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The Impact of the "Megazos" Educational Manipulative on Engineering Thinking Skills in Early Childhood Education

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Abstract

*Engineering thinking is a key component of early childhood Science, Technology, Engineering, Arts, and Mathematics (STEAM) education, fostering spatial reasoning, trial-and-error problem-solving, and structural logic. However, constructive play media in early childhood settings often remain limited to static, conventional building blocks, constraining engineering skill development. This study evaluated the effectiveness of an innovative, slot-interlocking geometric manipulative named **Megazos** in enhancing engineering thinking skills among children aged 4–5 years. Utilizing a quasi-experimental one-group pretest-posttest design (N=12), data were gathered via structured observational checklists and analyzed using paired-sample t-tests. The results revealed a statistically significant increase in children's mean engineering thinking scores, rising from 16.17 (SD=1.75) at pretest to 22.00 (SD=2.00) at posttest. Paired-sample t-test analysis confirmed the intervention's efficacy ($t_{11}=9.109, p<0.05$), exceeding the critical value ($t_{table}=2.201$). The findings demonstrate that ergonomically designed, slot-interlocking manipulatives paired with task-challenge cards significantly stimulate trial-and-error construction, structural re-engineering, and spatial problem-solving in early childhood learners.*

Keywords: *educational manipulatives, engineering thinking, STEAM education, constructive play, early childhood education, Megazos*

INTRODUCTION

Early Childhood Education (ECE) plays a pivotal role in establishing foundational cognitive capacities. In contemporary early childhood pedagogy, cognitive stimulation is increasingly driven by Science, Technology, Engineering, Arts, and Mathematics (STEAM) frameworks. Integrating engineering concepts with early science and mathematics empowers young children to develop higher-order thinking, spatial awareness, and creative problem-solving skills through hands-on exploration.

Within the STEAM paradigm, early engineering thinking facilitates a unique developmental process: it encourages children to design, innovate, test structural stability, and apply practical logic. Engineering behaviors naturally emerge when young children manipulate tactile materials to construct three-dimensional objects. For children aged 4–5 years, introducing basic structural problem-solving prepares them for complex logical reasoning in primary education. This aligns with modern early childhood curriculum frameworks, which mandate foundational competencies in literacy, mathematics, science, and engineering through play-based activities.

Constructive play—primarily using building blocks—is the primary vehicle for stimulating early engineering skills. Constructive play fosters spatial imagination, balance awareness, geometric understanding,

and structural planning. However, educational settings frequently suffer from a reliance on static, conventional wooden blocks. When manipulative media lack novelty or structural variety, children quickly experience play fatigue, limiting opportunities for deep engineering exploration.

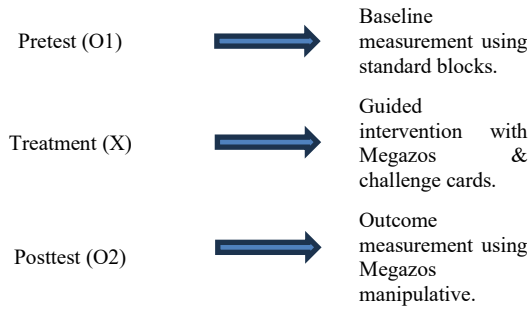
To address this gap, innovative Educational Game Tools (*Alat Permainan Edukatif* - APE) are needed. This study introduces **Megazos**, an innovative manipulative modified from traditional interlocking chips into lightweight, ergonomic geometric shapes designed for small hands. Each Megazos piece features side slots, allowing children to engage in trial-and-error assembly, slot-interlocking construction, and three-dimensional structural design.

This study empirically evaluates the effect of the Megazos manipulative on the engineering thinking skills of 4–5-year-old children at RA Ummul Quro, Bandung Regency.

RESEARCH METHODS

Research Design

This study adopted a quantitative, quasi-experimental research approach utilizing a **One-Group Pretest-Posttest Design**. This design was selected because the entire intact classroom was studied, precluding individual random assignment.



ONE-GROUP PRETEST-POSTTEST DESIGN

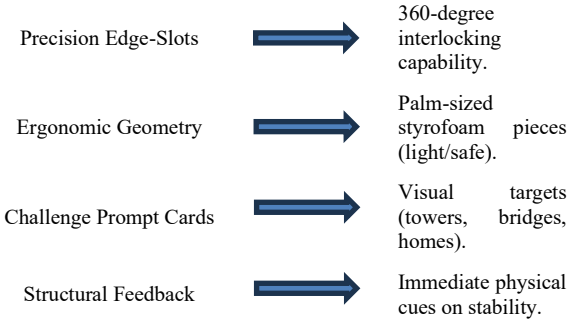
Participants and Context

The population comprised all Group A learners (ages 4–5) enrolled at RA Ummul Quro, Bandung Regency. A **total sampling** (census) technique was applied due to the small, bounded population size ($N = 12$; 7 boys, 5 girls). None of the participants had prior exposure to the Megazos manipulative.

The "Megazos" Manipulative Intervention

Megazos pieces are constructed from high-density, lightweight styrofoam shaped into basic geometric patterns (triangles, squares, circles) with precision edge-slots. The intervention included:

- **Ergonomic Design:** Scaled to fit preschool palm sizes, enabling fine-motor manipulation.
- **Challenge Cards:** Visual prompt cards depicting structural targets (e.g., towers, bridges, houses) and narrative characters to motivate goal-directed building.
- **Trial-and-Error Construction:** Edge-slots allow 360-degree interlocking, encouraging children to re-engineer unstable connections.



MEGAZOS MANIPULATIVE DESIGN FEATURES

Data Collection and Instrumentation

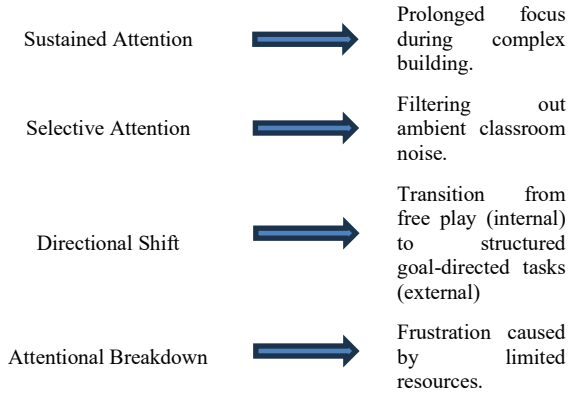
Data were collected via direct structured observation using a 4-point rating rubric (1 = Not Yet Developed to 4 = Very Well Developed) measuring four core engineering thinking indicators:

1. **Structural Planning:** Selecting appropriate pieces based on visual challenge targets.
2. **Interlocking Execution:** Connecting edge-slots to assemble stable 3D shapes.

3. **Trial-and-Error Problem Solving:** Identifying weak joints and adjusting piece orientation.
4. **Re-Engineering:** Modifying falling or leaning structures independently.

Data Analysis

Descriptive statistics (mean, standard deviation, variance) were computed. Pretest and posttest distributions were verified for normality using Chi-Square testing (χ^2) and variance homogeneity using F-tests. Hypothesis testing was conducted using a paired-sample t-test at $\alpha = 0.05$ significance level.



ATTENTION MANIFESTATION FRAMEWORK

RESULTS AND DISCUSSION

Prerequisite Test Results

Normality and homogeneity testing confirmed that the pretest and posttest datasets met parametric assumptions:

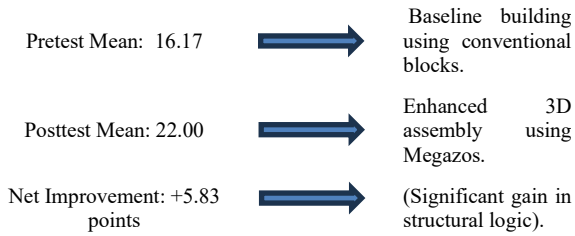
- **Normality:** Pretest ($\chi^2_{\text{calculated}} = 14.80 < \chi^2_{\text{table}} = 19.68$) and Posttest ($\chi^2_{\text{calculated}} = 9.87 < \chi^2_{\text{table}} = 19.68$) were normally distributed.
- **Homogeneity:** Variance ratio ($F_{\text{calculated}} = 1.30 < F_{\text{table}} = 4.46$) demonstrated homogenous variances across measurement points.

Measurement Stage	Mean ($\bar{X}$)	Std. Dev. (SD)	t-calculated	t-table (α=.05)
Pretest (O_1)	16.17	1.75	9.109	2.201
Posttest (O_2)	22.00	2.00	--	--
Difference (Δ)	+5.83	+0.25	$p < 0.001$ (Significant)	--

Table 1: Descriptive Statistics and Hypothesis Test Summary (N = 12)

Intervention Impact on Engineering Thinking Skills

The paired-sample t-test yielded t11=9.109, significantly exceeding the critical threshold ttable=2.201 ($p<0.05$). Consequently, the null hypothesis (H0) was rejected, confirming that Megazos significantly enhances early engineering thinking skills.



ENGINEERING SCORE PROGRESSION

Children demonstrated marked improvements across all four observation dimensions. During pretest sessions with conventional blocks, children primarily stacked blocks vertically without structural reinforcement. During posttest sessions with Megazos, children actively used the slot-interlocking mechanism to construct cantilevered bridges, multi-room enclosures, and stable towers. When towers began to lean, children engaged in re-engineering—disassembling unstable joints and inserting counter-balancing pieces.

Discussion

The empirical findings support Piaget's cognitive development theory, which posits that preoperational learners (ages 4–5) construct logical schemas through active physical manipulation and object interaction. The physical feedback provided by the edge-slots in Megazos triggers a cognitive cycle of **assimilation and accommodation**. When a child attempts to connect two pieces incorrectly, the physical mismatch forces the child to accommodate new spatial information and adjust their building strategy.

Furthermore, the results reinforce the efficacy of hands-on STEAM learning. By combining visual challenge cards with tactile manipulatives, Megazos bridges abstract structural concepts with concrete physical play. Lightweight, ergonomic materials eliminate fear of failure or injury, empowering children to experiment freely with complex 3D engineering designs.

Limitations

The primary limitation of this study is the single-group design (N=12) without an active control group, which limits control over maturation effects. Future research should employ randomized controlled trials (RCT) across larger sample sizes and extended intervention timeframes.

CONCLUSION

This study demonstrates that the **Megazos** educational manipulative significantly enhances engineering thinking skills in early childhood learners aged 4–5 years. The slot-interlocking design, combined with visual challenge prompts, actively stimulates spatial planning, trial-and-error problem solving, and structural re-engineering. Early childhood educators are encouraged to incorporate innovative, multi-dimensional manipulatives into classroom STEAM centers to promote active engineering logic and play-based problem solving.

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