Jurnal Sustainable

Volume 7 Number 1 2024, 153-165
E-ISSN: 2655-0695
DOI:https://doi.org/ 10.32923/kjmp.v7i1.4511

Study on Subitizing: Exploring Numeracy Mastery in Early Childhood

Mahfudz Reza Fahlevi[1*]

Abstract

Subitizing, the ability to rapidly and accurately recognize small quantities of objects without counting, has become a primary focus in developing numeracy understanding in early childhood. The research uses a qualitative approach with literature study techniques. The study aims to provide a comprehensive overview of the concept of subitizing, learning trajectories, and recommendations for teaching it to young children, as well as concrete examples from research involving multidisciplinary approaches. The findings indicate that current research explores various aspects of subitizing, ranging from effective teaching strategies to learning trajectories appropriate for children's developmental stages. Effective subitizing instruction includes the use of relevant number concepts in everyday interactions, practicing naming small collections of objects with numbers, and repeated experiences in recognizing and naming groups of objects. Subitizing learning trajectories encompass developmental processes and the creation of task-supportive environments, ranging from unconscious number understanding to the ability to recognize quantities up to 10 objects. Various research outcomes also highlight the application of subitizing in technology development, such as subitizing games to enhance children's mathematical abilities and assistive software for children with dyscalculia. Studies in psychology and health fields reveal the complexity of the relationship between subitizing and cognitive functions, such as in children with specific conditions like Cerebral Palsy or brain injuries. With a multidisciplinary approach, current research continues to expand understanding of the benefits of subitizing and its implications in various contexts, from education to health, aiming to enhance children's learning and well-being holistically.

Keywords: Childhood Development; Early Numeracy; Subitizing

History:
Received : 31 Mei 2024
Revised : 07 June 2024
Accepted : 10 June 2024
Published : 29 June 2024
[1]Institut Agama Islam Negeri Syaikh Abdurrahman Siddik Bangka Belitung
*Author Correspondent: mahfudzrezafahlevi@gmail.com

Publishers: LPM IAIN Shaykh Abdurrahman Siddik Bangka Belitung, Indonesia

Introduction

Mathematical ability is a crucial foundation in the intellectual development of every individual, playing a pivotal role in building the groundwork for future, more complex conceptual understanding. Mathematical ability is increasingly emphasized through national and international stage assessments that prioritize numeracy terms. However, the focus on numerical education often tends to be overlooked in the early stages of learning, particularly in the context of preschool education.

In these early stages of learning, it is important for every educator to understand that children possess a natural ability to comprehend and recognize quantities of objects directly without counting. The concept known as subitizing is one such ability that emerges and needs to be supported during this process. Subitizing refers to the ability to instantly recognize small quantities of objects without the need for explicit counting. Several researchers have aptly defined subitizing in previous studies.

Subitizing, defined as the rapid and accurate recognition of small quantities without the need for counting, operates uniquely from estimation by not processing multiple groups simultaneously. Subitizing functions as a subprocess within counting, facilitated by attentional

resources and recognizable patterns. Rapid perception of these small quantities aids children in transitioning from perceptual to conceptual processes. From various research findings, it has been found that subitizing emphasizes activities on grouping constructions of units (Katzin, Cohen and Henik, 2019; Liu *et al.*, 2020; MacDonald and Wilkins, 2019).

In teaching number concepts to preschool children, understanding subitizing has significant implications (Jung *et al.*, 2013). The ability to rapidly recognize small quantities of objects provides a strong foundation for understanding larger number concepts in the future (Newbury *et al.*, 2012). Therefore, it is important to understand how the subitizing process develops in children, and educators or caregivers are highly encouraged to facilitate its development in efforts to strengthen numeracy skills in early childhood (Banda, 2018).

Although the importance of subitization in early childhood mathematics learning has been recognized globally through various research findings, such as those related to technology (Broda *et al.*, 2019; Löfstrand, 2021), health (Ashkenazi *et al.*, 2022; Gosling, Demeyere and Dowker, 2023), and mathematics disorders (Danilov and Mihailova, 2022). Studies on this topic in Indonesia are still limited and less diverse, some of the research results focus on understanding subitization (Ariyana, 2018; Sari *et al.*, 2022) and summaries of subitizing teaching (Fahlevi, 2022a; Fahlevi, 2022b). Compared to other countries that have expanded the scope of subitizing research by involving technology and various disciplines such as psychology and health, research outcomes in Indonesia have not reached such stages. The lack of focus on subitizing in the context of preschool mathematics education in Indonesia may diminish the potential for effective learning in young children. Therefore, it is important to promote broader and more in-depth research on subitizing in Indonesia, integrating various scientific approaches and modern technology to enrich teachers' and researchers' understanding of the importance of this skill in early numeracy learning.

Furthermore, this research aims to provide a comprehensive overview of the concept of subitizing, learning trajectories, and recommendations for teaching it to young children, as well as concrete examples from research involving multidisciplinary approaches. By elucidating these concepts comprehensively, researchers hope to make a meaningful contribution to enhancing understanding and developing numeracy learning practices in the early stages of child development. Through the integration of diverse scientific approaches, including modern technology and insights from psychology and health fields, this research may pave the way for a better understanding of the role of subitizing in early childhood learning and its implications in the context of mathematics education in Indonesia.

The novelty in this study in the integration of diverse scientific approaches, including modern technology and insights from the fields of psychology and health, to explore the role of subitizing in early childhood learning. This approach goes beyond traditional methods by combining cutting-edge technology and interdisciplinary perspectives, thereby offering a more comprehensive understanding of subitizing and its implications for mathematics education in Indonesia. By utilizing modern technology, such as game subitization and assistive software, researchers have the potential to increase the effectiveness of teaching methods and support children's mathematical abilities. Additionally, insights from the fields of psychology and health provide valuable perspectives on the cognitive processes involved in subitization, particularly in children with certain conditions such as cerebral palsy or brain injury. Therefore, the novelty of this research lies in its innovative approach, which integrates diverse scientific disciplines to increase our understanding of subitization and its educational implications in the Indonesian context.

Subitizing, a term often denoted as "subitisasi" in Bahasa Indonesia, encompasses the cognitive capacity to swiftly discern the quantity of objects presented without the necessity of explicit counting. Despite its absence from the formal lexicon of the Kamus Besar Bahasa Indonesia (KBBI), this study maintains linguistic consistency by embracing the term "subitizing". This cognitive phenomenon is characterized by the rapid, nearly instantaneous recognition of

numerical values when confronted with an array of objects (Charlesworth and Lind, 2010). Etymologically, "subitizing" finds its origins in the Latin word "subitus", meaning sudden, from which the Italian term "subito" is derived (Kaufman *et al.*, 1949). Scholars of the early 20th century argued fervently for the significance of subitizing over traditional counting methods in accurately apprehending quantity (Sarama and Clements, 2014). This perspective emphasizes the pivotal role of subitizing in shaping the development of numerical cognition and perception, thereby shedding light on its profound implications across various fields of study, including education and psychology.

Furthermore, the concept of subitizing extends beyond mere numerical recognition, influencing various aspects of cognitive processing. Studies have shown that individuals proficient in subitizing often exhibit enhanced spatial reasoning skills and have a heightened ability to recognize patterns and organize visual information efficiently (Gallistel and Gelman, 1992). This suggests that subitizing not only facilitates rapid quantity assessment but also plays a crucial role in broader cognitive functions. Additionally, research indicates that deficits in subitizing abilities are associated with certain developmental disorders, such as dyscalculia, highlighting the significance of this cognitive process in understanding mathematical difficulties (Butterworth, 1999). Understanding the mechanisms underlying subitizing can thus have profound implications for educational practices, intervention strategies, and the design of instructional materials aimed at improving numerical proficiency among learners of all ages. Therefore, while the term "subitisasi" may not yet be formally recognized in linguistic dictionaries, its conceptual importance remains undeniable, warranting further investigation and integration into educational frameworks and cognitive theories.

There exist two distinct categories within the realm of subitizing: perceptual subitizing and conceptual subitizing (Sarama and Clements, 2014). Perceptual subitizing aligns closely with the fundamental notion of subitizing, wherein individuals can discern quantities without resorting to additional mathematical processes. For instance, children may effortlessly "grasp the concept of 3" without the need for formal mathematical comprehension. Perceptual subitizing may involve cognitive mechanisms akin to those observed in various animal species. Notably, this ability has been vividly demonstrated in two-year-old children (Gelman and Gallistel, 1986). Perceptual subitizing typically manifests when dealing with small quantities, typically falling within the range of 1 to 4 or 5. The role of perceptual subitizing also encompasses more fundamental aspects, often overlooked as they are considered natural. Its actual role lies in forming units or objects to be counted. Although this ability may seem straightforward to an individual, separating experiences into separate units and then coordinating them with numerical words is not an easy task for children. Even when they count their fingers, they must mentally divide one part of the hand from another to form units. Subsequently, children must associate each of these units with one, and only one, numerical word. The ability to subitize needs to be supported in various natural situations.

Perceptual subitizing, a seemingly instinctive cognitive process, carries deeper implications beyond mere numerical recognition. Its essence lies in the formation of discrete units or objects that can be readily counted, a task often taken for granted as effortless. However, for children, this seemingly simple task poses a significant cognitive challenge. The ability to discern and separate individual entities from a collective whole, whether it's counting fingers or distinguishing objects in their environment, requires intricate mental processes. Even when counting fingers, children must mentally segment one part of the hand from another to create distinct units for enumeration. Furthermore, they must align each of these units with a corresponding numerical word, a task demanding precise cognitive coordination. Thus, the development of perceptual subitizing not only involves the rapid recognition of quantities but also the intricate mental processes underlying the formation of discrete counting units.

Conceptual subitizing represents a cognitive process that transcends mere perceptual recognition of quantities, involving the understanding of numerical concepts in a more abstract

manner. Unlike perceptual subitizing, which relies primarily on visual perception to recognize small quantities without counting, conceptual subitizing entails grasping the numerical significance of a set of objects without necessarily seeing them all at once. Research in cognitive psychology and developmental neuroscience has revealed that conceptual subitizing develops as children gain proficiency in counting and understanding numerical symbols (Mix, Levine and Newcombe, 2016). Additionally, neurological studies employing brain imaging techniques have identified distinct neural pathways associated with conceptual subitizing, suggesting its reliance on higher-order cognitive processes beyond simple visual perception (Budd, 2015). Understanding the mechanisms underlying conceptual subitizing is crucial for educators, as it informs the design of instructional strategies aimed at promoting deeper numerical understanding and mathematical proficiency in learners of all ages.

In nurturing the ability to subitize, it's crucial to recognize the role of natural experiences in facilitating this cognitive skill. Everyday situations provide invaluable opportunities for children to engage in subitizing exercises, from counting objects during playtime to identifying items in their surroundings. Through these organic interactions, children learn to perceive and categorize discrete entities, laying the foundation for numerical comprehension. By seamlessly integrating subitizing activities into everyday routines, caregivers and educators can provide the necessary support for children to refine their cognitive abilities in a contextually relevant manner.

Method

This research is based on a literature study. Literature review research falls under the category of qualitative research, which requires descriptive analysis (Darmalaksana, 2020), the data analysis technique employed is content analysis, which is systematically conducted on notes or documents as the data source to ensure validity and reliability, including legislative documents, policies, and research findings (Hardani *et al.*, 2020). The research instruments pertinent to this study include a classification list of research materials and a writing scheme/map and format for research notes (Awalina & Purwoko, 2018).

In library research, the literature is derived from books, scientific articles, or other relevant literature used as sources of ideas to generate further thoughts or concepts without the necessity of conducting field research (Sari and Asmendri, 2020). In conducting this literature review study, the researcher examined a substantial number of articles to compile a comprehensive understanding of subitizing in children's education. Researchers typically access relevant articles through academic databases, such as DOAJ and Google Scholar, utilizing keywords related to subitizing, education, and cognitive development. The reliability of research data is determined by criteria such as publication credibility, relevance to the research focus, methodological variance, and alignment with established theory. Additionally, the inclusion of seminal texts such as Sarama and Clements (2014) and Walle, Karp and Bay-Williams (2019) contributes to the breadth and depth of the literature review, ensuring a thorough examination of subitizing within educational contexts.

Results and Discussion

As subitizing gains increasing attention in global research, scholars are delving into various aspects of the concept. This includes investigating effective instruction methods, teaching trajectories, and multidisciplinary findings. Across several countries, the focus on subitizing is intensifying, reflecting a growing interest in understanding its nuances and implications for learning and cognition.

1. Introduction and Effective Teaching of Subitizing

For introducing everyday numbers, especially to caregivers of toddlers or companions of three-year-old children, one of the simplest yet effective practices is consistently incorporating numerical values into daily interactions. Rather than saying, "Clean the cups from this table!", it would be better to phrase it as, "We need to clean this table, could you pick up three cups from the table?". This approach is more natural as it utilizes the use of words with relevant numerical concepts. Caregivers, companions, or teachers can also share this strategy with parents.

Furthermore, to support children in developing subitizing skills, parents, teachers, caregivers, or companions can initiate practices by naming very small collections with numbers. This is done after children have mastered naming and can categorize physical attributes such as shape and color. This approach helps children understand the concept of quantity without constantly switching between the use of ordinal and cardinal number words, as required in traditional counting methods. Repeat experiences in naming collections also help children build relationships between quantity terms and number words.

Repeated experiences involving naming specific collections or groups can help children build relationships between quantity terms (such as "number" and "how many") and number concepts in words. This process allows children to connect words with specific quantities (for example, the objects • • are "two") and ultimately, children are expected to connect different representations of the same number. Providing further examples, such as pointing out when a collection does not match the number mentioned ("That's not two circles, but three circles!"), is also important to clarify the boundaries of each number. (Walle, Karp and Bay-Williams, 2019).

These repeated experiences help children build both perceptual and conceptual subitizing skills. To reinforce conceptual subitizing, children should engage in various real-life activities, such as observing finger patterns, arrangements of dice and dominoes, and arrays separating into two subgroups. Teachers can also facilitate learning by discussing and collaboratively arranging arrays to facilitate determining their quantities. Continuous practice in naming groups helps children understand number concepts and enrich their subitizing skills.

However, it is important to avoid practices that may inadvertently hinder children's mathematical understanding. Misleading experiences, such as embedding groups in pictorial contexts, can lead children to perceive collections as figurative arrangements rather than precise quantities. Conversely, approaches that integrate subitizing with counting can enrich children's arithmetic understanding and facilitate the development of more advanced addition and subtraction strategies.

In various educational settings, such as classroom discussions and textbooks, children can benefit from the use of numbers that facilitate conceptual subitizing. adherence to the following recommendations proposed by Wästerlid (2020) is crucial:

a) Avoid embedding groups in pictorial contexts (pictures of animals or non-simple geometric shapes).
b) Utilize simple shapes, such as groups of circles or squares, for small groupings of units, rather than complex images or shapes.
c) Emphasize orderly arrangements, preferably symmetrical ones. Linear arrangements are suitable for preschoolers, while rectangular arrangements are more suitable for older children.
d) Ensure that the contrast of images is displayed well to enhance clarity and avoid visual misinterpretations by children.

2. *Learning Trajectory* on *Subitizing*

Suggesting a learning strategy labeled as a "learning trajectory" for identifying numbers and subitizing seeks to improve children's proficiency in quickly recognizing numbers,

particularly during early childhood. In pre-kindergarten, the priority is on comprehending the significance of numbers and discerning the quantity of items in small clusters without resorting to counting. Conversely, for children in kindergarten, the aim is for them to adopt, blend, and employ efficient approaches to solve numerical queries, encompassing swift identification of quantities within small sets. To achieve these objectives, the learning trajectory is divided into two additional components: (1) developmental processes and (2) the creation of a supportive task environment. Below is the recommended learning trajectory from Sarama and Clements (2014) to aid in developing subitizing skills in early childhood, from birth to five years of age.

a. Age: 0-1 Year

Developmental Progression: Unconscious Number Awareness

In the early developmental phase, children receive stimuli from their surrounding environment related to the concept of numbers, albeit without explicit awareness or deliberate understanding. This can be considered as the onset of their introduction to numbers, often starting with interactions with physical objects in their everyday environment.

Guidelines/Creation of a Supportive Task Environment:

Teachers or caregivers can ensure the presence of a rich and diverse sensory environment and facilitate children's interactions with physical objects, often involving the use of comparative vocabulary such as "more", which encourages children to engage in adding objects, thus helping to direct their attention to the concept of comparison.

b. Age: 1-2 Years

Developmental Progression: Naming a Small Collection

Referring to groups of objects ranging from one to two, sometimes three, such as a pair of shoes, teachers or caregivers can express this using appropriate vocabulary. For example, when showing a pair of shoes, assist the child by stating, "These are two shoes!".

Guidelines/Creation of a Supportive Task Environment:

When gesturing to a small group of objects, start by showing the quantity of two first, for example, by displaying two balls while saying, "There are two balls. Two!". Once the child is capable, the teacher or caregiver can ask about the quantity, thus helping them sharpen their understanding of the concept of quantity. Ensure that interactions like this become a natural part of daily activities. Additionally, provide clear and tangible examples of object grouping. For instance, if there are three balls, say, "That's not two. That's three!". This helps the child identify the difference between the quantities two and three. Furthermore, the teacher or caregiver can create their own groups of objects in a structured arrangement, such as three objects arranged to appear as one group, while three other groups have two objects each. Encourage children to find "what's different from the others" and discuss why they are different. By providing various experiences like these, children will quickly grasp the concepts of quantity and visual object grouping.

c. Age: 3 Years

Developmental Progression: Creation of a Small Collection

Nonverbally, teachers or caregivers can create small collections with the same number as other collections, not exceeding four. This can be done using mental representation (referring to how one forms a mental image or concept of something in their mind without needing to see or touch it physically), without requiring physical object matching. For example, if a teacher or caregiver displays a collection of three balls, they can

mentally model three other objects without physically arranging them. This can be accomplished by moving the teacher's or caregiver's hand in the air to indicate the quantity or by pointing to available objects around without physically grouping them. If necessary, teachers or caregivers can also provide verbal assistance. For instance, while displaying a collection of three balls, the teacher or caregiver could say, "Now, let's make another collection that has the same amount as this one." This will help children understand the concept of equal quantities visually and verbally (Nes, 2009).

Guidelines/Creation of a Supportive Task Environment:

Involve children in the process of obtaining the appropriate number of biscuits or similar objects for a small group. Form a small collection, such as two blocks, and engage in a hiding activity. Ask the children to arrange a group that has the same number of blocks as those prepared. Once completed, show them the result and ask if the quantity matches. In the final stage, give a name to the formed quantity.

d. Age: 4 Years

Developmental Progression: The Fourth Perceptual Subitizer

Quickly identify groups of objects up to the quantity of four displayed temporarily, then verbally state the number of objects.

Guidelines/Creation of a Supportive Task Environment:

Display pictures containing collections of dots from one to four, arranged in simple sequences or patterns, and ask the children to respond verbally by naming the depicted quantities. Use variations in the arrangement of the dots. Start with smaller quantities and simpler patterns, then increase to moderate difficulty levels as children demonstrate increasing proficiency and confidence.

e. Age: 5 Year (Stage 1)

Developmental Progression: The Fifth Perceptual Subitizer

Quickly recognizes visually presented collections up to a quantity of five, then verbally states the quantity of items. Briefly display five objects and immediately say "Five".

Guidelines/Creation of a Supportive Task Environment:

Present dot cards, starting with easy arrangements, and gradually progress to more challenging settings as children's abilities improve.

f. Age: 5 Year (Stage 2)

Developmental Progression: The Fifth Conceptual Subitizer

Provide verbal labeling for each card presentation up to about five dots/objects, even though the display is brief. For example, by stating, "Five! Why?" The expected response is, "I identified three and two, that's why I said five".

Guidelines/Creation of a Supportive Task Environment:

Utilize various rules from each modified picture to develop subitizing and concepts of addition and subtraction. The aim is to stimulate children to perceive addition and quantity concepts, such as "Two apples plus two apples make four apples".

g. Age: 5 Year (Stage 3)

Developmental Progression: Conceptual Subitizer Ten

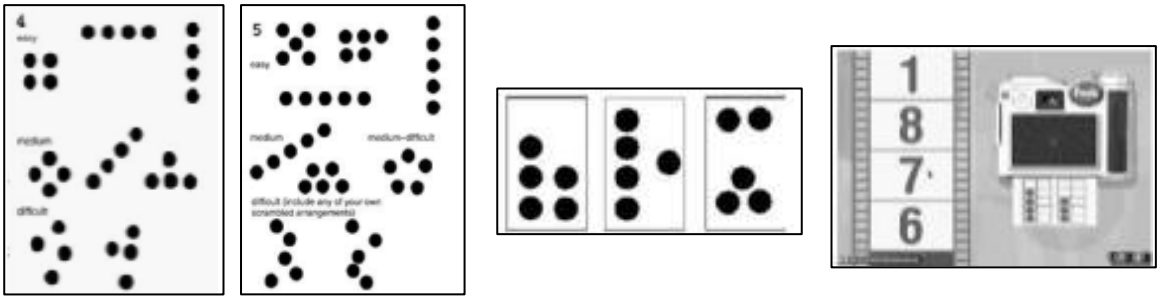
Provide verbal naming for arrangements with quantities from 6, and so on, up to 10, using grouping. For example, "In my mind, I make two groups of 3 plus one more, so it's 7".

Guidelines/Creation of a Supportive Task Environment:

Utilize images illustrating the process of turning on or off a computer with representations of dots corresponding to numbers. Feedback provided by the computer version can highlight that "adding three and four results in seven".

Figure 1.

Recommended Arrangement of Objects to Introduce to Children at Ages (a) 4 Years, (b) 5 Years (Stage 1), (c) 5 Years (Stage 2), and (d) 5 Years (Stage 3)



(a) (b) (c) (d)

Source: Sarama and Clements (2014)

The focus on pre-kindergarten children is to understand the meaning of numbers and recognize the quantity of objects in small groups without the need for counting, while at the kindergarten age, the aim is for them to be able to select, combine, and apply effective strategies in answering quantitative questions, including quickly recognizing quantities in small groups. With the proposed learning trajectories as described earlier, it is hoped to aid in the development of early childhood subitizing, at least from birth to five years old, with various strategies and approaches tailored to the child's developmental stage, ranging from unconscious understanding to the ability to verbalize more complex quantities.

3. Recent Research Findings Regarding Subitizing

The development of research on subitizing, a cognitive process that enables humans to rapidly and accurately recognize small quantities of objects without explicit counting, has become a primary focus across disciplines. Recent studies integrate this concept with technology, such as the development of applications that facilitate subitizing development support, and the utilization of subitizing games to enhance children's mathematical skills. Additionally, psychological research has deepened the understanding of the cognitive mechanisms behind subitizing, including factors related to brain memory. Health aspects have also come under scrutiny, with research exploring the subitizing abilities of children who have experienced certain academic disorders that can affect the accuracy and speed of subitizing processes. Through this multidisciplinary approach, current research on subitizing continues to broaden understanding of its benefits and implications in various contexts, from education to health.

a. In-depth research findings on subitizing

Previous studies have deepened the understanding of subitizing with a focus on two main types: perceptual subitizing and conceptual subitizing. One study, which examined perceptual subitizing in 119 children aged 3 and 4 years, highlighted the influence of visual features such as image, a group of homogenous objects, arrangement, and differences or variations in children's subitizing process activities. The results showed that simple images, with a group of the same or homogenous objects arranged linearly, yielded the best subitizing results achieved by children, while images with disruptions or overlapping objects decreased accuracy and prolonged response time from children (Splinter *et al.*, 2024).

Several studies related to conceptual subitizing have investigated the influence of activities supporting conceptual subitizing on the understanding of preschool children regarding the part-whole relationships of numbers. The activities outlined in these studies indicate support for children's mathematical knowledge development, with a test score increase of 18.1% after intervention. This research highlights the importance of organizing quantities into small, identifiable groups to support children's learning in mathematics while emphasizing the difference between perceptual and conceptual subitizing and the implications for future actions in supporting diverse learning needs (Wästerlid, 2020).

Next, a review of the development of subitizing games such as Show and Tell, Ice Cream, Penny Bug, and Hidden Picture reveals their utility in assessing preschool children's understanding of number concepts. The Ice Cream game helps students focus on subgroups relative to the total number of items, aiding their understanding of numbers. Various types of subitizing activities, such as Perceptual Ascending Subitizing (PAS) and Perceptual Descending Subitizing (PDS), are used to categorize and assess students' understanding of numbers. Teachers can leverage subitizing games to support counting activities and vice versa, enhancing students' understanding of numbers. Observing students' reliance on counters, fingers, or other materials during subitizing activities can provide educators with information about students' number understanding and serve as a guide for future instructional strategies. (Clements, Sarama and MacDonald, 2019).

b. Research on technology-based subitizing

In addition to focusing research on both types of subitizing, recent studies have also integrated various disciplines to produce more advanced findings. One example is the relationship between subitizing and technology, where previous research has shown the potential of technology to enhance subitizing abilities. A study observed human-computer interaction online as a method for intervention with the topic of subitizing activities to improve mathematical competence in children with dyscalculia. The intervention involved children being quickly exposed to images with few dots through various common problem-solving exercises. The software used in the intervention was implemented via mobile phones. Children engaged in tasks to select answers related to the arrangement of dots on the screen. The intervention aimed to broaden children's perception of dots, increase the size of the focal point of attention, and ultimately enhance numerical competence. The results of the intervention showed a positive relationship between perception expansion and numerical development in children with dyscalculia (Danilov and Mihailova, 2022).

Another study related to technology aimed to assess the abilities of preschool children in subitizing games (game-based) to determine the appropriate difficulty level. The research results showed that children were quicker and more accurate in identifying four objects, but if given more time, they tended to resort to counting, which could reduce the accuracy of subitizing games. The recommendation from the study is to adapt games by shortening the response time and developing the game interface to be more dynamic.

Subitizing games (game-based) could serve as promising educational tools with potential for further development in teaching subitizing skills (Broda *et al.*, 2019; Löfstrand, 2021).

c. Research on subitizing in the fields of psychology and health

Research on subitizing is not only related to children's ability to understand numbers as an achievement or the role of technology in developing learning media but can also involve studies in the field of psychology. Psychology plays a crucial role in understanding the cognitive and psychological aspects of the subitizing process. For example, research on the abilities of children with special conditions.

Research on subitizing has been conducted on children with Cerebral Palsy (CP). Children with CP show lower subitizing limits compared to children in the control group (normal condition), and these limits increase with age in both groups. Subitizing limits in children with CP correlate positively with counting ability and eye-hand coordination. This indicates an interdependence of these skills. Children with CP without lesions in the right hemisphere tend to have higher subitizing limits, indicating the involvement of the right hemisphere in subitizing. The impact of this research highlights delays in subitizing development in children with CP, which are associated with counting ability and eye-hand coordination, supporting a model of subitizing that depends on global processes. The relationship between subitizing and eye-hand coordination is significant in children with CP, with higher accuracy in eye-hand coordination associated with higher subitizing limits (Arp, Taranne and Fagard, 2006).

Subsequent research has investigated the enumeration process, particularly subitizing. The research focused on preschool children, emphasizing the role of visual-spatial working memory. Subitizing, believed to be crucial for developing a mature understanding of numerals, is associated with mathematical abilities. The study examined children aged 3 to 5 years in enumeration tasks and visual-spatial working memory, finding that performance in subitizing (1-4 items) correlated with visual-spatial working memory and age, while the ability in serial counting (referring to the process of counting objects one by one in a systematic order, such as saying "one, two, three, four...") did not show the same relationship. Controlling for visual-spatial working memory reduced the developmental impact on subitizing, indicating that both visual-spatial working memory and age influence individual differences in subitizing abilities in preschool children, implicating early childhood education, especially in enumeration (Ashkenazi *et al.*, 2022).

Other studies have explored subitizing abilities and arithmetic skills in patients who have experienced brain injuries, revealing intriguing findings. No significant correlation was found between subitizing and speed in addition or multiplication. Some patients showed differences between subitizing abilities and arithmetic skills, suggesting a componential view of arithmetic abilities. The research highlights the complexity of the relationship between subitizing and arithmetic, indicating that deficiencies in subitizing do not always result in deficiencies in basic arithmetic skills. The study also emphasizes the need for further research to understand the intricate relationship between numerical abilities and brain function. Future research should involve larger samples and explore various numerical abilities to gain comprehensive insights. Techniques such as transcranial magnetic stimulation and functional MRI can provide different and valuable research findings regarding the relationship between brain areas and specific abilities. Health focus is crucial for individuals with acquired brain injuries to support cognitive function and overall well-being (Gosling, Demeyere and Dowker, 2023).

Conclusion

Subitizing is the ability to rapidly and accurately recognize small quantities of objects without explicit counting, constituting a crucial and rapidly evolving field of research. In the realm of pedagogy, the emphasis lies on the significance of employing words associated with relevant numerical concepts in everyday interactions, as well as the practice of labeling small collections with numbers. This approach aids children in grasping quantity concepts without the need for constant switching between the use of ordinal and cardinal number words, as required in traditional counting methods. It is also imperative to avoid practices that may impede children's mathematical comprehension, such as embedding groups in pictorial contexts.

The trajectory of learning provides directed guidance for the introduction of numerical concepts and subitizing, starting from the early developmental stages to preschool-aged children. This aids in supporting the development of children's subitizing skills in accordance with their developmental stages. Recent research findings indicate that subitizing has become a focal point of interdisciplinary research, encompassing fields such as technology, psychology, and healthcare. This research aims not only to enhance understanding of the subitizing process itself but also to apply this knowledge in the development of applications and interventions that can improve children's mathematical skills, including those with special conditions such as cerebral palsy.

Recommendations for further research can be proposed in accordance with more focused research objectives. Proposed recommendations include adapting teaching strategies to align with children's developmental stages, encouraging interdisciplinary collaboration to explore various aspects of subitization, directing research efforts toward practical applications and interventions, conducting longitudinal studies to track development and assess the effectiveness of interventions, and ensuring inclusivity in research and intervention. interventions to accommodate diverse learning profiles. By following these recommendations, future research efforts can contribute to advancing knowledge and practice in subitization, ultimately improving children's mathematics skills and encouraging inclusive educational practices.

Reference

Ariyana, I.K.S. (2018) 'Subitizing Sebagai Kemampuan Mendasar Bagi Anak Usia Dini Untuk Menguasai Konsep Bilangan', *Purwadita*, 2(2), pp. 57–65.

Arp, S., Taranne, P. and Fagard, J. (2006) 'Global perception of small numerosities (subitizing) in cerebral-palsied children', *Journal of Clinical and Experimental Neuropsychology*, 28(3), pp. 405–419. Available at: https://doi.org/10.1080/13803390590935426.

Ashkenazi, S. *et al.* (2022) 'Early Subitizing Development: The Role of Visuospatial Working Memory', *European Journal of Education and Pedagogy*, 3(2), pp. 79–85. Available at: https://doi.org/10.24018/ejedu.2022.3.2.274.

Banda, A.M. (2018) 'Evaluating Factors of Autistic Hiring through Ajzen's Theory of Planned Behavior: The HASSQAC Scale', *International Journal of Humanities and Social Science*, 8(8), pp. 24–32. Available at: https://doi.org/10.30845/ijhss.v8n8p1.

Broda, M. *et al.* (2019) 'Small fingers, big data: Preschoolers' subitizing speed and accuracy during interactions with multitouch technology', *Journal of Educational Research*, 112(2), pp. 211–222. Available at: https://doi.org/10.1080/00220671.2018.1486281.

Budd, C.J. (2015) *Promoting Maths to the General Public*, *The Oxford Handbook of Numerical Cognition*. Available at: https://doi.org/10.1093/oxfordhb/9780199642342.013.47.

Butterworth, B. (1999) 'A Head for Figures', *SCIENCE'S COMPASS*, pp. 928–929.

Charlesworth, R. and Lind, K.K. (2010) *Math and Science. Six Edition*. Amerika Serikat.

Clements, D.H., Sarama, J. and MacDonald, B.L. (2019) *Subitizing: The Neglected Quantifier*. Available at: https://doi.org/10.1007/978-3-030-00491-0_2.

Danilov, I.V. and Mihailova, S. (2022) 'A Case Study on the Development of Math Competence in an Eight-year-old Child with Dyscalculia: Shared Intentionality in Human-Computer Interaction for Online Treatment Via Subitizing', *OBM Neurobiology*, 6(2). Available at: https://doi.org/10.21926/obm.neurobiol.2202122.

Darmalaksana, W. (2020) 'Metode Penelitian Kualitatif Studi Pustaka dan Studi Lapangan', *Pre-print Digital Library UIN Sunan Gunung Djati Bandung*, pp. 1–6.

Fahlevi, M.R. (2022a) 'Studi Literatur: Pemanfaatan Teknologi Dalam Pembelajaran Sebagai Upaya Untuk Menumbuhkembangkan Number Sense Siswa', *LINEAR: Journal of Mathematics Education*, 3(1), p. 42. Available at: https://doi.org/10.32332/linear.v3i1.4847.

Fahlevi, M.R. (2022b) 'Upaya Pengembangan Number Sense Siswa Melalui Kurikulum Merdeka (2022)', *Jurnal Sustainable*, 5(1), pp. 11–27. Available at: https://doi.org/https://doi.org/10.32923/kjmp.v5i1.2414 Upaya.

Gallistel, C.R. and Gelman, R. (1992) 'Preverbal and Verbal Counting and Computation', *Cognition*, 44(22), pp. 43–74.

Gelman, R. and Gallistel, C.R. (1986) *The Child's Understanding of Number*. Harvard University Press.

Gosling, E., Demeyere, N. and Dowker, A. (2023) 'Numerical Cognition after Brain Injury: Is There a Relationship between Subitizing and Arithmetical Abilities?', *Brain Sciences*, 13(3). Available at: https://doi.org/10.3390/brainsci13030381.

Hardani *et al.* (2020) *Metode Penelitian Kualitatif & Kuantitatif*. 1st edn. Edited by H. Abadi. Yogyakarta: CV. Pustaka Ilmu.

Jung, M. *et al.* (2013) 'The Effectiveness of Teaching Number Relationships in Preschool', *International Journal of Instruction*, 6(1), pp. 165–178.

Katzin, N., Cohen, Z.Z. and Henik, A. (2019) 'If it looks, sounds, or feels like subitizing, is it subitizing? A modulated definition of subitizing', *Psychonomic Bulletin and Review*, 26(3), pp. 790–797. Available at: https://doi.org/10.3758/s13423-018-1556-0.

Kaufman, E.L. *et al.* (1949) 'The Discrimination of Visual Number', *The American Journal of Psychology*, 62(4), pp. 498–525.

Liu, W. *et al.* (2020) 'Subitizing, unlike estimation, does not process sets in parallel', *Scientific Reports*, 10(1), pp. 1–8. Available at: https://doi.org/10.1038/s41598-020-72860-4.

Löfstrand, A. (2021) *Can You Practise Conceptual Subitizing On a Tablet ?* Linköping University.

MacDonald, B.L. and Wilkins, J.L.M. (2019) 'Subitising activity relative to units construction: a case study', *Research in Mathematics Education*, 21(1), pp. 77–95. Available at: https://doi.org/10.1080/14794802.2019.1579667.

Mix, K.S., Levine, S.C. and Newcombe, N.S. (2016) *Development of Quantitative Thinking Across Correlated Dimensions*, *Continuous Issues in Numerical Cognition: How Many or How Much*. Elsevier Inc. Available at: https://doi.org/10.1016/B978-0-12-801637-4.00001-9.

Nes, F. van (2009) *Young Children's Spatial Structuring Ability and Emerging Number Sense*.

Newbury, K. *et al.* (2012) 'From Policy to Practice: Laying the Foundation for Future Math Success.', *Delta Ka*, pp. 8–18.

Sarama, J.A. and Clements, D.H. (2014) *Learning and Teaching Early Math (The Learning Trajectories Approach)*. Second, *Routledge Taylor & Francis Group*. Second. USA: Routledge Taylor & Francis Group. Available at: https://doi.org/10.4324/9780203883785.

Sari, L.E. *et al.* (2022) *Psikologi Pembelajaran: Penerapan Psikologi dalam Pendidikan*. Edited by N. Eva and I.A. Farida. Available at: https://www.researchgate.net/publication/360877187.

Sari, M. and Asmendri (2020) 'Penelitian Kepustakaan (Library Research) dalam Penelitian Pendidikan IPA', *Natural Science*, 6(1), pp. 41–53. Available at: https://ejournal.uinib.ac.id/jurnal/index.php/naturalscience/article/view/1555/1159.

Splinter, S.E. *et al.* (2024) 'Perceptual subitizing performance in 3- and 4-year-olds: The impact of visual features of sets', *Journal of Experimental Child Psychology*, 244, p. 105946. Available at: https://doi.org/10.1016/j.jecp.2024.105946.

Walle, J.A. Van De, Karp, K.S. and Bay-Williams, J.M. (2019) *Elementary and Middle School Mathematics Teaching Developmentally*. 10th edn. Edited by SPi-Global. New York: Pearson.

Wästerlid, C.A. (2020) 'Conceptual Subitizing and Preschool Class Children'S Learning of the Part-Part-Whole Relations of Number', *Problems of Education in the 21st Century*, 78(6), pp. 1038–1054. Available at: https://doi.org/10.33225/pec/20.78.1038.