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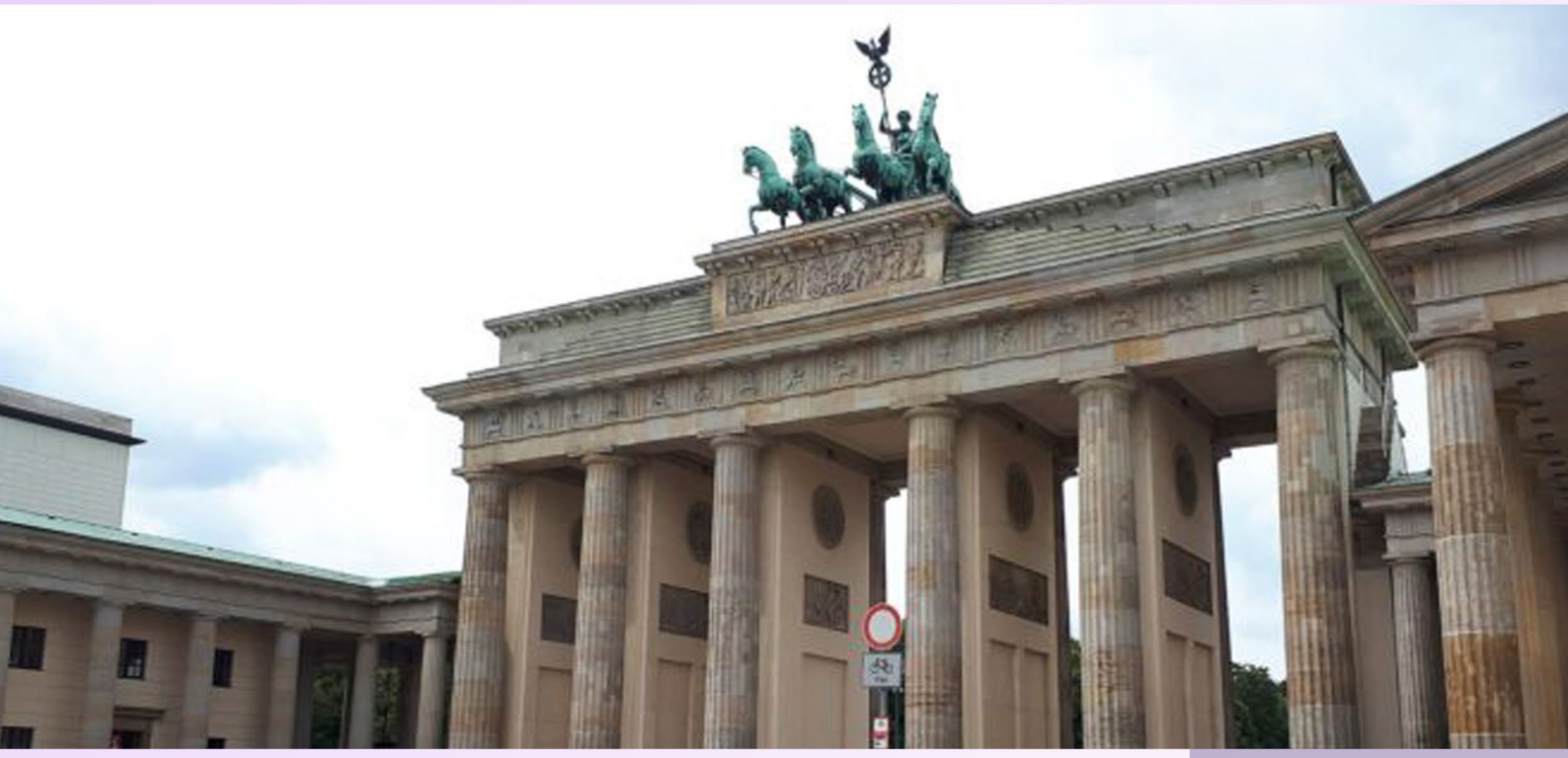

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ABSTRACT GEOMETRIC MODELING AS A MEANS OF DEVELOPING SPATIAL THINKING AT THE INITIAL STAGE OF PROFESSIONAL TRAINING OF ARCHITECTURE STUDENTS

Abstract. The article examines abstract geometric modeling as a teaching tool in the introductory (propaedeutic) stage of architectural education. Drawing on an analytical review of international and Ukrainian sources, it generalizes approaches that combine primary geometric forms, physical models, parametric modeling and digital fabrication in first-year teaching. A five-stage sequence of exercises and criteria for assessing student work are proposed. The combination of physical, graphic and digital modeling is shown to narrow the gap between abstract thinking and the constructive realization of form. The proposed model requires empirical validation, for which a pilot design is outlined in the article.
Keywords: abstract form-making, geometric modeling, architectural propaedeutics, spatial thinking, parametric design, model-making.

Problem Statement and Relevance: The first semesters of an architect's education shape the basic mechanisms of professional thinking: the ability to see form as a system of relations, to operate with spatial representations, and to move from an idea to its material realization. It is here that students first encounter abstraction, that is, the ability to separate the essential geometric and compositional properties of an object from its function, material and imagery.

The relevance of the topic is determined by three circumstances.

1. Difficulties with abstraction at the outset. A study at Akdeniz University shows that first-year students find it hard to master abstraction without practical application; this is partly attributed to their school-level habituation to test-based forms of assessment [10]. The authors also note that students abstract familiar scenes more easily than detached concepts.

2. Insufficient geometric preparation. According to a study on visual intelligence and geometric abstraction, school-level geometry is insufficient for design disciplines, so classical geometric systems should be studied in parallel with design training [10]. Italian researchers likewise note growing difficulties with spatial visualization among first-year students, as well as a tendency to separate mathematical knowledge from professional knowledge [4].

3. Risks of digital tools. Parametric and generative tools expand formal possibilities but may conceal geometric principles and orient students toward visual outcomes at the expense of constructive coherence [11]. Authors from the Politecnico di Torino warn that purely virtual models easily turn into "black boxes" [4].

The scientific and pedagogical problem therefore lies in finding a structure of introductory exercises that combines abstract geometric thinking with the material and digital realization of form.

Analysis of Recent Research and Publications: Abstraction as a learning task. Kavas and Mutlu Danaci propose a cognitive method in which students abstract a view of their own city into simple geometric forms, moving through a series of sketches to a two-dimensional composition and then to a relief. The method relies on a familiar context, and the instructor adjusts the work on the basis of critique of the completed steps [6]. A study of "body–space" exercises (Online Journal of Art and Design, 2022) demonstrates the transition from abstract sketches to a scale model of a structure with two groups of first-year students (67 and 41 students) [5]. A study at Fatih Sultan Mehmet Vakıf University describes a sequence of steps leading from the abstraction of natural objects to a final project [2].

Primary and complex forms. In the study on visual intelligence, first-year students were given precedent buildings ordered from primary forms to derived complex ones. The study concluded that working with primary forms is more productive in the early years, while more complex transformed forms become appropriate as geometric knowledge grows [10].

Physical modeling. A group at the Politecnico di Torino developed interdisciplinary first-year exercises at the intersection of mathematical analysis and architectural drawing: paper models of vaults based on developable surfaces were combined with digital tools. In a questionnaire survey (39 responses), students rated the usefulness of the models for understanding form at about 4.5 on a five-point scale. The authors nevertheless stress that tactile exploration must be structured, since it may lead to erroneous interpretations [4]. In a study at Al Yamamah University, hands-on model-making helped first-year students grasp abstract design rules [1].

Wagiri et al. use simple geometric forms and solids as a generative system: students built wireframe, surface and block models, then parametric models in Rhino-Grasshopper, and finally full-scale prototypes. The authors emphasize that fabrication works as a process of inquiry that tests geometric assumptions; they also candidly acknowledge the limitations of their study: a single elective course (24 students) and qualitative assessment without quantitative measurement [11].

Ukrainian publications and curricula describe form-making mainly through compositional means and manual graphics. They also cover techniques for modeling geometric form through perspective and light-and-shade rendering, and they substantiate the integration of manual graphics and digital technologies at the early stages of design. The syllabus of the Lviv National University of Nature Management (LNUP), "Fundamentals of Form-Making", includes the topic "Abstract Form-Making" [7], while the course "Model-Making of Volumetric and Spatial Forms" at the Kharkiv State Academy of Design and Arts (KhSADA) covers the shaping of simple and complex geometric solids [3].

In the sources analyzed, abstraction, physical models and parametric tools are usually treated separately or within a single course or typology. What is lacking is a described integral sequence that would lead from primary forms to transformation rules, parametric variability and material verification, with clear assessment criteria.

This conclusion is based on a non-systematic review and needs to be refined through a full search of scientometric databases.

Main Material: The aim of the article is to substantiate the methodological conditions for using abstract geometric modeling in the initial training of architecture students and to develop a sequence of tasks that ensures a traceable link between a geometric operation, a compositional solution and its architectural interpretation.

In this article, abstract geometric modeling is defined as the process of constructing form from primary geometric elements and rules for their transformation (translation, rotation, scaling, symmetry, modular repetition, unfolding), in which functional and figurative content is deliberately bracketed out. Abstraction does not mean the absence of constraints. If a student can change all parameters arbitrarily, the comparison of variants loses its precision. It is therefore advisable to specify a limited set of elements, the boundaries of the compositional field and a particular search parameter. The result is a model, in physical, graphic or digital form, that makes it possible to investigate the relations, proportions and structure of form.

It is important to distinguish geometric correctness from compositional appropriateness. Correctly constructed solids may form an incoherent composition, while an expressive model may contain contradictions between projections. Likewise, a completed model in itself does not show whether a student is able to reapply the principle discovered. This necessitates considering the product, the process of obtaining it and its new design application separately.

Physical and digital modeling are proposed to be used according to the content of the exercise. Manual rearrangement of elements is suited to the rapid comparison of variants; a digital model is suited to precise repetition, parameter variation and comparison of sections. The choice of medium should not determine the assessment of the compositional concept. If skills in working with the software or material are still insufficient, the complexity of the tool should be reduced while preserving the learning task.

A teaching module of five interrelated stages is proposed. Its duration should be determined by the working curriculum and the preparedness of the group. The tasks presented are the author's proposal rather than a description of a completed pedagogical experiment, and they are offered as a hypothesis for a teaching experiment.

Step 1: establishing the correspondence between image and volume. The student reproduces a simple structure from two or three projections, marks a possible section and checks the answer against a model. The task is diagnostic in nature: the instructor identifies which operations require explanation. If the projections admit several solutions, the student must articulate this ambiguity rather than guess a single expected variant.

Step 2: isolated investigation of geometric operations. Using the same set of solids, several configurations are produced, in each of which one parameter is varied: the angle of rotation, the interval, the height or the size of the removed part. The student predicts the result of the change, creates the variant and compares it with the original. Such a record makes it possible to trace the link between intention and observation.

Step 3: compositional combination of operations. The student forms a frontal, volumetric or depth-spatial structure, justifying the hierarchy of elements. It is

advisable to include tasks with different organizing principles rather than fixing a single type of composition as universally correct. Symmetry, asymmetry, static and dynamic qualities are assessed in relation to the concept and the task set.

At this stage, particular attention is proposed to be paid to inter-volume space. The student depicts not only the material elements but also the boundaries of voids, the directions of opening and the points of narrowing. For example, two identical prisms can be brought closer together, moved apart or rotated in order to investigate the character of the space between them. For a depth composition, a sequence of viewpoints is additionally defined so that the solution is tested through notional movement rather than from a single advantageous angle.

Step 4: testing the robustness of the compositional concept. After discussion, the student adjusts the model and records the reasons for the changes. Color is introduced as a separate variable: with the geometry unchanged, achromatic and chromatic variants are created. The comparison should show whether color supports the chosen hierarchy or creates a different one. This exercise links composition with color studies but does not presuppose a predetermined preference for either variant.

Step 5: architectural interpretation. To the selected model are introduced a human scale, a usage scenario and a minimal functional programme, for example that of a small exhibition pavilion. The student determines which compositional principle is retained and which elements need to change. Preserving all geometric details is not obligatory: the educational value lies in the reasoned adaptation of the structure. The entrance, the circulation, the place of the main activity and the correspondence between plan and section must be shown. The result remains an initial design proposal rather than a completed technical project.

Table 1. Correspondence between geometric operations and learning tasks

Operation	Learning task	Outcome
Translation and change of interval	To organize a group and alter the relationship between its parts	Variants with unchanged forms and an explanation of the role of the interval
Rotation	To change the directionality of the composition	Comparison of the original and rotated configurations from several viewpoints
Change of proportions	To test the role of elongation or height in forming the dominant	A series of models with a constant position of elements
Addition and combination	To construct a subordinated system of parts	A diagram of relations between the principal and auxiliary elements
Subtraction and dissection	To create a void, a passage or a spatial accent	A section and a model that consistently show the space produced
Repetition and gradation	To form a rhythm and a controlled change of density	A series with a defined rule of repetition and its variation

Conditions: physical models and digital tools are used together rather than in place of one another. In addition, the complexity of forms increases gradually, beginning with primary forms, and the context of the exercises should be familiar to the student.

The following assessment criteria are proposed: geometric coherence, i.e. the consistency of construction and the accuracy of relations; compositional expressiveness, i.e. the organization of elements according to the principles of rhythm, hierarchy and symmetry; variability, i.e. the number and quality of meaningful variants obtained by changing parameters; and adaptability, i.e. the possibility of adapting a principle to a different scale and function.

Abstract geometric modeling is best regarded as a method of investigating the relations of form and space through consecutive, explicable transformations. Its educational content is determined not by the complexity of the final model but by the nature of the actions the student performs and by the possibility of tracing their consequences.

The proposed model can be applied within a system of interrelated disciplines of the initial training of architecture students. Further research should test its effectiveness under comparable teaching conditions, assessing separately spatial skills, compositional solutions and performance on a new architectural task.

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