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Development of an Identification Instrument for Dyscalculia in Early Childhood (Ages 4-6): A Dichotomous Model Three Parameters Logistic Approach in Item Response Theory

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Abstract: This study aims to develop and validate an identification instrument for dyscalculia in early childhood (ages 4-6) using the Dichotomous Model Three Parameters Logistic approach within Item Response Theory (IRT). The research was conducted in two stages. The first stage involved determining dyscalculia indicators in early childhood through a literature review and focus group discussions (FGD) with special education experts. The outcome of this stage was the identification of specific indicators that served as the foundation for developing the instrument's blueprint. The second stage focused on the development and validation of the instrument, which consisted of dichotomous question items in accordance with the chosen IRT model. The instrument validation was carried out by involving experts in early childhood education and special education. The research results showed that the developed instrument has good content validity and can be used as a tool to identify dyscalculia in early childhood. This instrument is expected to assist educators and psychologists in the early detection of children with dyscalculia, enabling earlier intervention.

Keywords: Dyscalculia, Early Childhood, Item Response Theory, Identification Instrument

PRELIMINARY

Early detection of learning disorders, such as dyscalculia, in early childhood is crucial to ensure appropriate interventions and prevent long-term negative impacts on a child’s academic and social development (Geary, 2006; Shalev & von Aster, 2008). Dyscalculia is a specific disorder in mathematical abilities that affects a child's ability to understand number concepts, perform calculations, and solve basic math problems (Chinn & Steve, 2015). This disorder not only hinders mathematical ability but can also affect the child’s self-confidence and motivation to learn (Peters et al., 2018).

In Indonesia, awareness of the importance of early detection of learning disorders such as dyscalculia is still relatively low, particularly in early childhood (Afiati & Azwar, 2016). Most instruments used to identify this disorder are adapted from those developed

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abroad, which may not fully align with the cultural and educational context in Indonesia (Afiati & Azwar, 2016). This creates a gap in addressing children with dyscalculia, where many cases go undetected until the child enters primary school, requiring more complex and intensive interventions (Khawarizmi et al., 2017). Therefore, there is a need for a valid and reliable identification instrument specifically developed for early childhood in Indonesia. This instrument must comprehensively measure various aspects of mathematical abilities related to dyscalculia and be appropriate for the developmental stages of young children. Moreover, the approach used in developing this instrument should consider the unique characteristics of the target population, including the cognitive and language limitations of children aged 4-6 years.

This study aims to develop an identification instrument for dyscalculia in early childhood using the Dichotomous Model Three Parameters Logistic approach within Item Response Theory (IRT). This approach is chosen for its ability to address the various challenges that arise in developing instruments for early childhood populations (Amelia & Kriswantoro, 2017; Embretson & Reise, 2013), including accommodating individual differences in item difficulty levels (Sudaryanto et al., 2020; Wu & Adams, 2006) and sensitivity to children's basic abilities (DeMars, 2010; Hambleton & Swaminathan, 1985). The research involves several stages, with the first stage focusing on determining dyscalculia indicators, developing the instrument's blueprint, and validating the instrument through expert discussions. The results of this study are expected to make a significant contribution to early childhood education, particularly in the early detection of learning disorders such as dyscalculia.

METHOD

1. Research Design

This study employs a quantitative approach with an instrument development research design that involves two main stages: (1) the determination of indicators for early childhood children with dyscalculia, and (2) the development and validation of an identification instrument through expert evaluation. This design aims to produce a valid instrument for identifying early childhood children at risk of dyscalculia.

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2. Research Participants

The participants in this study are experts with expertise in early childhood education, developmental psychology, and special education. These experts play a role in the process of determining indicators and validating the instrument. Participants were selected purposively based on their qualifications and experience in relevant fields.

3. Determination of Indicators for Early Childhood Children with Dyscalculia

The first stage of this research is to determine the relevant indicators for identifying early childhood children with dyscalculia. This process is carried out through an in-depth literature review and discussions with experts in early childhood education, developmental psychology, and special education. The main focus is on aspects such as basic numerical abilities, number recognition, and understanding of simple mathematical concepts. The outcome of this stage is a list of indicators that will be used as the basis for developing the instrument.

4. Development of the Instrument Blueprint

Based on the determined indicators, the next step is to develop the instrument blueprint. This blueprint includes test items aligned with each indicator, designed to measure basic numerical abilities in early childhood. Each item is crafted with simple language and engaging visuals, appropriate for the development of 4-6-year-old children.

5. Expert Validation of the Instrument

After the development of the instrument blueprint, the next stage is the validation of the instrument through expert assessment. This validation involves evaluating the relevance, appropriateness, and clarity of each test item concerning the established indicators. The validation process is conducted through a Focus Group Discussion (FGD) with experts, where they provide feedback and suggestions for improving the instrument.

6. Final Instrument Draft Development

Based on the expert validation results, the final draft of the instrument is developed, incorporating the feedback and suggestions provided. This draft includes test items that have been validated and deemed to meet the necessary criteria for

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identifying dyscalculia in early childhood. The draft is then ready for use in subsequent research stages, including field testing and further analysis.

7. Ethical Research Procedures

This research involves an ethical approval process focusing on the protection of participants, namely the experts contributing to the instrument validation. All participants are provided with comprehensive information about the research's objectives and procedures, and the confidentiality of the data generated during the research is ensured.

RESULTS

No	Aspect	Indicator	Items	Val. 1	Val. 2	Val. 3
1	Ability to Recognize Numbers and Numerals (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in recognizing and verbalizing the sequence of numbers.	**Number Sequence Identification Test** *Example:* Present cards containing numbers 1-10 or 1-20 arranged randomly. The child is asked to recite the numbers in the correct sequence.	Y	Y	Y
			Number Recognition Test: *Example:* Present cards containing numbers 0-9 in varying sizes and colours. The child is tasked with identifying each number shown.	Y	Y	N
			Time Sequencing Test *Example*: Ask the child to sequence the steps of handwashing, from turning on the tap to drying their hands.	Y	Y	Y
2	Ability to Recognize Numbers and Numerals (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in identifying the quantity of items in a group.	**Counting Objects Test** *Example:* Show a group of 4 marbles and ask the child to count them. Repeat with groups containing different quantities.	Y	Y	Y
			Number to-Quantity matching Test *Example:* Provide a card with the number "3" and another card with an image of three marbles. The child is asked to match the number with the correct image.	Y	Y	N
			Counting Using Object or Picture Card *Example:* Provide cards featuring objects or animals. The child is asked to count and state the quantity shown on each card.	Y	Y	N

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No	Aspect	Indicator	Items	Val. 1	Val. 2	Val. 3
3	Understanding Basic Mathematical Concepts (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in understanding basic concepts such as addition, subtraction, multiplication, and division.	**Addition Concept Test** *Example:* Show images of two groups of animals (e.g., 3 cats and 2 dogs). The child is asked to add the animals in both groups and state the total number.	**Y**	**Y**	**N**
			Subtraction Concept Test *Example:* Show images of 5 apples and 3 oranges. The child is asked to subtract the oranges from the apples and state the remaining number of fruits.	**Y**	**Y**	**N**
4	Understanding Basic Mathematical Concepts (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in understanding the relationship between numbers and their corresponding quantities	**Number to Quantity Matching Test:** *Example:* Provide a card with the number "3" and a card with three marbles. The child matches the number with the corresponding quantity.	**Y**	**Y**	**Y**
			Grouping Objects by Numbers: *Example:* Provide cards with the numbers "4" and "7." The child groups the marbles according to these numbers.	**Y**	**Y**	**Y**
			Arranging Series of Numbers Using Objects: *Example:* The child is given the sequence "1," "2," "3," and "4" and asked to arrange marbles or blocks in this order.	**Y**	**Y**	**Y**
5	Mathematical Problem-Solving Ability (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in solving simple math problems involving basic concepts	**Addition Problem-Solving Test:** *Example:* The child is given the problem "3 marbles are added to 2 marbles. How many marbles are there in total?" The child is asked to solve the problem.	**Y**	**Y**	**Y**
			Subtraction Problem-Solving Test: *Example:* The child is given the problem "7 apples minus 3 apples. How many apples are left?" The child is asked to solve the problem.	**Y**	**Y**	**Y**
6	Mathematical Problem-Solving Ability (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in applying appropriate problem-solving strategies.	**Story-Based Problem-Solving Test:** *Example:* Provide a story about a child who has some marbles and needs to divide them fairly among their friends. Ask the child to determine the appropriate strategy for dividing the marbles fairly.	**Y**	**Y**	**N**

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No	Aspect	Indicator	Items	Val. 1	Val. 2	Val. 3
			Solution Planning Test: *Example:* Provide a problem about addition or subtraction and ask the child to plan the steps they will take to solve the problem.	**Y**	**Y**	**N**
			Using Models or Manipulatives in Problem-Solving Test: *Example:* Provide a problem involving addition or subtraction and give the children marbles as manipulatives. Ask them to use the marbles to solve the math problem.	**Y**	**Y**	**N**
7	Recall of Basic Math Facts (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in remembering basic math facts, such as multiplication tables or number sequences	**Number Sequence Recall Test:** *Example:* The child is given the sequence 1, 3, 5, 7, 9 and is asked to repeat it correctly.	**Y**	**Y**	**Y**
			Addition and Subtraction Fact Recall Test: *Example:* The child is given the question "What is 4+6?" and is asked to answer quickly without using calculators or visual aids.	**Y**	**Y**	**Y**
8	Use of Mathematical Symbols (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in understanding and using mathematical symbols, such as $+, -, \times, \div$.	**Mathematical Symbol Identification Test:** *Example:* The child is given a worksheet with symbols $+, -, \times, \div$ and is asked to identify and name each symbol.	**Y**	**Y**	**Y**
			Matching Symbols with Mathematical Operations Test: *Example:* The child is given a card with the operation "4−2" and is asked to match it with the symbol card containing "−".	**Y**	**Y**	**Y**
			Solving Math Problems Using Symbols Test: *Example:* The child is given the math problem "8−3" and is asked to solve it using the correct symbol for subtraction.	**Y**	**Y**	**Y**
9	Difficulty in Arranging Number Sequences (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in arranging numbers sequentially or according to specific rules	**Test for Sequential Number Arrangement**: *Example*: The child is given random numbers like 4, 7, 2, 9, 1. They are asked to arrange the numbers in sequential order.	**Y**	**Y**	**Y**
			Test for Arranging Numbers Based on Specific Rules: *Example*: The child is given a series of odd numbers such as 3, 7, 11, 15, 19. They are asked to	**Y**	**Y**	**Y**

No	Aspect	Indicator	Items	Val. 1	Val. 2	Val. 3
			arrange the numbers according to the odd-number rule.			
			Test for Filling in Missing Numbers in a Series: *Example*: The child is given a series: 5, 10, _, 20, _, 30. They are asked to fill in the blanks following the pattern of adding 5.	**Y**	**Y**	**Y**
10	Ability to Retain Mathematical Information (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty in retaining mathematical information over long periods	**Test for Recalling Mathematical Facts**: *Example*: The child is taught the fact that 2 x 3 = 6 and is asked to recall it after a few days.	**Y**	**Y**	**Y**
			Test for Retention of Mathematical Concepts: *Example*: The child is taught the properties of triangles and asked to explain them after a few days.	**Y**	**Y**	**Y**
11	Ability to Use Mathematical Tools (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty using tools such as rulers, clocks, or calculators to solve mathematical problems	**Test for Using Rulers**: *Example*: The child is tasked with measuring the length of a table using a ruler and determining its length.	**Y**	**Y**	**Y**
			Test for Using Clocks: *Example*: The child is tasked with determining the end time of a birthday party based on the time stated in the invitation.	**Y**	**Y**	**Y**
			Test for Using Calculators: *Example*: The child is tasked with calculating the total price of shopping items at a supermarket using a calculator.	**Y**	**N**	**N**
12	Difficulty in Identifying Mathematical Patterns and Relationships (Baccaglini-Frank & Di Martino, 2019; Geary, 2006; Shalev & von Aster, 2008)	Difficulty identifying patterns or mathematical relationships in numerical sequences or shapes	**Test for Identifying Geometric Patterns**: *Example*: The child is given a series of square shapes gradually forming into triangles and asked to identify the geometric pattern.	**Y**	**Y**	**Y**
			Test for Identifying Simple Patterns in Images or Number Rows: *Example*: The child is given a series of images showing rotational patterns and asked to identify the pattern and continue it in the next images.	**Y**	**Y**	**Y**

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DISCUSSION

The validation of mathematics ability tests, consisting of 12 aspects and indicators, revealed important findings regarding the suitability of test items for measurement purposes. The following is a descriptive discussion based on the feedback from three validators on each assessed aspect. In the aspect of recognizing numbers and numerals, the first indicator, which measures difficulty in recognizing and verbalizing the sequence of numbers, includes three types of tests: number sequence identification, number recognition, and time sequencing. Most validators deemed these tests valid. However, Validator number 3 noted that the number recognition test using varied colors and sizes was less relevant to this indicator and should be excluded. Meanwhile, other tests in this aspect were considered effective for identifying children's ability to recognize numbers generally.

For the aspect of recognizing quantities of objects, validators agreed that the tests involving counting objects and matching numbers to quantities were relevant for measuring this indicator. However, tests using cards with images of objects or animals for counting were deemed less relevant by two validators as they do not fully focus on the relationship between numbers and quantities. Therefore, this item is recommended for removal, while other tests are retained with minor improvements. In the aspect of understanding basic mathematical concepts, the indicators related to understanding addition and subtraction received mixed evaluations. Tests using images to illustrate addition and subtraction were considered less relevant by Validator number 3, who emphasized the need for more concrete tests directly related to everyday life. Meanwhile, the indicator measuring the relationship between numbers and their quantities through tests like matching numbers with quantities, grouping objects by numbers, and arranging objects in sequences was deemed valid without revisions.

The next aspect, mathematical problem-solving ability, received strong validation for simple problems involving addition and subtraction, such as counting marbles or apples. However, story-based and solution-planning tests were rejected by one validator for being too abstract and complex for children with mathematical learning difficulties. Consequently, overly abstract questions were removed, while tests involving concrete objects were retained. In the aspect of recalling basic math facts, all validators agreed that tests involving recalling number sequences and basic addition and subtraction facts were

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highly relevant. No test items were recommended for removal, but the validators suggested employing repetition and varying the questions to ensure consistent results. The ability to use mathematical symbols, such as recognizing and associating symbols (+, −, ×, ÷) with operations, received unanimous approval from the validators. Tests involving symbol identification and their application in basic operations were considered appropriate and relevant without any revisions.

In the aspect of arranging number sequences, all test types were deemed valid by the validators. Tests such as arranging random numbers sequentially, organizing numbers based on specific rules, and completing missing numbers in a series were fully approved, as they aligned with the indicators and were simple enough for children to perform. The ability to retain mathematical information also received unanimous approval for all test types. Validators agreed that tests involving recalling mathematical facts and retaining concepts after a few days were highly relevant for assessing this ability. No changes or deletions were suggested for this aspect. In the aspect of using mathematical tools, tests involving rulers and clocks received full approval from all validators. However, the calculator usage test was criticized by two validators, who stated that children need to have a basic understanding of mathematical operations before using such tools. Thus, this item was removed from the list.

Lastly, in the aspect of identifying mathematical patterns and relationships, validators agreed that tests involving simple patterns in number series or geometric shapes were relevant to the indicators. Tests involving rotational or reflective patterns in images were deemed valid, though Validator number 3 suggested that these test formats should be clearly explained to avoid confusing the children. Overall, the validation results show that most test items align with the assessed aspects and indicators. Some items were excluded due to being overly complex or less relevant, while the remaining items were retained with necessary adjustments. These validation results provide comprehensive guidance for developing a more accurate and effective mathematics ability test to identify learning difficulties in children.

CONCLUSION

The validation process of the mathematics ability test, which encompasses 12 aspects and indicators, has provided critical insights into the suitability and relevance of

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test items. Based on the feedback from the validators, most test items were deemed appropriate and effective for assessing the corresponding abilities, with several exceptions requiring modifications or removal. Key findings include the necessity to prioritize concrete and contextual tests, such as counting objects, solving real-life mathematical problems, and using tools like rulers and clocks, which were consistently validated as relevant and applicable. In contrast, overly abstract tests, such as story-based problem-solving or complex patterns without clear instructions, were recommended for exclusion or revision. Furthermore, tools like calculators were considered inappropriate for children lacking foundational understanding of mathematical operations.

The tests aimed at assessing fundamental abilities, such as number recognition, quantity matching, symbol identification, and basic arithmetic operations, were found to align well with the indicators. Additionally, tests focusing on retaining mathematical information and arranging sequential numbers also demonstrated high validity and reliability. This validation process highlights the importance of aligning test items with the developmental levels and cognitive capabilities of the target group. The results provide a strong foundation for refining the mathematics ability test, ensuring that it is both effective and practical for identifying learning difficulties in children. Future implementations should continue to emphasize clarity, simplicity, and real-world application to enhance the accuracy and usability of the test.

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