Psychology Research on Education and Social Sciences, 6(1), 45-60, March 2025
e-ISSN: 2717-7602
dergipark.org.tr/press

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Research Article

Effectiveness of using number glass media in improving learning outcomes of elementary school with dyscalculia tendencies

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Article Info

Received: 1 January 2025
Accepted: 15 March 2025
Online: 30 March 2025

Keywords:
Dyscalculia tendencies
Elementary school
Learning outcomes
Number glass media

Abstract

This quasi-experimental study examined the effectiveness of number glass media, a multisensory tool, in improving arithmetic skills among elementary students with dyscalculia tendencies in Makassar, Indonesia. Using a nonequivalent control group design, 11 participants (aged 9–11 years) were divided into experimental (n=6) and control (n=5) groups. The experimental group received 14 sessions of targeted instruction using number glass media, while the control group followed conventional methods. Pre-test and post-test data were analyzed via independent and paired samples t-tests. Results indicated statistically significant improvements in the experimental group's post-test scores (M=18.83, SD=1.47) compared to the control group (M=8.4, SD=3.29), with a large effect size (Cohen's d=2.25, 95% CI [-1.92, 6.46]; t(9)=-3.72, p=0.005). The experimental group showed a mean gain score of 8.00 (SD=3.46), while the control group's gain was minimal (M=0.60, SD=3.05). The intervention's hands-on approach reduced cognitive barriers in symbolic arithmetic, enhancing comprehension of addition, subtraction, multiplication, and division. However, the small sample size (N=11) and homogeneity of participants (urban Indonesian students) limit the generalizability of findings. While the study demonstrates the tool's potential for dyscalculia intervention, further research with larger, diverse cohorts is needed to validate scalability.

To cite this article

Mannesa, MN.H.I.S., Dewi, E.M.P., and Akmal, N. (2025). T Effectiveness of using number glass media in improving learning outcomes of elementary school with dyscalculia tendencies. *Psychology Research on Education and Social Sciences, 6*(1), 45-60. DOI: https://doi.org/10.5281/zenodo.15147866

Introduction

Learning outcomes are clear, assessable declarations that outline the precise knowledge, abilities, perspectives, and principles learners should gain by the end of an educational activity, like a course or degree (Suskie, 2018; Banta & Palomba, 2015). These outcomes reflect the result of structured educational planning and act as essential criteria for gauging the success of teaching practices (Hadjianastasis, 2017). As noted by Boud and Soler (2016), they form the basis for harmonizing instructional approaches, evaluations, and curricula with institutional objectives, ensuring coherence across all elements to optimize student development. Beyond assessment, learning outcomes shape both pedagogy and learner engagement. By defining target competencies, they offer students clarity on expectations, encouraging proactive learning and readiness for academic tasks (Hattie & Donoghue, 2016; Medland, 2016). Studies by Winstone and Boud (2022) reveal that awareness of these outcomes boosts learner motivation and active participation. Additionally, they empower educators to craft focused teaching methods and assessments that accurately evaluate achievement, supporting

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ongoing refinement of instructional quality (Wiggins & McTighe, 2005). Biggs and Tang (2011) emphasize that well-defined learning outcomes foster alignment among instructional objectives, pedagogical strategies, and assessment frameworks.

Learning outcomes also cultivate mutual clarity among students, instructors, and advisors about program objectives. This alignment strengthens transparency and accountability, as stakeholders collaborate toward shared goals (Fink, 2013; Whitfield & Hartley, 2019). Bearman et al. (2017) stress that robust outcomes establish a unified framework for discussing educational standards and achievements. Similarly, learning outcomes anchor education by setting measurable benchmarks for success. These benchmarks not only guide curriculum design but also reinforce institutional credibility, as they provide transparent evidence of program effectiveness to external stakeholders such as accreditors and employers (Ewell, 2009; Harden, 2002). They guide learners while enabling educators to enhance teaching strategies, driving overall academic improvement (Maki, 2017; Sambell et al., 2012). Recent findings by Ajjawi et al. (2022) affirm that institutions with clearly articulated outcomes see notable gains in student performance, satisfaction, and career readiness.

Learning outcomes encompass measurable transformations in students' cognitive, affective, and psychomotor development resulting from educational engagement (Susanto, 2013). These outcomes serve as critical indicators of educational efficacy, reflecting both institutional objectives and student competency acquisition (Biggs & Tang, 2011; Winstone & Boud, 2022). Central to achieving these outcomes is educators' capacity to strategically orchestrate instructional resources, materials, and time—a pedagogical skill that significantly influences student achievement (Ahmad, 2012). Research underscores that strategies tailored to learners' needs can elevate academic performance, with effect sizes of 0.40–0.60 demonstrating meaningful impacts (Hattie & Donoghue, 2016).

This study examines the persistently low mathematics outcomes among elementary students with dyscalculia, a neurodevelopmental disorder affecting numerical cognition. In Indonesia, where 77.13% of fourth graders fall below minimum math proficiency (Badan Pusat Statistika, 2018), systemic challenges persist. The nation ranked 74th of 79 countries in arithmetic (OECD, 2019), a position further corroborated by the 2022 PISA score of 372—100 points below the OECD average (OECD, 2023). TIMSS 2019 data reinforces this trend, with Indonesian students scoring 388 points against an international average of 500 (Mullis et al., 2020). Globally, over 50% of youth in sub-Saharan Africa and South Asia lack basic numeracy skills, a crisis exacerbated by systemic underinvestment in teacher professional development and pedagogies that fail to address diverse learning needs (UNESCO, 2022).

Students with dyscalculia, representing 5–7% of the population (Butterworth et al., 2011). Neuroimaging reveals structural (e.g., reduced gray matter density) and functional (e.g., atypical activation) irregularities in the intraparietal sulcus (IPS), a key region for numerical processing (Kucian & von Aster, 2015; Butterworth et al., 2011). These deficits manifest as challenges in symbolic/non-symbolic number comprehension, arithmetic procedures, and working memory (Szűcs & Myers, 2017; Morsanyi et al., 2018). Such difficulties extend beyond academia, impairing financial literacy and career prospects (Parsons & Bynner, 2005; OECD, 2013).

Diagnostically, dyscalculia is identified through persistent struggles with numerical magnitude processing, fact retrieval, and procedural application (Soares et al., 2018). Assessment frameworks now include markers like impaired subitizing and number-line estimation (Träff et al., 2017). Despite its neurobiological basis, dyscalculia remains underrecognized in educational systems, necessitating urgent reforms in teacher training and adaptive curriculum design (Fritz et al., 2019).

Mathematical proficiency, particularly early foundational skills in counting and cardinality, predicts stronger number-system knowledge at school entry (Geary et al., 2018). Furthermore, mathematics education fosters critical thinking and problem-solving abilities when pedagogical approaches emphasize inquiry and conceptual understanding (Schoenfeld, 2016). Targeted instructional strategies, such as visual tools and contextualized problems, can enhance algebraic knowledge in secondary students, though direct links to broader societal applications require further exploration (Star et al., 2015). Mathematics education prepares students for future societal demands by integrating problem-solving in authentic contexts (Gravemeijer et al., 2017), though the design of word problems necessitates careful attention to avoid misalignment with real-world reasoning (Verschaffel et al., 2020). Effective instruction requires tools like manipulatives and visual aids to bridge abstract concepts with tangible understanding, aligning with cognitive load theory to optimize learning (Moyer-Packenham & Westenskow, 2015; Sweller et al., 2019). Evidence-based strategies and challenging tasks are essential for fostering deeper mathematical engagement, as students perceive such tasks as opportunities for meaningful learning (Russo & Hopkins, 2017).

Research underscores the efficacy of targeted approaches, particularly for diverse learners, in enhancing conceptual understanding. Meta-analyses confirm that instructional strategy choices significantly impact academic achievement, with manipulatives serving as critical mediators for clarifying abstract concepts (Dietrichson et al., 2017; Moyer-Packenham & Westenskow, 2015; Rieser et al., 2016). For instance, number glass media—layered tools that visualize place value—have been shown to improve numerical comprehension by bridging mathematical symbols with quantitative meaning, as evidenced in studies on place-value instruction (Young-Loveridge & Bicknell, 2014) and the development of visual tools for early childhood mathematics (Baroody et al., 2019). Structured implementation of such tools not only enhances student engagement but also mitigates learning barriers for individuals with dyscalculia, fostering conceptual mastery over procedural memorization (Bugden & Ansari, 2016; Monei & Pedro, 2017). These findings underscore the necessity of pedagogical tools that render mathematical structures cognitively accessible and manageable.

Number glass media is a specialized instructional tool designed to enhance understanding of place value through tactile and visual representation. It consists of labeled glasses and numerical components arranged on a board, enabling students to physically manipulate numerical relationships (Yovelia & Efendi, 2019. Grounded in Bruner's enactive-iconic-symbolic theory, which emphasizes learning through physical action and visual aids (Bruner, 1966), and Piaget's concrete operational stage, which underscores the importance of hands-on experiences for cognitive development (Piaget, 1998), this tool aligns with neurocognitive research on dyscalculia. Studies highlight that dyscalculia is associated with deficits in number sense and magnitude processing, necessitating interventions that externalize abstract concepts (Butterworth, 2010; Skagerlund & Träff, 2016). By transforming operations like addition and subtraction into tangible activities, number glass media reduces cognitive barriers and fosters multisensory engagement, thereby aiding students in mastering mixed calculations (Kucian & von Aster, 2015; Yovelia & Efendi, 2019).

From a cognitive load perspective, the tool reduces working memory strain by externalizing numerical operations, benefiting students with dyscalculia who often struggle with visuospatial working memory (Sweller et al., 2019; Mammarella et al., 2018). Its structured design scaffolds learning through a gradual shift from physical manipulation to mental representation, consistent with evidence-based practices such as the Concrete-Representational-Abstract (CRA) approach (Bouck et al., 2018). Additionally, the tool enhances tactile and cognitive engagement, offering alternative routes to understanding for students who find symbolic methods challenging (Yuliana et al., 2014). Empirical studies, such as Mela and Armaini's (2021) intervention using number glass media, demonstrate significant improvements in arithmetic skills among dyscalculic learners, reinforcing the efficacy of concrete-to-abstract instructional sequences in special education contexts.

This research applies number glass media as a targeted intervention for dyscalculic students, building on prior work that emphasizes the role of multisensory tools in mathematics education (Merkley & Ansari, 2016). Unlike generic manipulatives, this tool explicitly bridges tactile interactions (e.g., counting objects) with symbolic operations (+, −, ×, ÷), addressing a critical gap in connecting concrete experiences to abstract arithmetic. The intervention aligns with neurocognitive evidence suggesting that multisensory methods enhance numerical processing in children with dyscalculia (Kucian & von Aster, 2015), while behavioral improvements from such approaches are well-documented (Butterworth, 2019). By integrating structured visual-tactile representations with principles of cognitive development—

such as Piaget's concrete operational stage—the approach offers a tailored solution for dyscalculic learners (Witzel et al., 2008), advancing pedagogical practices rooted in developmental psychology.

This research uniquely applies number glass media as a targeted intervention for elementary students with dyscalculia tendencies. Unlike previous methods, it aligns with their cognitive profiles, providing a structured framework for mastering arithmetic. By creating a concrete representation of place value, it scaffolds numerical understanding, transforming abstract concepts into experiential learning through multisensory engagement. The visually distinct system aids multilevel calculations, reducing math anxiety while enhancing motivation. Beyond improving learning outcomes, it offers educators an evidence-based tool for bridging concrete and abstract mathematics, ensuring consistent application across arithmetic operations to build computational fluency.

Research problem

Mathematical learning difficulties, particularly dyscalculia, are influenced by both neurobiological factors and instructional approaches (Geary, 2019). Dyscalculia is associated with reduced activation in the intraparietal sulcus, which impacts numerical cognition (Peters & De Smedt, 2018). However, the lack of structured, multisensory instructional methods remains a critical barrier for students with dyscalculia (Doabler & Fien, 2013). Research shows that explicit mathematics instruction significantly improves outcomes for students with learning disabilities, with meta-analyses reporting effect sizes of 0.45–0.68 (Gersten et al., 2009). Digital math games, for example, can enhance learning by incorporating interactive visual elements (Moyer-Packenham et al., 2019). Number glass media offers a promising intervention by transforming abstract numerical concepts into tangible representations, improving comprehension and engagement (Mela & Armaini, 2021). This approach aligns with the concrete-representational-abstract (CRA) instructional model, which has demonstrated effectiveness in supporting students with mathematical difficulties (Bouck et al., 2018). Structured multisensory tools, such as abacus instruction, enhance computational fluency and cognitive flexibility (Wang et al., 2015). Despite evidence supporting multisensory tools, research on number glass media as a targeted intervention for dyscalculia remains limited. To address this gap, this study employs a quasi-experimental pre-test/post-test design to evaluate its effectiveness in improving arithmetic skills among elementary students in Makassar City. By comparing students using number glass media with those receiving conventional instruction, this research aims to determine whether hands-on methods enhance mathematical understanding in students with dyscalculia tendencies.

Method

Research design

This study uses an experimental research method with a nonequivalent control group design, which aims to determine whether the learning intervention of number glass media effectively improves learning outcomes for elementary school students with dyscalculia tendencies in Makassar City. The nonequivalent (pretest and posttest) control group design is a model in which the experimental and control groups are selected, not randomly (Sugiyono, 2017). Both groups were given a pretest and posttest, where only the experimental group was assigned a learning intervention using the number glass media, while the control group used conventional learning.

Participants

In this research setting, the sampling approach applied was the purposive sampling method. The criteria for participants in this study were (1) students registered as grade IV students at elementary schools in Makassar city; (2) individuals who have an IQ (Intelligence Quotient) level from average to high as measured by the CPM test; (3) willing to take part in the entire series of research by filling out an informed consent sheet; (4) has passed the screening process with the "dyscalculia screening for kindergarten and elementary school level students" test tool with the results of scores below the 10^{th} percentile (<P10); (5) is not experiencing physical disability.

The population of this research were are at the fourth level grade elementary school students in Makassar city, totalling 221 students, including SDN Bontoramba, SD Inpress Kassi, SDN Tamalanrea, SD Inpres Karuwisi II and SD

Unggulan Puri Taman Sari which were determined using purposive sampling method. From the total population, 17 students were indicated with a tendency of dyscalculia, namely students who scored below the 10th percentile (<P10). Participants who were selected to participate in the experiment demonstrated intelligence levels that included average, above average, and high, which were assessed using a test coloured progressive matrices (CPM) test. From the results of the coloured progressive matrices (CPM) test, a total of 11 research participants remained, then divided into two groups, namely 5 participants in the control group and 6 participants in the experimental group. There were 2 female participants and 9 male participants, aged between 9 and 11 years old.

Data Collection Tools

Learning outcomes test

The learning outcomes test in this study assessed arithmetic operations (addition, subtraction, multiplication, and division) based on the Student Worksheet (LKS), Lesson Plan (RPP), and syllabus, aligned with the Indonesian Grade IV curriculum in Makassar City. To ensure content validity, the test underwent Content Validity Ratio (CVR) analysis, following Lawshe (1975). Seven Subject Matter Experts (SMEs) rated each item as Essential (E), Useful (G), or Not necessary (T), with CVR calculated using $CVR = (n_e - N/2) / (N/2)$. A CVR above 0.62 was considered acceptable (Wilson et al., 2012), and the results indicated CVR coefficients between 0.71 and 1, confirming strong content validity. Additionally, Aiken's V analysis assessed inter-rater agreement on item relevance using $V = \Sigma s / [n(c-1)]$, yielding values between 0.75 and 0.83, further supporting validity□. To ensure balanced difficulty, an item difficulty index (p-value) analysis was conducted, retaining items within the 0.30–0.70 range (Crocker & Algina, 1986). These results confirm that the learning outcomes test is a valid and reliable instrument for assessing mathematical proficiency in students with dyscalculia tendencies. The use of CVR, Aiken's V, and item difficulty validation ensures its suitability for educational assessment and intervention.

Number glass media

The intervention in this study utilized number glass media as a pedagogical tool for teaching arithmetic operations. Before implementation, the intervention underwent a manipulation check to ensure its effectiveness, following the framework outlined by Sugiyanto (2009). This process involved 13 assessment questions designed to verify participants' understanding of the learning process using number glass media. The manipulation check confirmed that the intervention conditions were successfully applied, ensuring that students could engage with the media effectively □. To establish content validity, the number glass media intervention was assessed by three Subject Matter Experts (SMEs) using Aiken's V formula, as recommended by Azwar (2019). This method evaluates the degree to which an item represents the construct it aims to measure. Aiken's V was calculated using the formula $V = \Sigma s / [n(c - 1)]$, where s represents the sum of rater scores adjusted for the minimum value, n is the number of raters, and c is the number of rating categories. The validity analysis yielded Aiken's V values ranging from 0.75 to 0.83, indicating strong content validity□. The assessment confirmed that number glass media effectively supports students with mathematical difficulties by providing a structured, interactive, and tangible learning experience. This validation process ensures that the intervention meets academic and instructional standards, reinforcing its suitability for enhancing arithmetic learning outcomes among elementary students.

Data analysis

The experimental procedure began with screening participants using an elementary-level dyscalculia screening tool with a one-on-one method. This screening test consisted of 25 items with a reliability score of 0.827, measuring counting ability instructions, number knowledge instructions, and basic arithmetic instructions (Bariroh & Wimbarti, 2016). The screening was conducted on 221 fourth-grade elementary students in Makassar City, identifying 23 students who scored below the 10th percentile (P10). These students then completed the Coloured Progressive Matrices (CPM) test (Raven, 2018), and 11 students meeting the criteria—those with average, above-average, and high intelligence levels—were selected as research participants. This criterion aligns with evidence that dyscalculia is unrelated to general intelligence. Children with dyscalculia often exhibit normal/high intelligence despite numerical difficulties (Butterworth, 2010; Geary, 2011). Defined as a specific learning disability affecting numerical cognition in individuals with typical intellectual functioning (Kaufmann et al., 2013), dyscalculia's dissociation from broader intellectual disabilities validates including participants with average-to-high IQ in intervention studies (Szűcs & Goswami, 2013).

To measure learning outcomes, a validated 30-item test was used, having undergone subject matter expert (SME) validation, face validity assessment, and a readability test. Before implementing the intervention, a pilot test of the number glass media was conducted with 14 students to ensure its feasibility. The intervention spanned four weeks, consisting of 14 sessions, with each session lasting 75 minutes. Each session followed a structured format, including a 5-minute ice-breaking activity, a 20-minute instructional phase introducing number glass media concepts, a 45-minute practice phase where students engaged in arithmetic problem-solving using number glass media, and a 5-minute reflection and feedback session.

During the first session, students completed a pre-test lasting 45 minutes. The experimental group received 14 sessions of number glass media instruction, while the control group followed conventional learning methods without intervention. At the end of the study, in the 14th session, both groups completed a post-test lasting 45 minutes to assess learning outcomes. Researchers supervised the test process and provided individual testing sessions for students unable to attend the scheduled post-test, ensuring the reliability of the final assessment.

Procedure

The experimental procedure stage is when the researcher conducts screening of participants using an elementary school-level dyscalculia screening tool with the one-on-one method. The dyscalculia tendency test contains 25 items with a reliability value of 0.827, where the test summarizes three aspects: counting ability instructions, number knowledge instructions and basic arithmetic instructions (Bariroh & Wimbarti, 2016). The screening results on 221 students in grade IV elementary schools in Makassar City obtained 23 students with screening results below the 10th percentile (P_{10}). After conducting a dyscalculia screening test, the 23 students took the CPM (coloured progressive matrices) test. Then, students who met the criteria for research participants were selected as research participants, totalling 11 students, namely those with average, above average, and high intelligence levels. The measuring instrument used is a learning outcome test constructed by the researcher with item questions consisting of 30 items. It has undergone the SME (subject matter expert) process, face validity, and readability test. The researcher also conducted a pilot test of the number of glass media to 14 participants.

During the initial meeting between the experimental and control groups, a pre-test sheet was given in the form of a learning outcome test, which was done for 45 minutes offline. The process of providing intervention in the form of learning using number glass media took place for 14 meetings given to the experimental group. In contrast, the control group only followed conventional learning and was not given learning intervention using number glass media. Then, in the final stage, namely providing a post-test in the form of a learning outcome test to the experimental and control groups, which was done for 45 minutes offline.


Figure 1. Dyscalculia tendency screening


Figure 2. Colored progressive matrices test (CPM)


Figure 3. Learning process using number glass media

Pilot test

The pilot test began with a presentation from the researcher regarding the purpose of the pilot test, the learning model, the mathematical arithmetic operation material and the tasks of the pilot test participants. Then, the researcher read and explained the contents of the research module that would be used. The researcher read and explained, starting from the introduction, dyscalculia problems, how to recognize dyscalculia, the definition of number glass media, the purpose of using number glass media, the time of learning implementation, the place of learning implementation, learning methods and how to use number glass media.

The results of the assessment given by the participants from the pilot test conducted showed that for the suitability aspect of 14 (100%) participants there were 14 (100%) participants who decipher the subject matter was "appropriate", 13 (92%) participants who expressing the student worksheets or questions were "appropriate", 12 (85%) participants who stated the learning atmosphere in the classroom was "appropriate" and 12 (85%) participants said the way the facilitator taught was "appropriate". For the attractiveness aspect of the 14 (100%) participants, 14 (100%) participants delivering the learning media was "interesting", 13 (92%) participants said the student worksheets or questions were "interesting", 12 (85%) participants who stated the learning atmosphere in class was "interesting", 13 (92%) participants who mentioned the way the facilitator taught was "interesting" and 14 (100%) participants who replied the subject matter was "interesting". For the aspect of motivation, out of 14 (100%) participants, 14 (100%) participants said they were "motivated to participate in further learning activities like the one I have participated in". For the approval aspect of 14 (100%) participants, there were 12 (85%) participants who confirm “Yes, I understand the material better by using the glass number media", 13 (92%) participants who explaining “Yes, I am interested in the appearance of the glass number media". So, it can be concluded that the number glass media module and number glass media are suitable for intervention in actual research.

Results

To determine the effectiveness of using number glass media on improving the mathematics learning outcomes of students with dyscalculia tendencies in Makassar city, independent samples T-test and paired samples T-test tests were conducted to see the difference in total pretest and posttest scores with the JAMOVI 2.3.28 application. The data used as research data is measured through the implementation of post-test results at the end, after the provision of learning interventions between the two groups, namely the control group using conventional learning and the experimental group using number glass media. The score is used as a reference to determine the mathematics learning outcomes of students with dyscalculia tendencies, especially in the cognitive domain.

On the results of the pre-test learning outcomes, out of 11 students with a tendency to dyscalculia, 55% of students scored below the average category, and 45% of students scored in the intermediate class. Furthermore, on the post-test of learning outcomes of students with a tendency to dyscalculia, 27% scored below the average class, 55% cut in the middle sort, and 18% scored above the intermediate course. The results of the acquisition of data that has been processed are as follows:

Table 1. Description of hypothetical and empirical data of learning outcomes in mathematical calculation operations

Variable	Data	Min	Max	Mean	St. Dev
Learning Outcomes	Hypothetical	0	30	15	5
	Empirical	5	21	14,09	5,92

The descriptive analysis of students’ mathematical arithmetic learning outcomes was conducted using both hypothetical and empirical statistical approaches, following the framework described by Widhiarso (2010). The analysis provided key statistical indicators, including the minimum, maximum, mean (M), and standard deviation (SD) values for both hypothetical and empirical data. Table 1 presents a summary of the descriptive statistics. The hypothetical data categorization follows a statistical reference model, ensuring that score classification reflects natural variations in student achievement. In accordance with Widhiarso (2010), the categorization of mathematical arithmetic learning outcomes is structured as follows:

Table 2. Categorization of hypothetical data of learning outcomes in mathematical calculation operations

Variable	Criteria	Category
Learning Outcomes	$X > M + SD = 15 + 5 = 20$	High
	$M - SD \leq X \leq M + SD = 10 \leq X \leq 20$	Medium
	$X < M - SD = 10$	Low

This classification ensures that score distributions align with standardized statistical categorization, avoiding arbitrary thresholds. By employing empirical statistics, this study ensures that classification represents actual student performance, while the hypothetical reference model provides a structured framework for interpretation (Widhiarso, 2010). Following this classification system, students' post-test scores were categorized accordingly. The post-test was administered after the intervention to the experimental group, allowing for an objective assessment of learning improvement. This method ensures a data-driven approach to performance evaluation, reinforcing the validity of the learning outcome measurement. The results obtained from participants after being given a post-test using the math arithmetic operations learning outcomes test questions are as follows:

Table 3. Pretest and posttest data of experimental group participants

Number	Initial name	Pretest	Category	Post-test	Category	Gain score
1	A	8	Low	19	Medium	11
2	BAS	11	Medium	17	Medium	6
3	M	7	Low	18	Medium	11
4	MYA	11	Medium	20	High	9
5	FHA	12	Medium	21	High	9
6	RAR	16	Medium	18	Medium	2
Min. score		7		17		
Max. score		16		21		
ΣX		65		113		
Mean		10,83		18,83		
St. Dev		3,91		1,47		

The experimental group's post-test average is 18.83. The standard deviation of the experimental group's post-test results is 1.47. Based on the table, one participant falls into the high category, while five participants are in the medium category, and none are in the low category. The categorization results showed that two participants who were previously in the low category in the pretest increased their scores, moving into the medium category. Additionally, one participant who was in the medium category in the pretest increased their score sufficiently to switch to the high category. Meanwhile, three other participants in the medium category also showed score increases, but the increments were not significant enough to change their classification, so they remained in the medium category.

Table 4. Pretest and posttest data of control group participants

Number	Initial name	Pretest	Category	Post-test	Category	Gain score
1	MNA	6	Low	11	Medium	5
2	ZDP	8	Low	5	Low	-3
3	MAK	9	Low	9	Low	0
4	FS	6	Low	5	Low	-1
5	IR	10	Medium	12	Medium	2
	Min. score	6		5		
	Max. score	10		12		
	ΣX	39		42		
	Mean	7,8		8,4		
	St. Dev	1,6		2,93		

The mean score of the control group's post-test was 8.4. The standard deviation of the control group's post-test was 3.29. Based on the table, it can be seen that there are no participants in the high category, two participants in the medium category, and three participants in the low category. The categorization results show that one participant in the previous pretest who was in the low category increased their score, moving into the medium category. Two participants in the previous pretest who were in the low category had a decrease in score, so they remained in the low category. One participant in the previous pretest who was in the low category had no change in score, so they remained in the low category. One participant in the previous pretest who was in the medium category experienced a change in score. However, because the increase was minor, they did not move from the medium category.

Normality Test

Table 5. Shapiro-Wilk Test

Parameter		Method	Statistic	P
Independent sample T test				
Gain score		Shapiro-Wilk	0,965	0,829
Paired sample test				
Control Group	Control Group	Shapiro-Wilk	0.981	0.940
Experimental Group	Experimental Group	Shapiro-Wilk	0.862	0.195

The Shapiro-Wilk normality test results indicate that the gain score has a significance value of 0.829, which is greater than 0.05, meaning the gain score data is normally distributed. Similarly, the control group data has a p-value of 0.940, which is also greater than 0.05, indicating that it follows a normal distribution. Likewise, the experimental group has a p-value of 0.195, which remains above 0.05, suggesting that the experimental group's data is also normally distributed. Thus, all datasets meet the assumption of normality, allowing for the application of parametric statistical tests.

Homogeneity Test

Table 6. Homogeneity of variances test

		F	Df	df2	p
Gain score	Levene's	0.107	1	9	0.751
	Variance ratio	0.775	4	5	0.828

The homogeneity test in this study was conducted using Levene's test with the assistance of the JAMOVI 2.3.28 application. This analysis aims to determine whether the variance of the data in this study is equal. The results indicate that the research data has equal variance, as shown by $F(1, 9) = 0.107$, $p = 0.751$, which is greater than 0.05. Thus, the assumption of homogeneity is met, meaning that the data can be analyzed using parametric statistical tests.

Hypothesis Test

Table 7. Hypothesis test

	Group	M	SD	*T*	*p*	*Effect Size*	Comment
Gain score	Control	0,60	3,05	-3,72	0,005	-2,25	Significant
	Experimental	8,00	3,46				

The results of the Independent Samples T-Test in Table 7 indicate that the experimental group (M = 8.00, SD = 3.46) achieved significantly higher learning gains compared to the control group (M = 0.60, SD = 3.05). The statistical test yielded a t-value of -3.72, with a p-value of 0.005, which is below the significance threshold of 0.05. To measure the magnitude of the effect, Cohen's d was calculated, resulting in a value of 2.25, indicating a large effect size. According to Cohen (1988), an effect size of 0.2 is considered small, 0.5 is medium, and 0.8 or higher is large, meaning the intervention had a substantial impact on student learning outcomes. The 95% confidence interval (CI) for the effect size ranged from -1.92 to 6.46, confirming the robustness of the findings. These results support the conclusion that using number glass media significantly improves learning outcomes for students with dyscalculia tendencies.

Discussion

The findings of this study demonstrate that the use of number glass media significantly improved the arithmetic learning outcomes of elementary students with dyscalculia tendencies in Makassar, Indonesia. The experimental group showed a mean post-test score of 18.83 (SD = 1.47), compared to the control group's mean of 8.4 (SD = 3.29), with a large effect size (Cohen's d = 2.25). This improvement can be contextualized through several theoretical frameworks, providing deeper insights into the mechanisms driving the intervention's effectiveness.

First, the efficacy of number glass media aligns with Dual Coding Theory (Paivio, 1986), which posits that combining verbal and nonverbal (visual/tactile) information enhances cognitive processing. The simultaneous use of pipettes (tactile), labeled glasses (visual), and verbal instruction likely created redundant coding pathways, reinforcing numerical concepts for students with dyscalculia. By grounding symbolic arithmetic (e.g., division) in physical manipulatives, multisensory methods address dyscalculia-related difficulties in symbolic number processing, which have been linked to irregularities in the intraparietal sulcus (IPS) (Kucian & von Aster, 2015). For instance, translating subtraction into the physical removal of pipettes reduces reliance on working memory, a domain where dyscalculic learners often face challenges (Szűcs & Goswami, 2013).

Second, the intervention resonates with Embodied Cognition (Wilson, 2002), which emphasizes the role of sensorimotor experiences in shaping cognitive processes. By physically manipulating number cards and pipettes, students engaged in "thinking through doing," a process that strengthens neural pathways associated with numerical magnitude representation (Fischer et al., 2011). This approach is particularly relevant for dyscalculic learners, as neuroimaging studies indicate atypical activation in the intraparietal sulcus—a region linked to quantity processing (Price et al., 2007). The hands-on nature of the media may have played a role in promoting cognitive engagement, which is essential for arithmetic fluency (Butterworth & Laurillard, 2010).

Additionally, the structured progression of the intervention aligns with Vygotsky's Sociocultural Theory (Vygotsky, 1978), particularly the concept of scaffolding. The facilitator's role in guiding students through incremental challenges—starting with concrete manipulation (enactive phase) and progressing to symbolic problem-solving—is consistent with the zone of proximal development (ZPD) approach. For example, students initially required explicit demonstrations to use the media but gradually internalized procedures, as evidenced by their ability to solve problems independently in the final sessions. This structured guidance may have supported students in overcoming procedural difficulties often observed in dyscalculia, where learners struggle to automate arithmetic steps (Geary, 2013).

Moreover, findings from the study suggest that number glass media played a role in fostering a more engaging and interactive learning experience, which may have influenced students' cognitive engagement. Multisensory tools have been associated with reducing affective barriers in mathematics learning (Siegler & Ramani, 2008), potentially allowing students to focus on conceptual understanding. However, the extent to which number glass media contributed to such outcomes requires further investigation.

The study's limitations warrant consideration. The small sample size (n = 11) and homogeneity of participants (urban Indonesian students) limit generalizability. Future research should replicate this intervention in diverse cultural contexts to assess cross-population validity. Furthermore, while the media improved basic arithmetic, its impact on higher-order skills (e.g., fractions, algebraic reasoning) remains untested. Integrating number glass media with digital tools, as suggested by the Cognitive Theory of Multimedia Learning (Mayer, 2021), could extend its utility to more complex domains.

In summary, the effectiveness of number glass media is not merely pedagogical but also theoretically grounded. Its design leverages neurocognitive processing (Butterworth et al., 2011), embodied learning principles (Wilson, 2002), and interactive engagement, offering potential benefits for dyscalculia intervention. These findings highlight the importance of multisensory, theory-driven approaches in mathematics education, particularly for learners facing numerical processing challenges.

Conclusion and Recommendations

This study demonstrates that the use of number glass media significantly enhances arithmetic learning outcomes among elementary students with dyscalculia tendencies in Makassar, Indonesia. The experimental group, which engaged with the tactile and visual tool, showed marked improvement in post-test scores compared to the control group relying on conventional methods. By transforming abstract mathematical concepts into tangible, hands-on experiences, the media effectively bridged gaps in numerical comprehension, reduced cognitive overload, and fostered greater engagement. These results highlight the critical role of multisensory, student-centered approaches in addressing the unique challenges faced by learners with dyscalculia.

The findings advocate for integrating tools like number glass media into mathematics curricula to support inclusive education. Educators and policymakers should prioritize training programs that equip teachers with strategies to implement such interventions, ensuring alignment with diverse cognitive needs. However, the study's small sample size and limited intervention period necessitate further research with larger, more diverse populations to validate scalability and long-term efficacy. Future investigations should also explore the media's applicability to advanced mathematical domains and its adaptability across varied cultural and educational contexts. Ultimately, this research underscores the transformative potential of innovative pedagogies in fostering equitable access to mathematical literacy for all learners.

This study demonstrates that the use of number glass media significantly improves arithmetic learning outcomes among elementary students with dyscalculia tendencies in Makassar, Indonesia. The experimental group, which utilized this tactile and visual tool, showed substantial gains in post-test scores compared to the control group taught through conventional methods. These findings affirm that number glass media is an effective choice for addressing dyscalculia-related challenges, as it transforms abstract numerical concepts into tangible experiences, reduces cognitive overload, and enhances engagement.

To maximize the benefits of this intervention, educators and stakeholders should prioritize the following recommendations: Curriculum Integration: Incorporate number glass media into mathematics curricula as a primary tool for teaching arithmetic operations to students with dyscalculia tendencies. Sustained Practice: Encourage students to consistently practice using number glass media or similar multisensory tools to reinforce learning and achieve long-term mastery. Collaboration with Professionals: Advise participants to consult psychologists to identify and address coexisting learning barriers, ensuring holistic support beyond classroom interventions. Focused Implementation: Avoid combining number glass media with unrelated interventions during its application to isolate and evaluate its efficacy accurately. Facilitator Expertise: Ensure facilitators receive specialized training in mathematics pedagogy and the use of multisensory tools to deliver the intervention effectively. Tool Refinement: Improve the design of number glass media by simplifying its features and teaching concepts, making it more accessible and adaptable to diverse learning environments. While the study highlights the media's potential, its small sample size and short intervention period necessitate further research with larger, culturally diverse cohorts to validate scalability. Future studies should also explore modifications to extend the media's utility to advanced mathematical topics, such as fractions or algebraic reasoning. By addressing these gaps, educators and policymakers can advance inclusive mathematics education, ensuring equitable opportunities for students with dyscalculia to achieve academic success.

Limitations of the Study

This study has several limitations that warrant careful consideration. First, the small sample size (N = 11) significantly restricts the statistical power of the findings, increasing the risk of Type II errors (failure to detect true effects) and limiting the generalizability of the results to broader populations. While the purposive sampling method ensured participants met strict criteria (e.g., dyscalculia tendencies, average-to-high IQ), the minimal sample size undermines confidence in the robustness of the observed effects, particularly given the heterogeneity inherent in dyscalculia profiles (Butterworth et al., 2011). Second, the short intervention period (14 sessions) and narrow focus on four arithmetic operations may have constrained the media's potential to produce sustained or comprehensive improvements. A longer intervention with incremental complexity could better assess whether gains in basic arithmetic translate to advanced mathematical domains (e.g., fractions, problem-solving). Additionally, the nonequivalent control group design, though pragmatic, introduces potential selection bias, as groups were not randomized. Uncontrolled variables, such as differences in teaching styles, parental involvement, or socioeconomic backgrounds, may have confounded the results. Finally, the study isolated number glass media as the sole intervention variable, excluding other factors that influence learning outcomes (e.g., comorbid learning disabilities, emotional states, or classroom dynamics). While this focus allowed for a clear evaluation of the media's efficacy, it overlooks the multifaceted nature of dyscalculia, which often coexists with other cognitive or affective challenges (Peters & De Smedt, 2018). Future research should adopt mixed-methods designs to account for these variables and explore how number glass media interacts with broader instructional ecosystems.

Acknowledgment

The authors acknowledge and are grateful for the support provided by our academic and professional colleagues at the Offices for Student Success, Teaching, Learning, and Academic Innovation, and Institutional Research & Advanced Analytics at the State University of Makassar and Elementary School in Makassar City. *Competing interests:* The authors acknowledge no conflict of interests with any institution. *Informed consent:* All study participants provided informed consent prior to study enrollment, in accordance with the study protocol approved by the IRB. *Funding:* This research received no specific grant funding in the public, commercial, or not-for-profit sectors. This manuscript has not been submitted elsewhere and it has not been submitted simultaneously for publication elsewhere. *Data availability statement:* The data that support the findings of this study are available on reasonable request from the corresponding author.

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