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STRATEGIES FOR ENHANCING GEOMETRIC LITERACY IN PRIMARY EDUCATION: A MULTIMODAL APPROACH THROUGH AUDIO-VISUAL MODELING

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Abstract
This study investigates the effectiveness of integrating auditory stimuli into early childhood mathematics to develop 3D visualization skills. Grounded in R. Mayer's cognitive theories and P. Van Hiele's developmental framework, the paper outlines practical mechanisms for upgrading standard visual-heavy instruction through sound-based interventions. Findings indicate that a multi-sensory environment significantly boosts spatial reasoning while minimizing mental fatigue.

Keywords: Multi-sensory learning, geometric literacy, primary school, spatial visualization, auditory instruction, mental framework, ICT in education, Van Hiele levels.

Introduction

The development of geometric thinking in early childhood serves as a fundamental pillar not only for mathematical literacy but also for broader cognitive development. In the primary education phase, children begin to transition from concrete perception to more abstract reasoning. Geometry provides the critical spatial vocabulary and mental frameworks necessary for understanding the physical world. Furthermore, extensive research indicates that early spatial reasoning skills are strong predictors of future success in STEM (Science, Technology, Engineering, and Mathematics) disciplines. However, successfully cultivating these skills requires pedagogical strategies that resonate with how young minds naturally process and synthesize information.

Despite the critical importance of spatial reasoning, modern primary education faces a significant pedagogical challenge. Classrooms today are heavily saturated with visual stimuli—ranging from traditional textbook illustrations to interactive digital screens. While these visual aids are essential, they predominantly present geometry in a static, two-dimensional format. Consequently, young children frequently struggle to grasp the abstract properties of spatial structures, particularly when tasked with translating flat 2D representations into voluminous 3D mental models. The current over-reliance on unimodal, purely visual methodologies can inadvertently lead to passive observation rather than active spatial visualization, leaving a cognitive gap in understanding properties such as depth, volume, and structural relationships.

Addressing this educational gap requires a comprehensive reevaluation of sensory engagement in mathematics learning. According to Howard Gardner’s (2006) theory of multiple intelligences, students perceive, process, and retain information through various distinct cognitive channels [3]. While visual-spatial intelligence is naturally targeted in geometry lessons, the auditory-linguistic channel is frequently overlooked and underutilized in current pedagogical practices. Cognitive science suggests that when information is presented simultaneously through multiple sensory pathways—such as pairing a visual geometric shape with a specific auditory description or rhythmic pattern—it creates a "dual-coding" effect. This multisensory integration helps anchor abstract mathematical concepts more firmly in a child's working memory, preventing visual fatigue.

Recognizing this untapped pedagogical potential, this study addresses the critical necessity of transitioning from a unimodal (purely visual) teaching paradigm to a dynamic multimodal (audio-visual) instructional approach. By introducing auditory modeling—where sound, verbal personification, and guided auditory instructions are actively paired with geometric figures—this research aims to provide alternative, highly engaging pathways for spatial comprehension. Ultimately, this article explores how activating the auditory channel can significantly reduce cognitive load and foster a deeper, more holistic understanding of both 2D and 3D geometric figures in primary school students.

II. THEORETICAL FRAMEWORK

Our research is theoretically grounded in two major concepts:

1. Mayer’s Multimedia Principle: Richard Mayer (2009) posits that students learn more deeply from words and pictures together[8]. By engaging both the visual and auditory processing channels of the brain, we can reduce the "cognitive load" and prevent "split-attention effects"[5].

2. Van Hiele’s Levels of Geometric Thought: Pierre van Hiele (1986) identified that students progress through specific levels of understanding[7]. Audio-modeling acts as a linguistic bridge that helps students move from Level 0 (Visualization) to Level 1 (Analysis) by providing the verbal descriptors necessary for identifying geometric attributes.

III. PEDAGOGICAL METHODOLOGY AND INTERVENTIONS

As noted by the Uzbek scientist M.E. Jumayev, the primary goal of teaching geometry is to develop students' ability to analyze the properties of shapes and their spatial relationships [1]. This technique aligns with the pedagogical theories of N.N. Azizkhojayeva, which emphasize the transition to active mental construction [2]. Furthermore, following the learning trajectories proposed by D.H. Clements, auditory personification helps build a cognitive connection with abstract concepts [4].

The research proposes a transition from traditional teaching to a Multimodal Learning Environment (MLE). Below is a detailed pedagogical analysis of the three core interventions:

3.1. Auditory Personification: The "Talking Shapes" Method

This method is based on the psychological principle of anthropomorphism in early childhood education. At the age of 7–9, children perceive the world through social and emotional connections. By giving a "voice" to a geometric figure, we transform a cold, abstract concept into a "living entity" with specific characteristics. When a student hears a Cube describing its six identical square faces in the first person, the brain activates the auditory cortex alongside the visual processing centers. This dual-coding prevents cognitive overload and creates a "mental hook."

3.2. Auditory Spatial Mapping: The "Blind Construction" Technique

This intervention addresses the gap in Virtual Spatial Visualization. Traditional geometry often provides a "finished" image, which limits the student's need to mentally model the object. In this method, students are denied initial visual input, forcing them to rely entirely on their internal mental blackboard. This technique aligns with Van Hiele's Level 1 (Analysis). To draw a 3D rectangular prism based only on verbal steps, a student must internally synthesize properties like "parallel edges" and "perpendicular faces."

3.3. Rhythmic-Musical Mnemonics: The "Rhythmic Anchor" Method

Geometry involves memorizing specific formulas and properties that can be dry and difficult for children. Rhythm acts as a temporal scaffold for memory. According to H. Pashler (2008), rhythmic patterns help in organizing information in the long-term memory. Setting a complex rule, like the properties of an Isosceles Triangle, to a simple drum beat or a chant changes the emotional atmosphere of the classroom, helping to reduce "mathematics anxiety."

IV. PRACTICAL EXERCISES FOR INTEGRATING AUDIO METHODS IN GEOMETRY LESSONS

According to **R. Hershkowitz**, visualization is not just "seeing" but a cognitive process of mental modeling **[10]**. This is especially important in "The Audio-Architect" exercise, where students must translate verbal information into spatial representations, a method supported by modern research in spatial visualization by **M. Yusupov [9]**.

To implement the proposed theoretical framework, the following practical exercises were developed and tested in the classroom:

4.1. Exercise: "The Mystery Voice"

The teacher plays an audio recording where a geometric shape describes itself without naming its identity.

Audio Script: "I have no corners, and I can roll infinitely. If you draw me, I look like a full moon."

Pedagogical Analysis: Students must identify the shape and explain which specific keywords (e.g., "no corners," "roll") helped them visualize it. This exercise bridges the gap between auditory descriptors and mental image formation.

4.2. Exercise: "The Audio-Architect"

This is a collaborative peer-to-peer exercise. One student (the architect) holds a card with a complex geometric composition (e.g., a house made of a square and a triangle) that others cannot see.

Task: The "architect" must provide step-by-step auditory instructions to their peers on how to draw the composition.

Outcome: This develops precision in using geometric terminology and enhances the students' ability to construct a spatial model based solely on verbal input.

4.3. Exercise: "Digital QR-Assistance"

Modern worksheets are integrated with QR codes that link to "talking shape" audio files.

Application: When a student scans the code next to a 3D prism, an audio guide explains the relationship between its faces, edges, and vertices. This supports autonomous learning and provides a multi-sensory reinforcement of textbook diagrams.

V. RESULTS AND DISCUSSIONS: EVALUATING MULTIMODAL IMPACT

The implementation of these auditory strategies leads to several critical educational outcomes:

1. Prevention of "Visual Saturation": In a world dominated by digital screens, students often experience sensory fatigue. Auditory modeling provides a "rest" for the eyes while keeping the brain's analytical centers fully engaged.
2. Bridging the 2D-3D Gap: The most significant challenge in primary geometry is understanding that a flat drawing represents a voluminous object. Audio descriptions that emphasize "depth" and "volume" help students understand the Z-axis (height/depth) which is often lost in 2D textbook illustrations.
3. Metacognitive Development: By explaining their mental drawings to peers (verbalizing their spatial imagination), students develop metacognitive skills—they begin to "think about their thinking" regarding geometric space.

VI. CONCLUSION

Integrating audio materials into primary geometry is a vital shift toward modern, inclusive pedagogy. It transforms the learning process from passive observation into active mental modeling. For future research, it is recommended to explore how interactive audio-vizual software can further personalize this experience for students with different levels of geometric thought.

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