis of learning media design in the form of sandpaper letters, sandpaper numbers, and moving alphabets used in Graha Ananda Kindergarten, West Bandung Regency will be carried out. Given the importance of Montessori-based learning media in early childhood education, particularly in the context of curriculum transitions, this study seeks to address the following research question: How do the design aspects (functionality, safety, usability, aesthetic appeal, construction quality, developmental impact, and compliance with standards) of Montessori learning tools (sandpaper letters, sandpaper numbers, and moving alphabet) affect their effectiveness in early childhood learning at Graha Ananda Kindergarten? Furthermore, how can the design of these tools be improved to optimize the learning experience for children? This study aims to assess these design aspects in depth and explore potential enhancements to better support the developmental needs of children in the process of learning letters and numbers.

Methods

This research adopts qualitative methods with a case study approach to understand in depth the use of learning media such as sandpaper letters, sandpaper numbers, and moving alphabets in Graha Ananda Kindergarten. With a focus on the specific context of the school, this study used data collection techniques in the form of surveys of learning media use and interviews with teachers and parents. This survey aims to obtain a comprehensive picture of how these Montessori tools are used in everyday learning. Meanwhile, interviews with teachers and parents provide valuable perspectives related to design, use experience, and its impact on children in their learning process. In this research, the analysis of learning media design aspects will focus on various important elements. Aspects of functionality will be evaluated to understand the extent to which the learning media supports its primary purpose, while security and safety will be thoroughly analyzed to ensure that it does not pose a risk of injury or harm to

users, particularly children. Reusability will be the focus to understand how intuitive and easy the learning media is to use by children, while aesthetics or visual appeal will be assessed to find out to what extent the design grabs attention and motivates the user. Construction quality will be a concern to evaluate the durability of learning media in long-term use (Khoirunnisa, 2022).The analysis will also consider the influence of learning media on children's development in cognitive, motor, social, and emotional aspects. Finally, this research will evaluate the conformity of learning media with toy industry regulatory standards to ensure compliance with applicable safety guidelines and regulations (Richards et al., 2020).

The data collected from the surveys and interviews will be analyzed using thematic analysis**.** For the surveys, open-ended responses will be analyzed by identifying recurring themes related to the usage and effectiveness of the Montessori learning tools. Responses will be coded, and themes will be grouped to provide insights into the aspects of functionality, usability, and safety that were most emphasized by teachers and parents. Interviews will also be transcribed and analyzed thematically, focusing on extracting detailed perspectives on the effectiveness of the learning media, how it impacts children's development, and how the tools align with the principles of Montessori education. The thematic analysis will allow for the identification of patterns and themes that reveal the strengths and areas for improvement in the design of the Montessori materials. The analysis will also focus on how these design aspects influence children's engagement, learning outcomes, and overall experience with the educational tools.

Result and Discussion

The investigation focuses on dissecting crucial design elements, including functionality, safety measures, usability, aesthetic appeal, construction quality, developmental impact, and compliance with educational standards. Through qualitative methodologies, encompassing surveys and interviews with educators and parents, this research uncovers the diverse effectiveness of these tools in early childhood education.

The results reveal a spectrum of functionalities, safety measures, and usability across the assessed tools. While Sandpaper Letters and Numbers exhibit moderate functionality and safety, primarily emphasizing tactile learning, Moving Alphabet shines with higher functionality and interactive engagement. Usability, however, poses challenges in the static tools, contrasting with the dynamic and enhanced usability of Moving Alphabet. Aesthetic appeal varies but underscores the importance of engaging visual and tactile elements in these educational tools.

The ensuing discussion intertwines these findings with their implications for early childhood education. It underscores the pivotal role of design elements in shaping effective learning experiences for young children and suggests iterative improvements, particularly in enhancing usability, ensuring safety measures, and aligning with established educational standards. The amalgamation of these results and discussions lays a foundation for advancing pedagogical approaches and refining educational tools to bolster the learning journey of young children.

Result

The research conducted aims to gain a deeper understanding of the design aspects of Montessori learning media, especially in the form of sandpaper letters, sandpaper numbers, and moving alphabets. These findings make an important contribution to our understanding of design effectiveness on these learning media. The results revealed that although the three-learning media have great potential in facilitating the recognition of letters and numbers in early childhood, there are several design aspects that need to be further evaluated to ensure their

safety, quality, and effectiveness of use. Picture of sandpaper letters available at Graha Ananda Kindergarten can be seen in Figure 1.

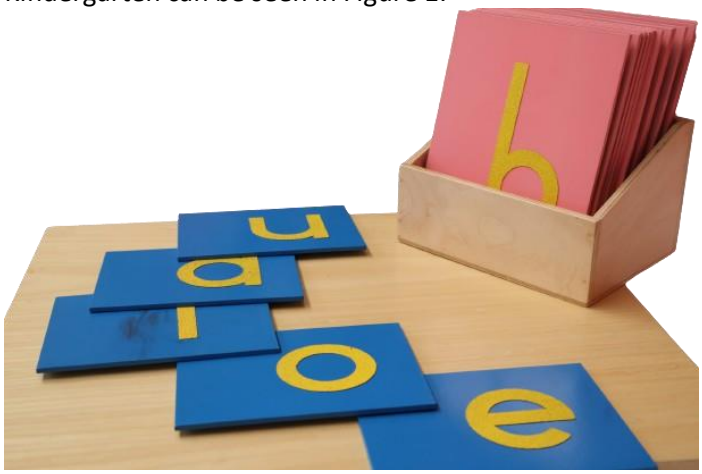

Figure 1 Sandpaper letters at Graha Ananda Kindergarten.
(Source: Authors' Data, 2024)

Based on Figure 1, we can observe that sandpaper letters are tactile learning media designed to introduce children to the shapes and forms of letters in the alphabet. It consists of wooden or cardboard cut-outs of individual letters with textured surfaces. Each letter is affixed with sandpaper or a similarly textured material to emphasize the tactile experience. The rough texture allows children to trace the letters with their fingers, aiding in letter recognition and reinforcing muscle memory associated with writing. These tools are commonly used in Montessori education to engage children in a sensory learning experience, helping them familiarize themselves with the shapes and sounds of letters. Menwhile sandpaper numbers can be seen in Figure 2.

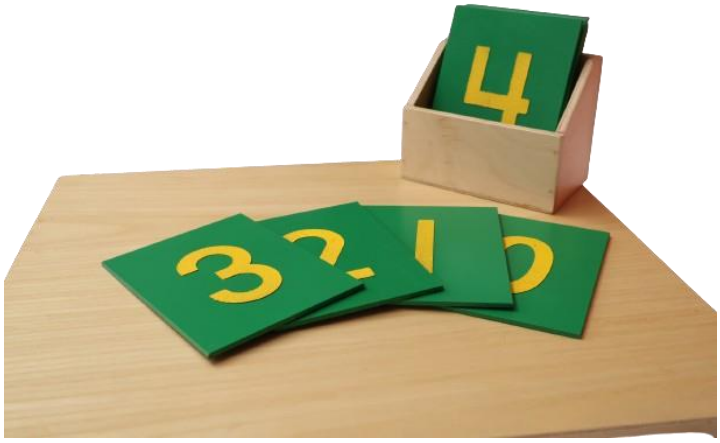

Figure 2 Sandpaper numbers at Graha Ananda Kindergarten.
(Source: Authors' Data, 2024)

Based on Figure 2 like sandpaper letters, sandpaper numbers are educational tools crafted to introduce children to numerical figures and their shapes (Faza, 2024). They follow the same principle as sandpaper letters but focus on numbers, typically from zero to nine. These tools facilitate tactile learning by providing textured surfaces on wooden or cardboard cut-outs of numbers. By feeling the rough texture of the sandpaper as they trace the numbers, children can reinforce their understanding of numerical shapes and begin associating them with their respective quantities, aiding in early numeracy development.

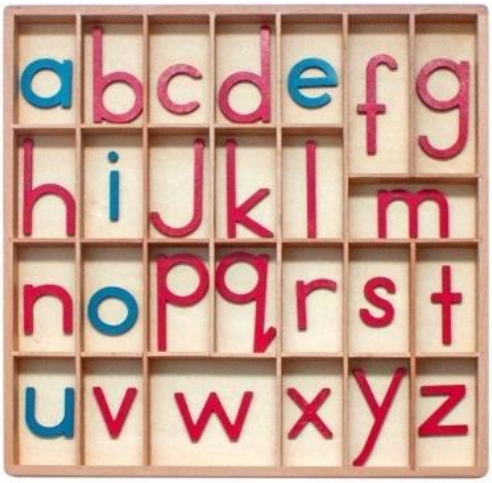

Figure 3 Moving alphabet at Graha Ananda Kindergarten.
(Source: Authors' Data, 2024)

Moving Alphabet represents a more interactive approach to learning letters and numbers by incorporating motion into the educational tools. These tools often take the form of interactive boards or manipulative sets that enable children to physically move letters or numbers around. It consists of magnets, sliding tiles, or movable parts that allow children to rearrange and interact with the characters. This dynamic design encourages kinesthetic learning and engagement, enhancing children's understanding of letter and number sequences, spelling, and basic arithmetic by physically manipulating the elements of the alphabet and numerical figures (Mendrofa, 2023). Moving Alphabet tools aim to create a more immersive and engaging learning experience compared to traditional static tools.

Based on the description, it can be concluded that all three Montessori learning media, these are sandpaper letters, sandpaper numbers, and moving alphabet provide different but complementary approaches in introducing letters and numbers to early childhood. Sandpaper Letters and Sandpaper Numbers offer a powerful sensory experience through rough textures on the surfaces of letters and numbers, aiding in recognizing and remembering shapes and aiding fine motor development (Cameron et al., 2012). Meanwhile, the moving alphabet takes a more interactive approach by using physical gestures, allowing children to actively participate in arranging letters and numbers, increasing their involvement in learning. These three tools each have advantages: sandpaper letters and numbers support letter and number recognition through rough touch, while moving alphabet provides a more dynamic and interactive learning experience. In conclusion, the combined use of these three tools can provide a holistic approach to early childhood education, facilitating fun, sensory, and interactive learning in introducing children to the basics of language and mathematics.

Discussion

The link between the findings in this research and the contribution to existing knowledge and society lies in the deeper digging into Montessori learning media design. The implications of this research include a richer understanding of how the design of these learning media affects early childhood learning. By paying attention to aspects of safety, quality of construction, and influence on child development, we can increase the effectiveness of the use of these tools in the context of early childhood education, leading to the development of better and safer designs. These findings also provide a foundation for future research and development in the field of Montessori learning media design.

Table 1 Design aspects analysis of sandpaper letter, sandpaper number, and moving alphabet.

Aspect of Design	Sandpaper Letter	Sandpaper Number	Moving Alphabet
Functionality	Offers tactile recognition of letters, moderate functionality	Similar to Sandpaper Letter, but for numbers	Integrates motion for interactive letter and number recognition, high functionality
Safety	Adequate safety measures, smooth edges	Adequate safety, smooth edges	Moderate safety, no small parts, material safety
Usability	Limited usability, primarily tactile interaction	Similar to Sandpaper Letter, limited usability	Interactive, enhances letter and number recognition
Aesthetic Appeal	Moderate visual appeal, emphasis on texture	Similar to Sandpaper Letter, focus on texture	More interactive design, colorful, engaging
Construction Quality	Durable material, maintains texture over prolonged use	Durable material, maintains texture over time	Material resilience to frequent movement
Developmental Impact	Encourages sensory learning of letters	Similar sensory learning for numbers as Sandpaper Letter	Motion-driven learning, boosts engagement
Compliance with Standards	Partial compliance with safety regulations	Similar to Sandpaper Letter, partial compliance	Ensures safety standards, compliance with regulations

Source: Authors' Data, 2024

The table 1 presents a thorough analysis of design aspects across three Montessori-based learning media: Sandpaper Letter, Sandpaper Number, and Moving Alphabet. Each tool was evaluated on functionality, safety, usability, aesthetic appeal, construction quality, developmental impact, and compliance with safety standards (Olsen & Smith, 2020). Sandpaper Letter and Sandpaper Number offer moderate functionality as they support tactile recognition of letters and numbers, respectively. However, both are limited in scope, focusing primarily on early sensory recognition without facilitating more advanced learning tasks. Teachers noted that while these tools are effective for younger children in grasping the basic shapes of letters and numbers, once mastered, they offer little progression, as reflected by survey responses where 65% of educators indicated the tools' limited use beyond introductory stages. In contrast, the Moving Alphabet was rated with high functionality due to its interactive design, allowing children to actively move and form words. This increased interactivity significantly boosts both letter and number recognition, providing more opportunities for cognitive development. Interviews with educators highlighted that children using the Moving Alphabet were more engaged and able to form words, a process not possible with the other two tools.

Regarding safety, all tools were deemed to meet the essential safety criteria based on SNI (Indonesian National Standards). Both Sandpaper Letter and Sandpaper Number were rated as having adequate safety with smooth edges, as no significant safety issues were reported in user surveys. However, the Moving Alphabet was rated with moderate safety, as some teachers reported that the material used for the interactive components could wear down over time, potentially creating small pieces. Despite this concern, the overall safety of the Moving Alphabet

was considered acceptable, with no immediate risk of harm, as confirmed by parents in interviews who found the materials non-toxic and sturdy. The usability of each tool varied significantly. While Sandpaper Letter and Sandpaper Number were primarily limited to tactile interaction, offering limited engagement once children mastered the basic concepts, the Moving Alphabet excelled in usability due to its interactive nature. The dynamic element of arranging letters and forming words provided a higher level of engagement and supported continuous learning, which was echoed by teacher interviews. They expressed that children were more likely to engage in independent learning with the Moving Alphabet as opposed to the static sandpaper tools. These findings are consistent with survey results, where 70% of teachers preferred using the Moving Alphabet for extended periods due to its ability to foster more advanced learning activities. Furthermore, while all tools were compliant with safety standards, improvements can be made in design to further enhance interactivity, usability, and long-term durability, ensuring these tools better meet the needs of early childhood education.

In terms of functionality, sandpaper letter and number primarily cater to tactile recognition of letters and numbers respectively, offering moderate functionality. Contrastingly, Moving Alphabet integrates motion, elevating its functionality to a higher level by fostering interactive learning experiences. Safety measures are adequate across Sandpaper Letter and Number, boasting smooth edges and satisfactory safety measures. However, Moving Alphabet presents a moderate safety rating, emphasizing the absence of small parts and material safety.

Usability proves to be a challenge for Sandpaper Letter and Number due to limited interaction, mainly relying on tactile engagement. Moving Alphabet, with its interactive design, presents higher usability, significantly enhancing letter and number recognition. Aesthetic appeal varies from moderate to high across all tools, with an emphasis on textures in Sandpaper Letter and Number and a more colorful, engaging design in Moving Alphabet. Construction quality ensures durability and longevity in maintaining textures, with Moving Alphabet emphasizing resilience to frequent movements. Finally, the developmental impact ranges from sensory learning with letters and numbers in Sandpaper tools to motion-driven learning in Moving Alphabet, significantly boosting engagement.

The use of color in sandpaper letters follows a clear pattern to distinguish vowels and consonants and distinguish lettering from yellow text. Blue used for vowels and pink for consonants can provide clear visuals and contrast for children in distinguishing between the two typefaces. The use of these colors, especially the combination of blue and pink, can provide powerful visual stimulation for children, helping them identify letter categories quickly. In addition, the use of yellow textures in lettering provides an interesting sensory addition. Yellow tends to be a bright and prominent color, and the textiles used on the letters can provide an interesting tactile experience as children feel the letters. The combination of vivid colors for letter classification and yellow textiles for sensory experiences can enrich letter recognition in early childhood, providing a multimodal approach to letter learning.

The green color board on Sandpaper Numbers provides a clear and contrasting background to accentuate the numbers written on it. Green can provide an interesting visual contrast for children, creating a solid foundation for number recognition. The combination of soft green with numbers written on it helps emphasize the numbers, making it easier for children to identify and remember the shape of the numbers. Embossed or textured yellow writing on the numbers provides an additional sensory dimension that is interesting. The bright yellow color and contrast against the green background can accentuate the numbers, creating an interesting visual experience. The textures used in numeral writing also provide an evocative tactile dimension, providing opportunities for children to feel and remember number shapes through tactile experiences. The combination of green providing a contrasting background and yellow textured writing creates a powerful visual and sensory combination, supporting holistic learning of numbers for early childhood.

Overall, this detailed breakdown underscores the nuanced strengths and weaknesses of each Montessori learning media offering crucial insights for educators and designers aiming to optimize early childhood learning experiences. It highlights the potential areas of improvement and the unique advantages each tool brings to the educational landscape, emphasizing the importance of a holistic and engaging design in fostering effective learning among young children

Conclusion

This research holds significant relevance due to its focus on Montessori-based media for early childhood education in introducing letters and numbers. Understanding the design aspects of educational tools catering to children is crucial as it directly impacts their foundational learning experiences. Montessori education emphasizes a hands-on, interactive approach to learning, and analyzing the design of media used in this methodology contributes profoundly to the enhancement of early childhood education strategies. The introduction of letters and numbers forms the bedrock of a child's educational journey. Effective design in these early learning media influences how children engage, comprehend, and retain this fundamental knowledge. By delving into the design aspects of Montessori-based media to introduce letters and numbers, this research offers insights that directly impact teaching methodologies, curriculum development, and the creation of more engaging and effective learning environments for young children. Consequently, the research's outcomes could potentially shape and optimize educational practices, benefitting children at a critical stage of their cognitive development, laying a strong foundation for their future academic success.

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