

Methodology for developing students' spatial imagination through the use of 3D modeling elements in fine arts lessons

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Abstract: This article examines the scientific and methodological foundations of developing students' spatial imagination through the use of 3D modeling elements in the process of fine arts education. The rapid introduction of modern digital technologies into the educational process requires new approaches to the content, tools, and methods of teaching fine arts. In particular, the ability to imagine a three-dimensional object based on a two-dimensional image, understand its shape, volume, proportions, spatial position, and relationships between light and shadow plays an important role in developing students' visual-spatial thinking. The study explains the concept of 3D modeling from the perspective of fine arts education and identifies the main components of spatial imagination, including spatial perception, mental rotation, spatial transformation of forms, understanding proportional relationships, perceiving an object from different viewpoints, and the ability to move from a two-dimensional image to a three-dimensional model. An analysis of the scientific literature demonstrates that the use of 3D modeling and spatial visualization tools has the potential to develop students' spatial skills. At the same time, educational effectiveness depends not simply on the technology itself, but on the pedagogically appropriate organization of its use. The article proposes a staged methodological model for integrating 3D modeling elements into fine arts lessons, together with scientific hypotheses, pedagogical conditions, assessment criteria, and mechanisms for experimental verification.

Keywords: fine arts, 3D modeling, spatial imagination, spatial thinking, visualization, digital education, composition, form, volume, proportion, mental rotation, digital modeling, pedagogical technology

Introduction. Today, the digitalization of the educational process requires not only the transformation of educational materials into electronic formats but also a reconsideration of how students perceive, process, imagine, and apply knowledge in practical activities. In particular, the use of digital technologies in fine arts education does not negate traditional work with pencils, paints, paper, and volumetric materials; rather, it complements them with new visual and interactive opportunities. One of the important objectives of fine arts education is to develop students' ability to observe reality, analyze it, understand form and volume, perceive spatial relationships, and

transform observed objects into artistic images. Such skills are developed not merely by viewing a finished image but through the active analysis of an object's structure and the process of mentally representing it from different viewpoints. Spatial imagination is of fundamental importance in such areas of fine arts as drawing, painting, composition, sculpture, applied arts, architectural graphics, and design. For example, if a student cannot simultaneously understand the front, upper, and side surfaces of a simple cube, they may experience difficulties in constructing perspective images correctly, analyzing complex forms, or depicting an object from different viewpoints. Therefore, many types of visual activity require students to establish a mental connection between a two-dimensional image and a real three-dimensional object.

In traditional fine arts lessons, such skills are often developed through exercises involving observation of geometric solids, drawing from nature, perspective representation, construction of paper models, and shaping forms from clay or plasticine. Although these methods are pedagogically important, they have certain limitations. For example, a student may only be able to see an object from an available physical viewpoint, may not be able to directly observe its internal structure, or may have limited opportunities to modify the model quickly. 3D modeling technology provides new possibilities for addressing some of these limitations. With the help of a digital three-dimensional model, students can rotate an object, enlarge or reduce it, view it from different angles, separate and recombine its components, and observe transformations of its form. Such activity requires active visual manipulation rather than simple observation.

Scientific literature has paid particular attention to the relationship between 3D modeling and spatial abilities. For example, a 2025 systematic review concerning 3D modeling and 3D printing in teacher education noted that these technologies can enhance practical skills, active participation, and learning experiences. At the same time, resources, time, and teachers' pedagogical preparation were identified as important challenges in integrating such technologies into education. Other studies devoted to the use of 3D modeling have specifically examined the development of abilities such as mental rotation and spatial visualization. This question is associated not merely with the availability of technology but with the pedagogical mechanism of its use. The introduction of any digital tool into a lesson does not automatically lead to an improvement in educational quality. The important issues are what task the student performs with the 3D model, what type of thinking is activated through its use, how the student explains their activity, and how the result is evaluated.

Research Objective and Scientific Hypothesis. The main objective of the research is to develop a methodological system aimed at developing students' spatial imagination through the use of 3D modeling elements in fine arts lessons and to

identify its scientific and pedagogical foundations. This general objective makes it possible to propose the following scientific hypothesis:

If 3D modeling elements are used in fine arts lessons in accordance with students' age and level of preparation, through a gradual system of visual-practical tasks and in integration with traditional visual activities, then the development of students' spatial imagination, their ability to imagine objects from different viewpoints, mentally rotate forms, understand volume and proportion, and move from two-dimensional images to three-dimensional models will be enhanced. Scientific and Methodological Essence of the Concept of Spatial Imagination Spatial imagination is the ability of an individual to mentally represent the location, shape, volume, direction, relationships, and transformations of objects and phenomena in space. This concept is considerably broader than simple visual perception, as it involves interconnected processes such as perception, memory, imagination, analysis, comparison, and mental manipulation. The third component is spatial transformation. Students mentally anticipate how a form will appear as a result of cutting, stretching, compressing, dividing, or combining it with other geometric elements.

The Role of 3D Modeling in Fine Arts Education. Considering 3D modeling merely as a technical activity in the educational process would constitute a one-sided approach. From the perspective of fine arts, a 3D model is a tool for studying form, volume, rhythm, proportion, composition, space, and visual imagery. For example, when creating a composition from simple geometric solids, a student may arrange elements such as cubes, cylinders, spheres, and cones in different proportions. The student can then change the camera position and examine how the composition appears from different viewpoints. In this way, composition is understood not merely as a frontal plane but as a system existing in space. In fine arts lessons, 3D modeling can be integrated into the following content areas: geometric shapes and solids; still-life composition; architectural forms; interior and exterior design; sculpture; applied art objects; ornaments and patterns; simplified models of animal and human anatomy; models and design; and landscape composition.

An important methodological principle in this integration is that 3D modeling should not replace fine arts. Rather, the digital model should be used as a means of preparation, analysis, and visual experience for real artistic activity. For example, a student may create a simple still-life composition in a 3D program. At the next stage, the student depicts the same composition on paper using a pencil. In this process, the 3D model allows the student to examine the relative arrangement of objects, perspective reductions, and overall compositional proportions. Subsequently, the student may be asked to create a drawing from nature or from memory without using the program. At this point, technological activity begins to transform into artistic activity.

Research Methodology. A comprehensive methodological approach is appropriate for the scientific investigation of this topic. The theoretical foundation of the research consists of activity-based, constructivist, competency-based, and visual-cognitive approaches. From a constructivist perspective, the student is regarded not as a passive recipient of ready-made knowledge but as an active subject who constructs knowledge through activity. 3D modeling requires precisely such activity: an object is selected, its components are analyzed, a model is created, errors are identified, and the model is modified. Within an activity-based approach, the student's level of knowledge is determined not only through theoretical responses but also through practical actions. Therefore, the research should assess not only the student's ability to recognize a ready-made 3D model but also their ability to independently create a model, modify it, and explain the reasons for those modifications. The following methods can be used in the research: analysis of scientific and methodological literature; pedagogical observation; content analysis of students' works; pedagogical experiment; testing; interviews; practical tasks; expert assessment; and statistical comparison.

To measure spatial ability, standardized tasks or tasks adapted to the objectives of the study can be used to assess mental rotation, spatial visualization, and identification of objects from different viewpoints. The validity of the tests and their suitability for the relevant age group should be examined separately. The relationship between 3D modeling and spatial ability has also been investigated empirically in scientific literature. In particular, one study involving 30 hours of SketchUp-based training observed positive changes in the spatial visualization of lower secondary school students. Another study associated 3D modeling activities conducted using Tinkercad or physical models with the development of spatial abilities among prospective teachers. These findings should not be directly transferred to the context of fine arts education; however, they provide a theoretical and empirical basis for this methodological direction.

Integration of 3D Modeling with Other Types of Fine Arts Activities. The methodological effectiveness of 3D modeling can be enhanced by connecting it with other types of visual and artistic activities. In drawing, a 3D model can be used to determine the constructive structure of an object. Students can rotate the model and observe its principal axes, perspective directions, and volume. They then represent the model on paper. In painting, the influence of light and shadow on the form of an object can be demonstrated by placing different light sources around a 3D model. However, students should also study separately the material and expressive characteristics of traditional painting.

Conclusion. The use of 3D modeling in fine arts education has broader pedagogical implications than simply introducing digital technology into the

classroom. Its main potential lies in enabling students not only to observe an object but also to actively manipulate it in space, analyze it from different viewpoints, separate and recombine its components, and observe its transformations. In future empirical studies, it is advisable to form experimental and control groups, conduct initial and final diagnostics, measure mental rotation, spatial visualization, 2D-3D transfer, compositional analysis, and the quality of artistic representation, and determine the reliability of changes through statistical analysis. In particular, controlling students' initial level of spatial ability is an important methodological requirement for determining the actual effect of the proposed methodology. Thus, 3D modeling should be regarded in fine arts education not as a replacement for traditional methods but as a tool that expands their possibilities. Its pedagogical value lies not in the student's ability merely to create a model on a computer, but in their deeper understanding of the relationships among form, volume, space, proportion, viewpoint, composition, and representation during the modeling process.

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