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GEOMETRIC ELEMENTS TEACHING - A METHODOLOGY FOR ENHANCING CREATIVITY THROUGH 3D MODELING AND INNOVATIVE EDUCATIONAL TECHNOLOGIES

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Abstract: This article examines the methodological potential of innovative educational technologies for increasing learners' creativity in the teaching of geometric elements through 3D modeling. The relevance of the topic is determined by the transition of school education toward digital, competence-based, and practice-oriented instruction, where spatial reasoning, design thinking, and creative problem solving are regarded as core learning outcomes. The paper synthesizes contemporary international findings on 3D modeling, virtual environments, and mathematical creativity, and correlates them with the digital transformation agenda of Uzbekistan's education system. Particular attention is given to the pedagogical conditions under which 3D modeling becomes not merely a visualization tool but a medium for productive inquiry, experimentation, and divergent thinking. The study argues that the most effective methodology is based on staged integration of digital visualization, collaborative project work, interactive assessment, and reflective design tasks. The proposed methodological model can be adapted for primary and lower secondary mathematics education and may serve as a conceptual basis for future empirical classroom research.

Keywords: 3D modeling, geometry teaching, creativity, innovative educational technologies, spatial thinking, mathematical visualization, digital pedagogy, design-based learning, STEM integration, primary education

ENTRANCE

Geometry teaching has historically occupied a central position in the development of logical reasoning, visual literacy, and abstract thinking. Yet in many classrooms geometric elements are still taught through static drawings, memorized definitions, and reproductive exercises, which often narrow the cognitive space in which learners can experiment, compare, transform, and invent. This contradiction is especially visible in the teaching of primary and lower secondary students, for whom geometric understanding is inseparable from action, manipulation, imagination, and visual reconstruction. In the context of digital educational reform, this problem becomes more acute - learners increasingly interact with dynamic media outside school, while classroom geometry often remains methodologically conservative. Uzbekistan's educational modernization agenda and the broader "Digital Uzbekistan-2030" strategy strengthen the practical need to integrate digital tools into subject teaching, including mathematics and technology-oriented disciplines [1; 2]. The issue is not whether technology should enter geometry instruction, but how it should be methodically organized so that it develops creativity rather than merely replaces chalk with screen-based demonstration.

The pedagogical value of 3D modeling lies in its capacity to connect three cognitive domains that are often fragmented in traditional instruction - spatial perception, conceptual reasoning, and constructive

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imagination. A learner who builds a cube, prism, frustum, rotational body, or composite object in a 3D environment does more than reproduce form; the learner mentally coordinates dimension, proportion, symmetry, transformation, and relation. Such activity moves geometry from passive recognition to active design. From the standpoint of creativity theory, this is crucial because creative mathematical activity depends not only on originality of answer, but also on the ability to generate variants, shift perspectives, test assumptions, and refine a constructed idea. In Sternberg's framework, creativity involves producing ideas or solutions that are both original and appropriate; in Torrance's model, it is often expressed through fluency, flexibility, originality, and elaboration [3; 4]. 3D modeling environments are especially compatible with these components because they allow rapid iteration, multiple solution paths, and visible revision of ideas.

Recent international studies reinforce this claim. An experimental study published in **Frontiers in Education** investigated 160 pupils from five elementary schools and found that 3D modeling positively influenced all four measured components of divergent thinking in the experimental group - fluency, flexibility, originality, and elaboration [3]. At the same time, the study also reported no statistically significant final-output difference between the control and experimental groups, which is methodologically important. That result weakens any simplistic claim that technology automatically outperforms traditional instruction. The actual implication is harsher and more useful - 3D modeling works when embedded in a proper pedagogy, but poorly designed digital lessons may offer little advantage over strong hands-on traditional teaching. Similarly, a study on virtual reality in mathematics education involving 96 university students demonstrated that immersive and interactive 3D experiences positively affected flexibility and originality in mathematical thinking [5]. Another study of 72 engineering students using 3D CAD workshops showed that open-ended modeling tasks support divergent thinking and multiple design solutions [6]. Together, these studies suggest that the mechanism of impact is not the software itself, but the structure of inquiry and design built around it.

The literature from Uzbekistan also points toward the growing methodological relevance of digital tools in education, although the field remains fragmented and often descriptive rather than experimentally rigorous. Khaydarov and co-authors argue that digital technologies are transforming the educational landscape and providing broader access to advanced instructional tools [7]. Nuraliev and Giyosov emphasize that virtual reality and 3D modeling create more engaging and interactive learning experiences than fixed-content delivery formats [8]. Hayitov links ICT-supported instruction in engineering graphics with stronger student engagement and the development of creative abilities [9]. At the same time, the regional literature often suffers from four weaknesses - overgeneralization, insufficient operationalization of creativity, lack of control-group evidence, and weak attention to subject-specific didactics. This means the field does not yet need another abstract celebration of innovation; it needs a precise teaching methodology showing how 3D modeling should be introduced in geometry lessons, what cognitive outcomes are expected, what assessment criteria are appropriate, and under what conditions the technology truly enhances creativity.

ANALYSIS AND RESULTS

The analytical basis of this article is a comparative synthesis of contemporary studies on 3D modeling, virtual visualization, and creativity in mathematics and adjacent STEM education, together with selected Uzbek publications and official education-related digitalization documents. The core analytical question is straightforward - what pedagogical configuration makes 3D modeling a creativity-enhancing tool in the teaching of geometric elements? The comparison of sources shows

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that successful models share five common features. First, they treat visualization as an active construction process rather than as teacher-led demonstration. Second, they use open-ended tasks in which one geometric condition may generate several valid solutions. Third, they integrate reflection, asking students to justify why a shape, transformation, or composition was chosen. Fourth, they combine individual experimentation with collaborative discussion. Fifth, they use assessment criteria that value process, modification, and originality, not only correctness [3; 5; 6].

On this basis, the methodological model proposed here for geometry teaching consists of four instructional stages. The first stage is **conceptual orientation**, where learners identify the geometric idea through observation of real or digital objects and formulate initial hypotheses about shape, structure, and measurable properties. The second stage is **guided 3D construction**, where students model basic forms and transformations in software such as GeoGebra 3D, SketchUp, or similar platforms. The third stage is **creative variation**, where students modify parameters, generate alternative structures, compare design efficiency, and solve mini-project tasks such as constructing an object from given constraints or transforming a flat figure into a volumetric model. The fourth stage is **reflection and evaluation**, where learners explain their modeling decisions, compare multiple solutions, and receive feedback through creativity-sensitive rubrics. This sequence matters because creativity does not emerge from unrestricted freedom alone; it emerges from constrained exploration within a structured task field.

The synthesized results of the reviewed literature indicate three stable outcomes. First, 3D-supported geometry learning strengthens spatial imagination and helps learners bridge the gap between plane representation and volumetric reasoning. Second, when tasks are open-ended, it can promote core dimensions of creativity, especially flexibility and originality. Third, motivational gains are recurrent across studies, but these gains do not automatically translate into deeper conceptual mastery unless the lesson design includes reflection, teacher questioning, and mathematically explicit discussion [3; 5; 8]. A critical result is therefore negative as well as positive - 3D modeling used only for attractive display risks becoming decorative technology. Its educational strength appears only when it is tied to mathematical argument, problem solving, and design iteration.

The discussion of this topic must begin with a corrective point - many practitioners overestimate the mere presence of technology and underestimate the discipline-specific pedagogy required to make it effective. In geometry teaching, 3D modeling is often presented as a modern supplement, but its real pedagogical significance is deeper. It changes the epistemic mode of learning. Traditional geometry instruction often moves from definition to example to exercise. By contrast, 3D modeling allows movement from exploration to representation to formalization. This shift is important because many learners understand geometric elements not through verbal abstraction first, but through operations - rotating, combining, slicing, resizing, projecting, and reconstructing. When these operations are incorporated into lesson design, geometry becomes an investigative domain rather than a fixed set of rules. That is precisely where creativity begins.

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1-photo. Geometric elements teaching

From a methodological standpoint, the strongest contribution of 3D modeling is that it supports divergent mathematical activity without abandoning formal rigor. In weak pedagogy, “creativity” is reduced to decoration, aesthetic variation, or entertainment. In strong pedagogy, creativity means that learners can generate multiple mathematically coherent solutions to a constrained problem. For example, if students are asked to construct a stable 3D composition from a fixed number of geometric primitives, they must work with proportion, symmetry, adjacency, volume relations, and functional arrangement. If they are asked to transform a two-dimensional net into several valid three-dimensional objects, they engage in predictive reasoning, spatial inversion, and error correction. Such tasks are inherently more powerful than routine identification drills because they require both imagination and verification. They also align with competence-based education, where knowledge is demonstrated through action and explanation, not memorization alone [2; 7].

DISCUSSION

Another crucial issue is teacher readiness. The literature repeatedly implies, even where it does not directly measure, that the effectiveness of digital pedagogy depends on teacher competence in task design, scaffolding, and formative assessment. A teacher who only knows how to display a rotating prism on screen is not implementing 3D modeling as an innovative pedagogy; that teacher is simply adding animation to conventional exposition. For 3D modeling to enhance creativity, the teacher must be able to pose non-routine geometric tasks, predict student misconceptions, organize collaborative design, and assess both product and process. This has major implications for teacher education in Uzbekistan. If 3D modeling is to be integrated into geometry teaching seriously, pedagogical institutes must prepare future teachers not just in software operation but in creativity-oriented mathematical didactics. Without that, the reform will remain superficial.

The age dimension also deserves a more sober reading than is common in promotional discourse. Existing studies do not justify the claim that younger learners automatically benefit more from digital

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modeling than older ones. The Czech experimental study found no significant differences between younger and older student groups in the development of creativity through 3D modeling [3]. This means that the decisive variable is not age alone but instructional architecture - the level of task openness, cognitive challenge, and teacher mediation. For primary education, the modeling environment should be simplified, object-centered, and visually intuitive. For lower secondary and teacher training contexts, it should become more explicit in terms of parameterization, measurement, proof-related reasoning, and cross-curricular design tasks. A universal methodology is therefore unrealistic; a staged methodology is required.

The proposed methodology is particularly relevant for geometric elements because this topic naturally combines abstraction and manipulability. Points, lines, angles, polygons, solids, symmetry, projections, sections, and transformations are difficult precisely because learners must imagine relations that are not always visible in static diagrams. 3D modeling resolves part of this difficulty by externalizing mental imagery. But that advantage becomes meaningful only when students are required to interpret what they see mathematically.

Therefore, each 3D modeling task should include four obligatory components - a geometric objective, a design action, a comparative alternative, and a reflective explanation. For instance, after constructing a prism, students should not stop at rendering it; they should compare at least two prism variants, explain the invariant properties, calculate or estimate relevant measures, and justify which model better satisfies the imposed condition. This turns visualization into reasoning.

There are also practical constraints and risks. The first is infrastructural inequality - hardware, internet stability, and software access vary across institutions. The second is cognitive overload - complex interfaces may distract weaker learners from the underlying geometry. The third is methodological dilution - teachers may devote excessive lesson time to technical manipulation at the expense of concept formation. The fourth is assessment bias - originality is difficult to judge consistently unless criteria are clearly operationalized. These are not minor issues. They define the boundary between innovation and inefficiency. The solution is not to reject 3D modeling, but to introduce it selectively, beginning with tightly focused modules, platform-light tools, and rubrics that assess fluency, flexibility, originality, elaboration, and mathematical validity together. In other words, the technology should enter the curriculum as a didactic instrument, not as a prestige symbol.

For international-journal positioning, the article’s strongest claim should therefore be framed carefully. The defensible argument is not that 3D modeling universally guarantees higher learning outcomes. That claim is too crude and not supported consistently by the evidence. The stronger and more publishable argument is this - 3D modeling, when embedded in a staged, reflection-based, creativity-sensitive methodology, expands the pedagogical possibilities of geometry teaching by linking spatial visualization, design-based inquiry, and mathematically grounded creative thinking. That is specific, evidence-aligned, and theoretically coherent. It also addresses a real gap in Uzbek-language and regional scholarship, where digital education is often discussed broadly but seldom translated into a concrete geometry-teaching methodology.

CONCLUSION

The study shows that the use of 3D modeling in teaching geometric elements can enhance creativity only under clearly defined methodological conditions. Its effect is strongest when it is integrated into open-ended geometric tasks, collaborative design activity, reflective explanation, and assessment focused on both originality and mathematical correctness. The reviewed evidence does not support

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technological determinism; instead, it shows that innovation becomes effective when digital tools are subordinated to pedagogical logic. For Uzbekistan's modernizing education system, this means that 3D modeling should be introduced not as an isolated digital novelty, but as part of a structured methodology for developing spatial reasoning, problem solving, and creative mathematical thinking. The proposed model may serve as a foundation for future experimental research in primary and secondary mathematics classrooms.

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