PEDAGOGICAL APPROACHES FOR DEVELOPING STUDENTS' THREE-DIMENSIONAL THINKING

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Abstract

The practice of fostering visual thinking and the ability to create three-dimensional imagery in students is a crucial component of architectural design education. This study emphasized the importance of enhancing students' creative thinking skills and their capability to devise and execute spatial solutions. To achieve this, a design studio was established for first-year university students, where they examined current conditions and utilized design tools and visual elements to depict space in three dimensions.

The one-semester training program, developed and implemented within the design studio, focused on the perception of three-dimensional scenes, considering spatial organization, movement, orientation, the arrangement of basic visual elements, and the application of light and color. Students were actively engaged in expressing their concepts through three-dimensional space representations.

The findings demonstrated that using space as a catalyst for creative thinking and as a method for studying design, which underscores the significance of visual communication, can markedly enhance students' creative thinking abilities. Consequently, this approach significantly boosts the effectiveness of the creative design processes.

Keywords: Teaching methods, three-dimensional thinking, spatial perception**,** design education, visual thinking, creative development

Introduction. Spatial thinking transcends the mere visualization and manipulation of three-dimensional objects; it also enhances students' abilities in abstraction, synthesis of elements, and structural analysis. This cognitive skill is pivotal in discerning primary elements from secondary ones, which is essential in the design process. The article delves into how spatial thinking influences students' success and creativity during their educational journey and subsequent practical endeavors. The research highlights that honing this ability not only fosters creativity but also augments analytical skills and elevates the overall professional competency of design students.

Human development encompasses multiple stages, each contributing to various facets of intelligence and cognitive skills, including spatial thinking. Irrespective of innate capabilities, the development of spatial thinking is not significantly constrained by initial intelligence levels. This critical skill can and should be nurtured, independent of a person's starting point.

The significance of cultivating spatial thinking in students is particularly pronounced in design education. The field of design demands creativity coupled with spatial perception and modelling capabilities, enabling future designers to effectively tackle challenges related to the creation of three-dimensional objects and structures. Throughout design education, considerable emphasis is placed on the use of visual aids and materials, which are instrumental in developing these skills. This approach not only bolsters creativity but also sharpens analytical proficiency and overall professional preparedness among design students.

Problems and approaches. The cultivation of spatial thinking in students encounters several challenges. Firstly, there is a notable lack of systematic methodologies and techniques specifically designed to effectively enhance this cognitive skill. Secondly, resources are often limited, including access to contemporary tools and technologies such as 3D modelling software and virtual reality platforms. Psychological barriers also contribute, as transitioning from two-dimensional to three-dimensional perception demands significant effort and time.

Despite these obstacles, several proven strategies can help mitigate these difficulties. The implementation of visual aids and materials, such as graphic diagrams, drawings, and models, facilitates students' comprehension and visualization of three-dimensional structures. Additionally, interactive technologies like virtual reality and 3D modelling software offer substantial opportunities for advancing spatial thinking.

Types of thinking. In analyzing various cognitive styles, the significance of spatial thinking as a crucial element in the educational framework for future designers is emphasized. Spatial thinking enables the detailed and three-dimensional visualization of objects, encompassing the following abilities:

- Distinguishing essential elements from less critical ones;
- Integrating diverse elements into a cohesive whole;
- Abstracting from specific details to perceive the overall context;
- Representing the structure of objects within space;
- Concrete realization of ideas and concepts.

This mindset is integral to the development of future designers, as it supports the creation and manipulation of three-dimensional objects and structures, thereby enhancing both their creative and analytical capabilities.

Impact of spatial thinking on problem-solving and creativity. These cognitive abilities are crucial for addressing a wide range of theoretical and practical problems. The article explores the profound influence of spatial thinking on the success and creativity of students throughout their education and practical aspirations in design. The development of spatial thinking enhances both analytical and creative skills, making it an invaluable tool for students, particularly in the design field.

Spatial thinking not only aids students in visualizing and constructing three-dimensional models but also fosters the development of innovative solutions, a critical aspect of professional training. By honing these skills, students can better integrate elements, and abstract concepts, and create comprehensive and practical designs, ultimately leading to improved problem-solving abilities and heightened creativity. This cognitive approach enables future designers to navigate complex spatial challenges and contribute effectively to their field.

Research of methods. The article examines the study of Tung Y-H and Chang C-Y in "How three-dimensional sketching environments affect spatial thinking: Virtual reality research using functional magnetic resonance imaging", which analyzes differences in cognitive processes when using 2D and 3D sketching tools. The study involved 20 students with experience in painting landscapes by hand. Their brain activity was compared while using 2D tools (iPad Pro and Apple Pencil) and 3D tools (Oculus Quest VR). Significant differences were found in the activation of different brain regions when drawing in 2D and 3D environments, especially in areas such as the right medial temporal gyrus, both sides of the parietal lobe and the left medial occipital gyrus. Visual-spatial functions were also investigated: in which the use of 3D tools in virtual reality activated more visual-spatial brain functions compared to 2D tools. Differences in brain activation were noted when performing tasks related to drawing lines, and geometric and naturalistic objects, which highlights the enhanced spatial perception and navigation capabilities provided by 3D tools. The study highlights the potential of immersive virtual reality tools to improve design-related processes and spatial thinking. This makes such tools valuable for educational practices in the field of design, as they help to improve students' spatial perception and creative abilities.[1]

Exploration of spatial thinking in design education. In the research by Ya. A. Lugin and O. M. Koshelev titled "The Development of Spatial Thinking Among Design Students," the authors highlight the importance of defining the concept of space in design to understand the development of spatial thinking. They identify two primary approaches: Objective space: This approach views space as a physical reality, referring to the arrangement of simultaneously existing real objects.

Subjective space: This approach considers space as a way of organizing the world related to cultural and artistic perspectives. It emphasizes that everyone, influenced by their cultural context, has a unique understanding of the world [3].

Similarly, Park, E.J., and Kim, M.J., in their study "Visual communication for students' creative thinking in the design studio: translating filmic spaces into spatial design," stress the importance of nurturing creative thinking within design education, especially in architectural design [2]. They argue that traditional design education often relied on subjective methods rather than systematic academic approaches, potentially hindering the development of creativity.

Practical application in education. The study describes a visual design studio for first-year architecture students at a university in Korea, which integrates cinematic elements into architectural design. This innovative approach helps students transform cinematic elements into spatial design, thereby enhancing their creative thinking. Tasks in this studio focus on stimulating creativity rather than merely addressing functional aspects, reflecting a shift in educational environments to foster creative development.

This method aims to provide students with alternative ways to cultivate creative thinking, thus preparing them to tackle complex and multidisciplinary challenges in their future professional careers.

The design studio fosters a procedural exploration of design challenges, emphasizing the importance of rethinking problems and employing various representation methods throughout the design process. This approach facilitates a deeper understanding of the relationships between cinema and real space, the development of new architectural expression methods, and the overall enhancement of creativity in architectural education.

Three-dimensional thinking in design education core competence in design careers**:** Three-dimensional thinking is essential for a successful career in design, enabling designers to visualize and create objects within space, comprehend their interaction with the environment, and propose innovative solutions. Developing this skill in design students requires a comprehensive approach that combines theoretical learning, practical assignments, and the use of modern technologies.

Introducing students to three-dimensional thinking involves familiarizing them with spatial thinking and visualization. This includes understanding the necessity of considering objects and processes in three dimensions and recognizing the importance of three-dimensional perspectives in various fields. Early education on this topic helps students grasp the fundamental principles of three-dimensional thinking, which they will apply in advanced studies and practical work.

Three-dimensional thinking is crucial in creating visually appealing and functional products. It enables designers to envision the final product in real space, considering all its aspects and interactions with the surrounding environment. This skill aids in producing more precise and detailed projects, improving the quality of final products and enhancing their market competitiveness.

The psychological and cognitive aspects of three-dimensional thinking encompass spatial imagination, visual-spatial memory, and cognitive flexibility. Developing these skills enhances the learning and practical performance of designers. Research indicates that regular exercise and training can significantly improve these cognitive abilities, positively impacting three-dimensional thinking.

Teaching visualization and spatial thinking involves various techniques such as drawing, sculpting, and modeling. These practices help students develop observation and visualization skills and improve their understanding of proportions and perspective. Regular practical sessions and exercises foster the development of spatial imagination and visual-spatial memory, which are essential for effective design education.

Designing and modeling in three-dimensional space are crucial aspects of educating design students. This includes using various materials and tools to create prototypes and models. Working with physical objects helps students better understand three-dimensional structures and their interactions. Additionally, the use of computer programs to create digital models and animations allows students to develop skills in working with modern technologies.

The role of technology in the development of three-dimensional thinking is significant. Modern computer programs such as AutoCAD, 3ds Max, Blender, and others provide powerful tools for creating and visualizing three-dimensional models. Learning these programs enables students to create sophisticated digital prototypes and animations. Virtual reality (VR) and augmented reality (AR) open up new opportunities for learning and practice, allowing students to immerse themselves in and interact with three-dimensional spaces. Furthermore, 3D printing provides students with the chance to create physical models of their projects, aiding in the visualization and testing of ideas in the real world, thereby improving their understanding of the shape and functionality of objects.

Modern technologies contribute to the development of students' three-dimensional imagination. However, they can also interfere with the independent formation of consciousness and intelligence. While technological capabilities speed up the learning process, they can ultimately slow down the development of visual thinking. Technology supports students' thinking and imagination by facilitating modeling and self-expression processes, but overuse can lead to dependence and limit independent development.

Howard Gardner is known for his theory of multiple intelligences, which revolutionized the understanding of intelligence and learning processes. Gardner argued that traditional IQ tests treat intellectual abilities too narrowly, emphasizing that people have many different types of intelligence. In his theory, he identified eight main types of intelligence: linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic[5].

Gardner emphasized the importance of recognizing and developing these diverse intellectual abilities in educational settings to create a comprehensive and inclusive learning environment. For instance, spatial intelligence, which involves the capacity to visualize and manipulate objects in three-dimensional space, is crucial for fields such as architecture, engineering, and design.

To foster three-dimensional thinking in students, Gardner's theory advocates for teaching methods that include hands-on projects, interactive simulations, and visual arts, engaging students in spatially oriented tasks [6].

While Gardner's theory has significantly influenced educational practice by promoting an individualized approach to learning, it has also faced criticism for its lack of empirical support and the difficulty of clearly distinguishing each type of intelligence from broader cognitive abilities. Despite this, Gardner's ideas continue to shape modern educational strategies, particularly in enhancing creativity and problem-solving skills across various disciplines.

According to Gardner, individuals possess multiple intelligences: "As unique beings, we humans are endowed with a range of relatively autonomous intelligence "[4, c. 25].

An experiment was conducted among first-year design students to assess their knowledge and skills required by the course. It included tasks aimed at evaluating their mathematical thinking, drawing skills, and ability to complete assigned projects.

The primary goal of the design studio was to develop critical thinking, design skills, and the ability to think in both 2D and 3D. The preparation process for the tasks was organized around a sequence of four design studies, which served as the main tool for achieving the course objectives. Each project focused on a set of tasks aimed at developing conceptual, technical, and analytical skills. Various methodological approaches were used, such as two- and three-dimensional composition, design and modeling, form generation processes, transformation and conversion, analytical and comparative studies, and the study of the relationship between architectural space and visual elements.

Students were expected to analyze and synthesize information in the context of other subjects, identify their strengths and interests, and then go beyond the minimum course requirements. These assignments helped students develop creative thinking and improve design processes, allowing them to take risks and experiment with new ideas and approaches.

Course objectives and learning outcomes:

1. Skill development: Students should develop the conceptual, technical, critical, and analytical skills necessary to shape, develop, evaluate, and express a coherent design proposal. This includes the ability to generate ideas, bring them to life, and then critically assess their alignment with the set objectives.

2. Questioning and conclusions: Students should learn to ask thoughtful and precise questions, draw justified conclusions, and verify the compliance of their work with established criteria and standards. This is important for both analyzing existing projects and developing new proposals.

3. Effective management of design elements: The course aims to develop skills in managing the fundamental elements of architecture and design, such as form, space, structure, order, proportion, mass, surface,

light, program, space, human body scale, and material properties. Students should learn to intuitively and effectively manage these elements.

4. Application of architectural elements: Students should be able to apply the basic elements of architecture and design to create spaces with clear and appropriate area relationships. This includes creating harmonious and functional spaces that meet specified requirements.

5. Expression of design ideas: At each stage of the design process, students should be able to express the concept and ideas of the project orally, as well as through sketches and models.

This contributes to the development of both two-dimensional and three-dimensional thinking [24]. The primary outcomes of the course pertain to the following aspects:

1. Theory, precedents, and design methods: Students are expected to master theoretical foundations, study existing precedents, and learn design methods.

2. Design skills: The course emphasizes the development of practical design skills.

3. Design tools: Proficiency in various tools used in the design process is essential.

4. Software analysis: Students should be able to analyze and use specialized design software effectively.

5. Design context: Understanding the context in which design is implemented and the ability to integrate design into existing environments is crucial.

6. Project documentation: The ability to create detailed project documentation is an important outcome.

7. Critical thinking and communication: Developing critical thinking and communication skills is a key focus.

8. Cultural diversity and global perspectives: understanding and considering cultural diversity and global perspectives in the learning process is essential.

Course structure: To achieve these goals, the course includes 180 hours of classes (6 credits), consisting of theoretical and practical sessions designed for the first semester. The main theme of the final project is the design of an exhibition environment, the development of a spatial solution, and the application of visual elements in space according to the concept [Fig.1].

This approach promotes the comprehensive development of students, preparing them to tackle complex tasks in the field of architecture and design. Architectural space and its visual realization reach their pinnacle when their construction demonstrates a unique interplay of parts, creating a sense of enchantment. In such a scenario, the construction becomes an effective art form, evoking a sense of mystery among viewers. Using the same elements in different combinations, however, can result in the loss of this magic of form. Thus, knowledge of the structure of architectural form and its space is essential for achieving perfection. Each culture addresses this task in its unique way.

To address such issues, we have transitioned from descriptive analysis to structural analysis. The artistic language of architectural form and its spatial resolution are among the most complex aspects, and difficult to describe analytically. Therefore, presenting the intended concept, realizing the idea, and developing three-dimensional thinking in students require a special approach [23].

Course topics

- **Topic 1: Introduction to the subject. Course requirements. introduction to literature. Introduction to the topic. Overview and use of technology in visual design.** This topic introduces students to the course, outlining its requirements and expectations. It provides an overview of key literature and resources, highlighting the primary concepts in visual design. Students will also receive information on the software tools they will be using and how to apply them to complete assignments.
- **Topic 2: Research and concepts. Foundations of research. Linear thinking/Lateral thinking. Visualization of ideas.** This topic delves into research methodologies and conceptual frameworks. It contrasts linear and lateral thinking approaches, helping students understand different ways of visualizing and developing ideas.
- **Topic 3: Elements in design. Introduction to design elements through projects.** Students will explore design elements through practical projects, such as creating color schemes using graphic software. They will learn about the use of color, lines, shapes, space, and texture in design.
- **Topic 4: Elements of design. Fundamental elements in 2-D and their definitions. Theories of Image and text.** This topic covers the basic elements of 2-D design, including negative and positive space, void, line, plane, volume, form, size, and value. It also examines texture, pattern, and their significance in visual design.
- **Topic 5: Element of design: Light and Color. Definition and Importance of Color. Color associations and contrast.** Students will study the definition of color, its variations, and its importance in communication design. They will learn about lighting principles, calculating illumination levels, and understanding light intensity in spaces.
- **Topic 6: Principles of design 1.Design principles: composition, balance, saturation, emphasis, dominance, unification.** This topic introduces students to essential design principles that guide composition and visual balance.
- **Topic 7: Principles of design 2. Symmetry and asymmetry, proportions, scale, hierarchy, contrast.** Students will explore advanced design principles, including symmetry, asymmetry, proportions, scale, and the creation of visual hierarchies and contrast.
- **Topic 8: Visual elements in composition. Exploring visual elements in composition for visual expression.** This topic focuses on the arrangement and impact of visual elements in creating compelling compositions.
- **Topic 9: Group and system concepts. Hierarchy of elements in planes and space. Creating balance in constructive composition.** Students will learn about the grouping and systematization of design elements, understanding how to create balance and hierarchy in both two-dimensional planes and three-dimensional spaces.
- **Topic 10: Rules of spatial placement. Principles of element placement in space. Element significance and symmetry.** This topic covers the fundamental principles of placing elements within a space, including understanding element significance, force fields, and system symmetry in visual design.
- **Topic 11: From concept to visualization. Initial concepts and idea organization. Coordination and creation of visual series.** Students will learn how to translate initial concepts into visual designs, focusing on coordination, visual series creation, photography, and illustration.
- **Topic 12: Studio tools and skills. Software proficiency, page layouts, digital photography, image manipulation and computer illustration.** This topic emphasizes the technical skills required in the studio, including proficiency with design software, creating page layouts, digital photography, image manipulation, and computer illustration.
- **Topic 13: Visualization of design concepts. Space saturation and artistic solutions. Informative Space.** Students will study the visualization of design concepts, focusing on the artistic and informative aspects of space.
- **Topic 14: Content and form in space. Design model in space. Structural units and complexity of plastic elements.** This topic covers the integration of design models into spaces, examining structural units and the complexity of plastic elements.
- **Topic 15: Design concept of selected environment. Main and additional functions of zones. Functional unit division. Facades, walls, zone functions, compositional elements.** Students will develop a design concept for a selected environment, considering the main and additional functions of different zones, the division of zones into functional units, and the role of facades, walls, and compositional elements.

Fig. 1. *Syllabus of the course.*

This curriculum fosters a comprehensive development of students, preparing them for complex tasks in architecture and design. Understanding the interaction of architectural space and its visual representation is crucial for achieving excellence, as each culture approaches this task uniquely. By transitioning from descriptive to structural analysis, the course helps students present their ideas effectively and develop three-dimensional thinking skills.

The methodological foundation of the research is based on new knowledge about the nature of the artistic language of architecture. According to the theory, the artistic form of architecture should be considered not as a universal phenomenon but as a method of self-expression of a particular culture [7]. In this case, it is easier to determine the components of the artistic form in the architecture of a specific culture, the methods of their structuring, and the criteria for evaluation. It also becomes simpler to find answers to questions about the specifics of the artistic language of the architecture of a particular culture and the possibilities of influence by the methods of other cultures.

Comparing artistic methods of constructing architectural forms in parallel or opposite cultures, using different means and dramaturgical solutions, also becomes more accessible. This methodology has long been used in linguistics, where there are models of language structure that explain its functioning [22].

The form of expression of three-dimensional thinking and especially its creation in the imagination of space is a key skill for designers in their work. Spatial thinking is a type of mental activity that allows for the formation of the dimensional and spatial parameters of objects and ensures the functioning of all elements in the process of solving practical and theoretical problems. Bringing to life the three dimensions of any space in the imagination occurs through the constant transition from two-dimensional perception [18,14].

The main question is what methods to use for developing three-dimensional thinking in students. These methods include:

- Development of three-dimensional imagination through sketches.
- Creation of linear, planar, volumetric, and spatial compositions that imply three-dimensionality.
- Involvement of students in the process of creating compositions corresponding to each topic [25].
- Expression of the conceived idea through emotions and consciousness.
- Use of models for visualization and construction.
- Guiding creative thinking following the given task.

List of practical tasks [Fig. 2]:

Task 1: Creating a composition of lines. The aim of the task: to develop skills in working with lines as a key element of visual perception and to teach students to create effective compositions.

Task 1a: creating a composition of lines in space. The aim of the task: to develop skills in working with lines as an important visual element in interior design and to learn to create effective compositions.

Task 2: creating a composition of planes. The aim of the task: to develop students' skills in working with planes as an important element of visual design and to teach them to create interesting and balanced compositions. This task provides an opportunity for students to develop their skills in working with planes and experiment with various aspects of visual design, creating original and effective compositions.

Task 2a: creating a composition of planes in space. The aim of the task: to develop students' ability to transform two-dimensional compositions of planes into three-dimensional spatial compositions, enriching the visual experience and adding depth. This task allows students to experiment with transforming two-dimensional compositions into three-dimensional ones, developing their skills in creating spatial visual compositions.

Task 3: creating a composition of volumetric figures. The aim of the task: to develop students' ability to work with volumetric figures, forming compositions using three-dimensional elements. This task will help students develop their skills in working with volumetric forms, creating original and characteristic compositions using three-dimensional elements.

Task 3a: creating a volumetric-spatial composition from geometric figures. The aim of the task: to develop students' ability to transform compositions from volumetric figures into more complex three-dimensional spatial compositions, deepening the visual experience and adding elements of the surrounding space. This task allows students to delve into working with three-dimensional elements, transforming simple compositions from volumetric figures into complex three-dimensional works and expanding their visual perception.

Task 4: creating a spatial composition from lines, planes, and volumetric figures. The aim of the task: to develop students' skills in placing various geometric forms in three-dimensional space, enriching the composition and visual experience. This task allows students to experiment with different forms in three-dimensional space, creating a composition considering visual, spatial, and color aspects.

Task 4a: Skills in using visual elements in a given interior space.

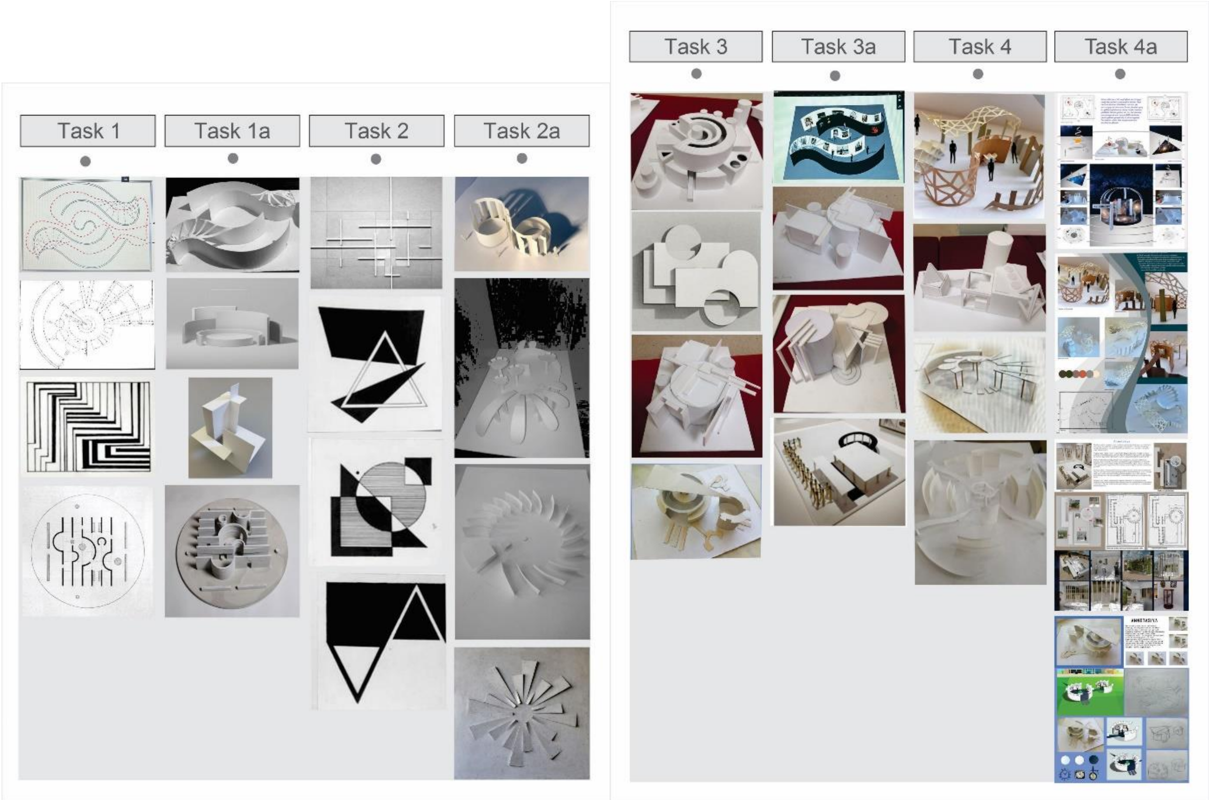

Fig. 2. Examples of students' work on the topic of assignments.

This method is based on the premise that questions arising in the world of art can serve as examples of solutions. Art, always one step ahead of science, constantly influences the development of creative thinking.

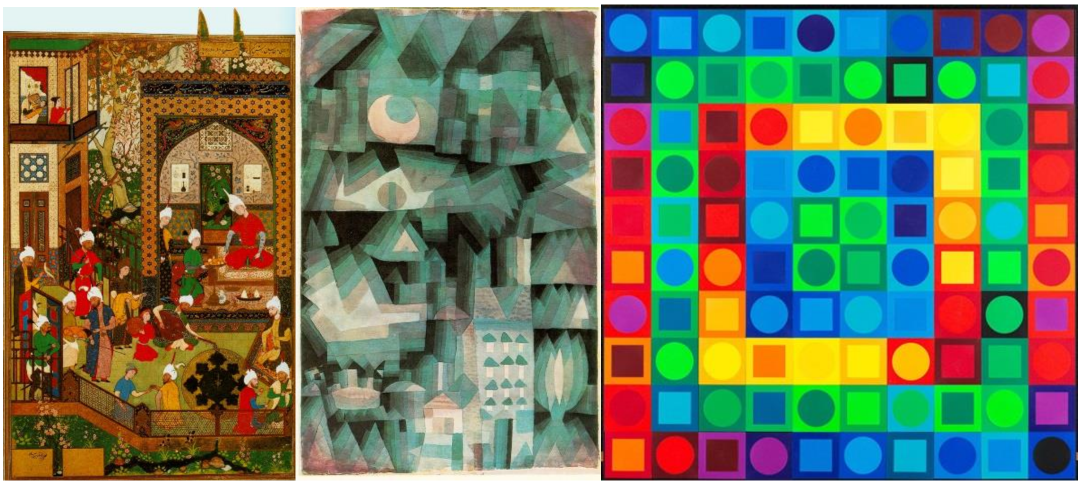

Fig.3. Creative expressions in art.a. Barbad Plays for Khusraw, 1539-43, British Library, London [12]; b. Dream City, Klee Paul,1921-22 [13]; c. Victor Vasarely, Planetary folklore No 1, 1969 [11].

Art, often associated with creativity, imagination, and aesthetic expression, and science, characterized by logic, observation, and empirical data, have a deep interconnection that transcends their apparent differences. Together, they form a symbiotic relationship that mutually enriches each other, expanding the boundaries of human understanding and creativity [8]. Both art and science are essentially methods of exploring the world: science seeks to understand and explain phenomena through careful observation, experiments, and analysis, while art explores the world through subjective interpretations, emotions, and sensory experiences.

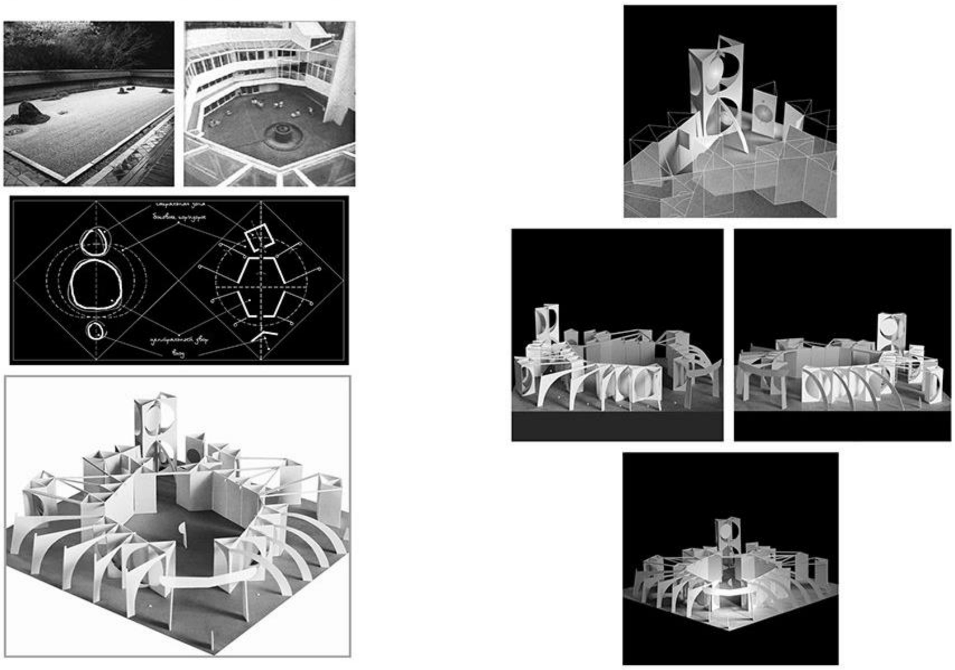

Fig.4.
The scientific model of spatial construction is based on methods and concepts that allow for the exploration and representation of complex spatial structures. It includes specific components and fragments that provide understanding and visualization of space. a. model of spatial structure; b. fragments of space visualization [7].

Nick Zangwill's research, "The Concept of Aesthetics," is dedicated to the nature and scope of aesthetic properties and judgments. Zangwill studies aesthetic experience, the characteristics that make an object aesthetically appealing or repulsive, and the criteria for making aesthetic judgments. He analyzes how aesthetic properties are related to the physical and formal characteristics of objects and how they interact with human perception and cultural context [9].

Art is the expression or application of human creative abilities and imagination through various forms such as painting, sculpture, music, theater, literature, cinema, and much more. It encompasses a wide range of disciplines and forms of expression, reflecting subjective interpretations, emotions, aesthetics, and cultural context. Artistic works are often created to evoke feelings, provoke thoughts, convey ideas or experiences, giving people the opportunity to explore and express their perception of the world. The goal of art is to inspire, evoke emotions and convey ideas through subjective expression, contributing to cultural comprehension, empathy, and social change [17].

Art and science, despite their differences, intersect: art helps convey scientific concepts to the general public, and science inspires the creation of new artistic works. Both fields contribute to our intellectual and cultural development, enriching life and expanding our perspectives. Developing three-dimensional thinking in students through art and science includes developing skills such as creative and analytical thinking, problem-solving, critical thinking, visualization, and communication [Fig. 4].

Based on the methods used in art and science, which foster creative inspiration, visualization, observation, experimentation, communication, and aesthetic perception, key points can be highlighted:

- Art draws inspiration from scientific concepts, embodying them in artistic works [Fig. 3].
- Visualization and representation are crucial in both art and science for conveying ideas and concepts.
- Experiments and research push boundaries and reveal new truths.
- Communication and self-expression are important in both art and science for conveying emotions, ideas, and research results.
- Aesthetics and beauty are valued in both fields, appreciating the visual appeal and elegance of both artistic and scientific creations [9].

Thus, the methods and approaches used in art and science mutually enrich each other, contributing to creative inspiration, visualization, observation, experimentation, communication, and aesthetic perception.

Architectural studies and design education still need to develop such knowledge, which should become the content of its theory, so necessary for architectural science, the education system, and creative practice [10].

Conclusion. The article thoroughly examines the problems and approaches to developing spatial thinking in design students, highlighting the use of visual aids and materials. Spatial thinking allows students to visualize and manipulate three-dimensional objects, improving their ability to abstract, synthesize elements, and perform structural analysis. This is critically important in design development.

Modern technologies such as 3D modeling and virtual reality play a significant role in developing these skills [15]. Research shows that the use of 3D tools activates more visual-spatial functions of the brain and provides additional opportunities for creative thinking and solving complex problems [16].

The methodological basis of the research, based on Howard Gardner's theory of multiple intelligences, emphasizes the importance of recognizing and developing various intellectual abilities in educational institutions to create a comprehensive and inclusive learning environment [19].

Main conclusions of the article:

- The key role of spatial thinking: Spatial thinking is critically important for the successful professional activities of designers, as it allows for effectively solving tasks related to creating three-dimensional objects and structures [20].
- The use of modern technologies: 3D modeling and virtual reality significantly contribute to the development of spatial thinking, activating more visual-spatial functions of the brain and improving students' creative abilities [21].
- Systematic approach to learning: To effectively develop spatial thinking, it is necessary to use systematic approaches and methods that include visual aids and materials.
- Diversity of intellectual abilities: The development of spatial thinking should consider the theory of multiple intelligences, allowing for the creation of a comprehensive and inclusive educational environment.

Overall, the article concludes that developing spatial thinking in design students is a key element of their professional training, enhancing their creativity and analytical abilities and contributing to success both in the learning process and in their future careers.

In conclusion, it should be noted that developing spatial thinking in design students is a critically important aspect of their educational program. Effective use of visual aids, interactive technologies, and visual materials can significantly improve students' ability to perceive and model space, ultimately enhancing their creativity and success in professional activities. Thus, creating a systematic and integrated approach to developing spatial thinking in design education is necessary for preparing highly qualified and creative specialists ready to solve complex tasks in the field of design.

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