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Effect of Mathematics Pedagogical Simulation Methods on Mathematics Attainment of Grade Three Children in Loitokitok Sub-County, Kajiado County, Kenya

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Abstract

Based on Gardner's theory of multiple intelligence, which argues against one-sided teaching, this study aimed to investigate the effects of different types of mathematics pedagogical simulation methods on the mathematics achievement of third-grade children. The study employed a quasi-experimental research design with two non-equivalent study groups to investigate the effects of different types of mathematics pedagogical simulation methods on mathematics achievement. The study sample consisted of 1842 participants selected through stratified random sampling. Data collection tools included pre-tests, post-tests, and classroom observation questionnaires. Quantitative data were analyzed using a quantitative statistical approach, employing the Pearson Chi-Square test. Qualitative data were analyzed thematically. Ethical considerations included obtaining informed consent and protection from psychological distress. The study showed that the percentage of above-average attainment in the experimental group increased from 62.30% to 92.90%. The study found that different types of mathematics pedagogical simulation methods resulted in positive attitudes and significantly improved mathematics attainment. The study recommends the inclusion of different types of mathematics pedagogical simulation methods in the grade three children mathematics curriculum, ongoing teacher professional development training on non-routine mathematics pedagogical simulation strategies, flexible supportive mathematics teaching and learning policies, and further research on the long-term effects of the mathematics pedagogical simulation methods, especially in the affective domain, so that no child is left behind in the learning in the mathematics classroom. These strategies can promote children's engagement and improve mathematics outcomes in early primary schools. Multiple intelligence-based mathematics learning gives children who are gifted in areas other than logical-mathematical intelligence the opportunity to fully utilize their competency-based minds and abilities in mathematics learning.

Keywords: *Types of mathematics pedagogical simulation methods; mathematics attainment; positive disposition*

1. Introduction

Research over several decades has shown that children frequently struggle to understand mathematical concepts (Fuson, Kalchman & Bransford, 2005; Kenya National Examinations Council, 2018; Mangarin & Caballes, 2024; Njaru, Kang'ethe-Kamau, & Ng'asike, 2021; Research Triangle Institute, 2014; Piper & Mugenda, 2014; UNESCO, 2012; 2014; Uwezo East Africa, 2016). This underscores the necessity for non-routine mathematical pedagogical simulation methods strategies designed to create an emotionally engaging and contextualised learning environment for mathematics. These methods aim to place children at the centre of mathematics teaching and learning. From my own experience in a third-grade classroom, I have observed that children lack the support they need to understand complex math concepts. Instead, they are often taught to follow algorithms with limited opportunities to understand the math concept, which leads to rote memorisation (Nardi & Steward, 2003). Research has shown that simply memorising mathematical concepts is insufficient for achieving mastery in mathematics (Nardi & Steward, 2003; Piper, Ralaingita, Akach & King, 2016). The key challenge in mathematics education lies in fostering mathematical thinking within the confines of the mathematics classroom. Waswa and Al-Kassab (2023) note that children's innate cognitive competencies can contribute to their difficulties in mathematics learning. In addition, Acharya (2017) also



points out that children's lack of prior math knowledge causes problems in learning mathematics. This study hypothesises that multiple pedagogical simulation methods can serve to introduce complex concepts, provide diverse avenues for discovering mathematical principles, and reinforce learning in various ways. Children can only benefit from a better understanding and application of mathematics skills when mathematical concepts are tied to real-life situations.

The aim of using diverse mathematics pedagogical simulation methods-mathematical stories, music-based simulation methods, game-based simulation methods, drama based simulation methods, mathematics based discussion, teachers and peers as simulation methods sources, time spent on simulation methods and the classroom climate is to provide children with a realistic real life scenario for understanding mathematics concepts, that enable them to practise new concepts and think mathematically. These methods use emotionally engaging, real-life scenarios to help children learn mathematical ideas effectively (Pentronzi, Schalkwyk, & Pentronzi, 2024). They can positively influence children's understanding of various mathematical concepts and promote the development of authentic mathematical thinking (Hansberry, Moore, & Perkins, 2015). However, the effectiveness of these simulation methods in the classroom largely depends on how teachers integrate them into their mathematics lessons.

This study examines the effectiveness of mathematics pedagogical simulation methods rooted in constructivist and cognitivist beliefs, which suggest that children learn more effectively in interconnected contexts rather than through isolated mathematical concepts. Various forms of integration, such as mathematics embedded in stories, games, music, drama, and classroom discussions, can enhance children's learning experiences. One significant advantage of these simulation methods is their ability to create authentic and emotionally engaging real-life contexts for teaching mathematics, thereby improving children's mathematical attainment (Gardner, 2020). It is crucial not to underestimate the value of these methods, as they enable teachers to move beyond teacher-led instruction and engage more fully with children's understanding of mathematics concepts. Research in mathematics has indeed demonstrated that these methods are effective for organising and presenting mathematical concepts to young children (Afari, Tindal, & Thomas, 2013).

Despite the promising results in terms of pedagogical simulation methods, mathematics research reveals both global and regional gaps in the mathematics performance of grade three children. Both globally and regionally, there are often significant percentages of third-grade children who do not meet the officially mandated maths standards of the official curriculum (Education Quality & Accountability Office Canada, 2014; California Performance & Progress Report, 2016). From a regional perspective, more than 55% of children in grade three struggle to learn mathematics and consistently fall below the official mathematics curriculum benchmark (Kenya National Examinations Council, 2010, 2021; Njaru, Kang'ethe-Kamau, & Ng'asike, 2021; Uwezo East Africa, 2016). Specifically, the study aimed to explore the effects of different mathematics pedagogical simulation methods on the mathematics achievement of grade three children in Loitokitok Sub-County, Kajiado County, Kenya, to address the local mathematics achievement gap in Loitokitok Sub-County by investigating the effects of different types of mathematics pedagogical simulation methods on the mathematics achievement of grade three children.

The study employs a range of pedagogical simulation methods, including mathematical story-based, game-based, music-integrated, drama-contextualised, and discussion-driven approaches. It utilises teachers and peers as sources of simulation methods to enhance children's understanding of complex mathematical concepts. Previous studies have indicated that these methods can lead to improved cognitive processing and foster a more engaging learning environment (An & Capraro, 2011; Abramovich, 2010). Research in mathematics acknowledges the impact of teachers' and children's attitudes toward mathematics instruction on learning outcomes, noting that negative perceptions can hinder mathematical educational success (Mensah, Okyere, & Kuranchie, 2013). Therefore, a comprehensive study is essential to understand how these different simulation methods interact and how they affect the attitudes and performance of third graders in mathematics in Loitokitok Sub-County, Kajiado County, Kenya.

Despite ongoing efforts to improve the teaching of mathematics, grade three strand a crucial stage because it marks the last year of early primary school and the beginning of primary school as a whole. Children, typically aged 7 to 8 years old, require a solid mathematical foundation at this stage of development. Many grade three children in Loitokitok Sub-County, Kajiado County, Kenya, continue to fall below the officially required standards of the mathematics curriculum (Kenya National Examinations Council, 2021; Njaru, 2016; Njaru et al., 2021; Uwezo East



Africa, 2016). The reliance on conventional and disjointed teaching strategies has led to low academic performance in mathematics and low mathematical engagement among grade three children. This study addresses the critical need to contextualise different types of mathematical pedagogical simulation methods to improve logical-mathematical cognition by examining how various types of mathematics pedagogical simulation methods can enhance the mathematics achievement of grade three children.

2. Methodology

The study employed a quasi-experimental design to assess the mathematics achievement of two non-equivalent control groups, measuring their performance both before and after the intervention. In this instructional intervention, one group of third-grade children received support through different types of mathematics teaching simulation methods, while the control group did not receive any such support. The twelve third-grade primary schools, comprising thirty-six teachers and 1,800 grade three children, participated in the study. The confidentiality of the information shared was ensured through appropriate disclosure channels, with parents signing informed consent on behalf of their children. The children were also informed of their right to withdraw from study at any time without repercussions. However, the replacement had to be immediately, and if ethically applicable, it was necessary to investigate the cause of the withdrawal in order to determine and secure the underlying issue. Participation in the study was entirely voluntary, and no child was at risk of psychological distress. Pseudonyms were used to protect the identity of the children and to publicise their views.

The raw data were validated and edited before being coded into themes of the research objectives. Data on math attainment was analyzed using a quantitative statistical approach and presented using frequency distribution tables, percentages, and means. The raw qualitative data were analysed by theme and evaluated using descriptive statistics. The results were presented using frequency tables. Chi-square was used to test the statistical null hypothesis.

3.0 Results and Discussion

The study aimed to test the null hypothesis that there is no significant difference in the math scores of third-grade children taught using various pedagogical simulation methods compared to those taught without such methods. Data was collected through a 28-item questionnaire administered to teachers in both control and experimental groups to evaluate the effectiveness of these simulation methods, which included mathematical stories, games, drama, music, discussions, and peer tutoring. The questionnaires are detailed in Appendix II, and responses were rated on a scale from 1-4; 4 = Effective, 3 = Somewhat Effective, 2 = Ineffective, and 1 = Not Observed. The data were analyzed using frequency tables and Pearson's Chi-square correlation to assess the relationship between the use of different pedagogical methods and students' math achievement. The analysis aimed to determine whether the integration of these methods had a significant impact on the math performance of third-grade students.

3.1 The Relationship between Mathematical Stories, Pedagogical Simulation Method, and Mathematics Academic Attainment

This section examines the relationship between using mathematical stories as a teaching method and students' academic performance in mathematics. Children scoring 25 or more out of 50 were considered above average, while those scoring below 25 were deemed below average. The results were analyzed using frequency tables and Pearson's Chi-square tests, as detailed in the table below.

Table 1.1: The relationship between mathematical story pedagogical simulation and mathematics academic attainment.

Story		Academic attainment				Pearson Chi-square Tests		
		below average		above average		Chi-square	df	Sig.
		Count	Column N %	Count	Column N %			
The classroom mathematics teacher introduces mathematics concept through mathematical	Not Observed	4	23.50%	0	0.00%	9.707	3	.021*
	Ineffective	6	35.30%	3	15.80%			
	Somewhat Effective	5	29.40%	7	36.80%			
	Effective							



story to address continuum of children's mathematics concepts in the classroom	Effective	2	11.80%	9	47.40%			
The classroom mathematics teacher present mathematics concepts to children through mathematical story pedagogical simulation methods until the end of the mathematics lesson	Not Observed	11	64.70%	3	15.80%	13.528	3	.004*
	Ineffective	3	17.60%	1	5.30%			
	Somewhat Effective	1	5.90%	6	31.60%			
	Effective	2	11.80%	9	47.40%			
The children appear to be at ease while learning mathematics concepts through mathematical story until the end of mathematics lesson	Not Observed	9	52.90%	4	21.10%	14.884	3	.002*
	Ineffective	5	29.40%	0	0.00%			
	Somewhat Effective	1	5.90%	6	31.60%			
	Effective	2	11.80%	9	47.40%			

* The Chi-square statistics are significant at the .05 level.

The results indicate that using mathematical stories significantly enhances students' academic performance in mathematics. In classes utilizing mathematical stories, 47.4% of children scored above average, compared to the control group that did not employ this method ($X^2 = 9.707$, $p = .021$). The persistent use of these stories throughout the lesson also resulted in 47.4% of students achieving above-average scores. In contrast, only 15.8% of students in the control group did so (Chi-square = 13.528, $p = .004$). Furthermore, when mathematical stories were effectively integrated, 47.4% of students performed well, compared to 21.1% in the control group ($X^2 = 14.884$, $p = .002$).

These findings align with existing research that affirms teaching through mathematical stories enhances logical-mathematical reasoning (Pentronzi, Schalkwyk, & Pentronzi, 2024). Scholars argue that these stories foster emotional connections with the content (Egan, 2005; Ewing, Haworth, Carr, & De La Mare, 2018), making mathematical concepts more comprehensible and engaging. This approach offers an effective non-routine method for teaching complex topics and can significantly boost academic achievement in mathematics (Farrugia & Trakulphadetkrai, 2020).

Overall, the use of mathematical stories fosters a better understanding of math concepts, enhances motivation, and reduces anxiety among students, leading to a more comfortable learning environment. This approach aligns with the National Council of Teachers of Mathematics (NCTM, 2000) communication standards, emphasizing the importance of dialogue in the classroom. Engaging with mathematical stories encourages discussions with teachers and peers, ultimately enriching the learning experience (Goral & Gnadinger, 2006). Additionally, the findings suggest that mathematical stories are effective in motivating children to learn math.

3.2: The Relationship between Mathematics Games, Pedagogical Simulation Method and Academic Attainment

Next, the study also examined the relationship between the use of games as a mathematical pedagogical simulation and the mathematics attainment of third-grade children. The results from the data analysis are shown in the table below.

Table 1.2: The Relationship between story mathematics pedagogical Simulation method and academic attainment



Games		Academic attainment				Pearson Chi-square Tests		
		below average		above average		Chi-square	df	Sig.
		Count	Column N %	Count	Column N %			
The classroom mathematics teacher introduces mathematics concept through games-mathematics pedagogical simulation methods to make sure that all children are involved in mathematics learning activities	Not Observed	12	70.60%	4	21.10%	13.557	3	.004*
	Ineffective	2	11.80%	0	0.00%			
	Somewhat	2	11.80%	9	47.40%			
	Effective							
	Effective	1	5.90%	6	31.60%			
The classroom mathematics teacher presents mathematics concepts to children through games-mathematics pedagogical simulation methods until the end of the mathematics lesson.	Not Observed	12	70.60%	2	10.50%	15.104	3	.002*
	Ineffective	2	11.80%	2	10.50%			
	Somewhat	2	11.80%	9	47.40%			
	Effective							
	Effective	1	5.90%	6	31.60%			
The children appear to be at ease while learning mathematics concepts through games- mathematics based pedagogical simulation method until the end of mathematics lesson.	Not Observed	8	47.10%	4	21.10%	15.295	3	.002*
	Ineffective	6	35.30%	0	0.00%			
	Somewhat	2	11.80%	9	47.40%			
	Effective							
	Effective	1	5.90%	6	31.60%			

* The Chi-square statistic is significant at the .05 level.

The results indicate a strong positive link between game-based

mathematical teaching methods and improved academic performance in mathematics. Classrooms that effectively used games demonstrated higher achievement, with 31.6% of students in the experimental group scoring above average, compared to the control group, which did not use games (Chi-square = 13.557, $p = .004$). Additionally, maintaining consistent game use throughout the lesson resulted in 31.6% of students achieving above-average scores, compared to 10.5% in the control group (Chi-square = 15.104, $p = .002$). Students also felt more at ease and performed better with games, achieving 31.6% above-average scores compared to 21.1% in the control group (Chi-square = 15.295, $p = .002$).

These findings support previous research showing that game-based methods can enhance children's mathematics test scores (Rittle-Johnson & Jordan, 2016). Games make learning complex mathematical concepts enjoyable and engaging (Adoke, 2015). For example, Pareto, Arvemo, Dahl, Haake, and Gulz (2011) noted that arithmetic games significantly improved the basic arithmetic skills of third graders. This approach is effective for teaching challenging concepts by increasing retention, attention, and interest (Gardner, 2020). Given that many children engage in gaming regularly (Riley, 2019), integrating game-based learning in mathematics can leverage this interest to promote



interactive problem-solving and critical thinking. Studies such as Yang and Cheng (2010) demonstrate that instructional games enhance attention spans and test scores, while research by Banerjee, Esther, and Duflo (2007) shows significant improvements in scores through computer-based simulations.

3.3: The relationship between Music Pedagogical simulations and Mathematics Academic attainment

This subsection examines how music-based teaching simulations influence children's math performance. It analyzes the effectiveness of integrating music into math instruction by evaluating students' outcomes. The findings are presented on the table below.

Table 1.3: Results on the relationship between Music Pedagogical simulations and Mathematics Academic attainment

Music pedagogical simulations		academic attainment				Pearson Chi-square Tests		
		below average		above average		Chi-square	df	Sig.
		Count	Column N %	Count	Column N %			
The classroom mathematics teacher presents mathematics concepts to children through music-mathematics pedagogical simulation methods until the end of the mathematics lesson.	Not Observed	7	41.20%	3	15.80%	14.058	3	.003*
	Ineffective	7	41.20%	1	5.30%			
	Somewhat Effective	1	5.90%	6	31.60%			
	Effective	2	11.80%	9	47.40%			
The classroom mathematics teacher introduces mathematics concepts through music-mathematics pedagogical simulation methods to address continuum of children's mathematics concepts in the classroom	Not Observed	8	47.10%	2	10.50%	14.531	3	.002*
	Ineffective	6	35.30%	2	10.50%			
	Somewhat Effective	1	5.90%	6	31.60%			
	Effective	2	11.80%	9	47.40%			
The classroom mathematics teacher provides children with sufficient time to internalize and mathematize mathematics concepts.in the classroom.	Not Observed	14	82.40%	4	21.10%	13.512	2	.001*
	Ineffective	0	0.00%	0	0.00%			
	Somewhat Effective	1	5.90%	6	31.60%			
	Effective	2	11.80%	9	47.40%			

The findings demonstrate a notable positive effect of music-based teaching methods on students' mathematics performance. When effectively integrated into lessons, 47.4% of children scored above average, compared to just 5.3% when these methods were poorly implemented (Chi-square = 14.058, $p = .003$). Similarly, 47.4% achieved above-average scores when music was used to introduce math concepts, compared to 10.5% without it ($X^2 = 14.531$, $p = .002$).

These results support existing research that indicates music-mathematics pedagogies significantly improve mathematical understanding (An, Capraro, & Tillman, 2013). Incorporating elements like melody and rhythm can enhance comprehension of complex topics such as number operations and geometry (Harkleroad, 2006). Using music to contextualize math creates a powerful learning experience that makes abstract concepts more accessible (Shanders, 2018). This approach not only boosts motivation and self-reflection (Peterson, 2005) but also fosters a collaborative and enjoyable classroom atmosphere (Robertson & Lesser, 2013). Empirical evidence shows that children taught math



through music tend to achieve better results and develop more positive attitudes toward the subject (Rauscher & Hinton, 2011).

3.4: The Relationship between Drama Pedagogical Simulation and Mathematics Academic Attainment

This study subsection investigated how the use of drama as a pedagogical simulation method in mathematics affects the academic attainment of mathematics in grade three children. The results of the frequency tables and the Pearson Chi-square tests are presented below:

Table 1.4: Results on the relationship between drama Pedagogical simulation and Mathematics academic attainment

Drama-Pedagogical Simulation		Academic attainment				Pearson Chi-square Tests		
		below average		above average		Chi-square	df	Sig.
		Count	Column N %	Count	Column N %			
The classroom mathematics teacher introduces mathematics concept in the class through drama-mathematics pedagogical simulation methods to address the continuum of children's mathematical concepts	Not Observed	10	58.80%	4	21.10%	13.958	3	0.003*
	Ineffective	4	23.50%	0	0.00%			
	Somewhat Effective	2	11.80%	9	47.40%			
	Effective	1	5.90%	6	31.60%			
The classroom mathematics teacher presents mathematics concepts to children through drama-mathematics pedagogical simulation methods until the end of the mathematics lesson	Not Observed	12	70.60%	4	21.10%	13.958	3	.003*
	Ineffective	2	11.80%	0	0.00%			
	Somewhat Effective	2	11.80%	9	47.40%			
	Effective	1	5.90%	6	31.60%			
The children appear to be at ease while learning mathematics concepts through mathematics-drama based pedagogical simulation method until the end of mathematics lesson	Not Observed	14	82.40%	3	15.80%	16.082	3	.001*
	Ineffective	0	0.00%	1	5.30%			
	Somewhat Effective	2	11.80%	9	47.40%			
	Effective	1	5.90%	6	31.60%			

The findings demonstrate a notable positive effect of music-based teaching methods on students' mathematics performance. When effectively integrated into lessons, 47.4% of children scored above average, compared to just 5.3% when these methods were poorly implemented (Chi-square = 14.058, $p = .003$). Similarly, 47.4% achieved above-average scores when music was used to introduce math concepts, compared to 10.5% without it ($X^2 = 14.531$, $p = .002$).

These results support existing research that indicates music-mathematics pedagogies significantly improve mathematical understanding (An, Capraro, & Tillman, 2013). Incorporating elements like melody and rhythm can enhance comprehension of complex topics such as number operations and geometry (Harkleroad, 2006). Using music to contextualize math creates a powerful learning experience that makes abstract concepts more accessible (Shanders, 2018). This approach not only boosts motivation and self-reflection (Peterson, 2005) but also fosters a collaborative and enjoyable classroom atmosphere (Robertson & Lesser, 2013). Empirical evidence shows that children taught math through music tend to achieve better results and develop more positive attitudes toward the subject (Rauscher & Hinton, 2011).

3.5: The Relationship between Mathematics Discussion Pedagogical Simulation Method and Mathematics Academic Attainment



This subsection explores how discussing mathematical concepts with children enhances their understanding and performance in mathematics. The effectiveness was evaluated through questionnaires, with results analyzed using frequency tables and Pearson's Chi-square tests. The findings are summarized in the table below:

Table 1.5: Results on the relationship between Mathematics discussion Pedagogical simulation method and Mathematics academic attainment

Mathematics-discussion		Academic attainment				Pearson Chi-square Tests		
		below average		above average		Chi-square	df	Sig.
		Count	Column N %	Count	Column N %			
The classroom mathematics teacher introduces mathematics concepts through music-mathematics pedagogical simulation methods to address continuum of children's mathematics concepts in the classroom	Not Observed	8	47.10%	2	10.50%	14.531	3	.002*
	Ineffective	6	35.30%	2	10.50%			
	Somewhat	1	5.90%	6	31.60%			
	Effective							
	Effective	2	11.80%	9	47.40%			
The classroom mathematics teacher present mathematics concepts to children through classroom mathematics-discussions pedagogical simulation methods until the end of mathematics lesson	Not Observed	10	58.80%	3	15.80%	13.526	3	.004*
	Ineffective	4	23.50%	1	5.30%			
	Somewhat	1	5.90%	6	31.60%			
	Effective							
	Effective	2	11.80%	9	47.40%			
The children appear to be at ease while learning mathematics concepts through mathematics-discussions based simulation methods until the end of mathematics lesson	Not Observed	9	52.90%	3	15.80%	13.624	3	.003*
	Ineffective	5	29.40%	1	5.30%			
	Somewhat	1	5.90%	6	31.60%			
	Effective							
	Effective	2	11.80%	9	47.40%			

The study demonstrates a significant positive effect of discussion-based pedagogical simulations on academic achievement in mathematics. When these discussion methods were effectively implemented, 47.4% of students scored above average, compared to just 10.5% when they were absent (Chi-square = 14.531, $p = .002$). Maintaining discussions throughout the lesson also resulted in improved performance, with 47.4% of students achieving above-average scores, compared to 15.8% without these strategies (Chi-square = 13.526, $p = .004$). Furthermore, effective discussions made children feel more comfortable, leading to 47.4% of them obtaining above-average scores, while only 15.8% succeeded without discussions ($X^2 = 13.624$, $p = .003$).

These results align with the existing literature, which highlights the benefits of discussion-based methods in mathematics, encouraging "math talk" (Payne, 2023) and enhancing understanding through collaborative dialogue (Waggoner, 2015). The social constructivist theory supports this approach, emphasising that children learn more effectively in collaborative environments (Bermejo et al., 2021; Johnston & Johnston, 2021). Research indicates that allowing students to voice their thoughts during math discussions improves their conceptual understanding, cognitive skills, and attitudes toward mathematics (Johnston-Wilder & Lee, 2019). Overall, studies confirm that engaging children in mathematical discussions leads to better outcomes (Payne, 2023; Von Spreckelsen, Dove, Coolen, Mills, Dowker, Sylva, Ansari, Merkley, Murphy, & Scerif, 2019), underscoring the effectiveness of these interactive methods in enhancing mathematical achievement.

4. Conclusions and Recommendations



The study found that different types of mathematics pedagogical simulation methods resulted in positive attitudes and significantly improved mathematics attainment. The study recommends the inclusion of different types of mathematics pedagogical simulation methods in the grade three children mathematics curriculum, ongoing teacher professional development training on non-routine mathematics pedagogical simulation strategies, flexible supportive mathematics teaching and learning policies, and further research on the long-term effects of the mathematics pedagogical simulation methods, especially in the affective domain, so that no child is left behind in the learning in the mathematics classroom. These strategies can promote children's engagement and improve mathematics outcomes in early primary schools. Multiple intelligence-based mathematics learning gives children who are gifted in areas other than logical-mathematical intelligence the opportunity to fully utilize their competency-based minds and abilities in mathematics learning.

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