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DEVELOPING STUDENTS' CREATIVE THINKING IN THE PROCESS OF STUDYING PROJECTIVE GEOMETRY

Abstract

This article discusses methods for completing complex geometrical construction tasks to develop students' creativity. The effectiveness of methods for developing creative qualities such as flexibility, lateral thinking, and a creative approach is noted. It also describes methods for developing students' creative thinking and creative skills, problem-based learning methods, and students' research skills. The aim of this study is to improve students' creative abilities in lectures, practical work, and independent work on projective geometry. In this article, we present methodological methods and approaches aimed not only at teaching but also at developing creative thinking. These methods were applied in the educational process at Margulan University in teaching projective geometry and led to a positive shift in the development of students' creative thinking.

Keywords: creativity, creative thinking, creative approach, projective geometry, teaching methods.

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ПРОЕКТИВТІК ГЕОМЕТРИЯНЫ ОҚУ БАРЫСЫНДА ОҚУШЫЛАРДЫҢ ШЫҒАРМАШЫЛЫҚ ОЙЛАУЫН ДАМЫТУ

Аңдатпа

Бұл мақалада студенттердің шығармашылық қабілеттерін дамытуға бағытталған күрделі геометриялық салу есептерін орындау әдістері қарастырылады. Икемділік, латералды ойлау және шығармашылық тәсіл сияқты шығармашылық қасиеттерді қалыптастыру әдістерінің тиімділігі атап өтіледі. Сонымен қатар студенттердің шығармашылық ойлауын және шығармашылық дағдыларын дамыту жолдары, проблемалық оқыту әдістері мен білім алушылардың зерттеушілік дағдылары сипатталады. Зерттеудің мақсаты – проективтік геометрия бойынша дәрістерде, практикалық сабақтарда және өзіндік жұмыста студенттердің шығармашылық қабілеттерін дамыту. Бұл мақалада біз оқытуға ғана емес, сонымен қатар креативті ойлауды дамытуға бағытталған әдістемелік әдістер мен тәсілдерді ұсынамыз. Аталған әдістер Марғұлан университетінде проективтік геометрияны оқыту барысында оқу үдерісінде қолданылып, студенттердің шығармашылық ойлауын дамытуда жақсы өзгерістерге қол жеткізуге мүмкіндік берді.

Түйін сөздер: креативтілік, шығармашылық ойлау, шығармашылық тәсіл, проективтік геометрия, оқыту әдістері.

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РАЗВИТИЕ ТВОРЧЕСКОГО МЫШЛЕНИЯ СТУДЕНТОВ В ПРОЦЕССЕ ИЗУЧЕНИЯ ПРОЕКТИВНОЙ ГЕОМЕТРИИ

Аннотация

В данной статье рассматриваются методы выполнения сложных задач на геометрические построения, направленные на развитие творческих способностей студентов. Отмечается эффективность методов формирования таких творческих качеств, как гибкость мышления, латеральное мышление и творческий подход. Также описываются способы развития у студентов творческого мышления и творческих навыков, методы проблемного обучения и исследовательские умения обучающихся. Целью исследования является развитие творческих способностей студентов на лекциях, практических занятиях и в самостоятельной работе по проективной геометрии.

В статье мы представляем методичсекие методы и подходы не только обучению , но и развитию креативного мышления. Эти методы были использованы в учебном процессе в Маргулан университете при преподавании проективной геометрии и позволил добится положительного сдвига в развитии творческого мышления студентов.

Ключевые слова: креативность, творческое мышление, творческий подход, проективная геометрия, методы обучения.

Introduction

Main provisions

The relevance of the topic lies in the fact that knowledge and understanding of the essence of geometric positions is not sufficient for studying geometry; analytical and creative thinking are also necessary. To this end, we propose the development of students' creative thinking when studying projective geometry at university. The goal and objectives of the lesson are to develop creative skills and abilities in projective geometry lessons using interactive programs and models. In this article, we propose a number of methods and technologies for teaching projective geometry in lectures, practical classes, and independent study. The main conclusions are the need to develop creative thinking, improve modern teaching aids, and increase the effectiveness of practical training. The importance of focusing on the use of interactive programs for solving and proving geometric problems is also emphasized, which contributes to the development of creative thinking in future mathematics and physics teachers.

The article discusses the section of geometry known as "projective geometry" and its teaching in pedagogical HEI. Due to the difficulties in assimilating theoretical knowledge, the article proposes that theoretical material be presented using a creative approach and the creative thinking of students. The difficulty of studying this material is primarily due to its multifacetedness and the large number of imaginary objects, as this section is directly aimed at developing students' spatial imagination and geometric intuition. Projective geometry is one of the traditional sections of the geometry course studied by future mathematics teachers. The complexity of studying this topic lies in the fact that students have studied Euclidean geometry throughout their conscious lives and are accustomed to its standards. Therefore, when studying projective geometry, it becomes difficult for them to understand its structure and basic elements. Recently, there has also been a decline in student interest in this discipline, mainly due in part to an excessive amount of theory and less visualization. In this regard, the relevance of our research lies in the search for new methodological approaches to teaching students the elements of projective geometry on a plane. Therefore, the aim of our research is to develop a creative approach for a better understanding of the basics of projective geometry on a plane by students of physics and mathematics at pedagogical HEIs. A creative approach to teaching projective geometry includes the use of real-life examples (architecture, art), interactive methods (linear perspective, 3D modeling), gamification (puzzles), and links to other disciplines (computer graphics, philosophy) to help students understand the invariant properties of figures under transformations and develop spatial thinking by turning abstract concepts into visual and engaging ones.

V.N. Druzhinin defines creativity as a person's general ability to create and, in his works, equates the concepts of "creativity" and "creative work" [1]. We agree with his opinion and consider it necessary to note that in this work, we use the concepts of "creativity" and "creative work" as synonyms. Currently, the most well-known and frequently used psychodiagnostic methods for studying the level of development of creative thinking (creativity) in students are the following: verbal and image tests of creative thinking by E.P. Torrance, S. Mednik's Remote Associates Test, A.S. Lachins's Flexibility of Thinking method, and a battery of creativity tests created by E.E. Tunik based on J. Guilford's creativity tests. The empirical and theoretical levels of creative thinking and a creative approach to problem solving must be incorporated into the training system for future mathematics teachers. They determine the readiness and ability of future teachers to carry out creative or educational research. They develop the ability to assess the reliability of results obtained using experimental or theoretical research methods. Creative thinking, independent cognitive work skills, and the ability to model situations using a computer are developed; during the learning process, students master the skills of planning and conducting experiments (real and virtual), as well as the skills related to processing and presenting research results. Creative thinking is the ability to see approaches that differ from accepted standards and to find a way out in difficult circumstances. People with creative skills move away from stereotypes and realize that there are many solutions to a single problem. A creative approach does not question the balance between intellect and imagination, logic and creativity – on the contrary, it harmoniously combines these elements.

To develop creative thinking, Astafieva V. and Proshkin V. consider using projective and constructive geometry in the training of future mathematics teachers [2]. In the article, the authors emphasize that the tasks and methods of projective geometry (for example, Desargues' theorem) allow not only to "teach theorems," but also to practice analysis, argumentation, and the development of solution strategies, which is important for future teachers. Jafaruddin M. and Wen- Haw Chen use elements of "ethnomathematics" in their projective geometry course: they include cultural constructs (e.g., traditional houses) in their assignments, linking abstract geometrical concepts to the realities of their students' lives in order to increase motivation and understanding [3]. They apply the Hypnoteaching model, a pedagogical strategy aimed at engaging and actively involving students, especially in the context of distance learning. Ultimately, the integration of cultural context and a project-based/practical approach to distance learning can make projective geometry more accessible, understandable, and motivating. Lucas Cunha Bastos et al. provide a historical overview of the development of projective geometry – from its origins to modern approaches – and discuss how it can be implemented in the educational process (especially at the primary and secondary levels) [4]. In their opinion, one of the key prospects is the use of dynamic geometry systems (e.g., GeoGebra) to visualize and model projective concepts, which greatly facilitates the understanding of abstract concepts. The authors emphasize that this approach helps to make a "smooth transition" from familiar Euclidean geometry to projective geometry, reducing the cognitive load on students and increasing clarity and intuitivism. In general, the introduction of a historical and visual-interactive approach can serve as a bridge between traditional school geometry and more "adult" projective geometry. In her article, Ravshanova Ugylshod Abdurashid kyzy shows that projective geometry methods can even be applied to solving problems in "elementary" school geometry [5]. In other words, projective ideas make it possible to simplify, generalize, and find new solutions to problems involving collinearity, intersections, and relationships between points and lines, using concepts such as "points at infinity," "harmonic division," "cross ratio," and others. This makes it possible not to limit projective geometry to the "university level," but to use it as a tool in school geometry, broadening students' horizons and enriching their methods for solving. Kazakh scientists [6-8] suggest using digital technologies and programs (3D modeling, dynamic geometry) when teaching the construction of geometric shapes – an important skill that is similar in spirit to projective and spatial geometry. They use the method of local axiomatization and active problem-based learning, collective work, and reflection on mistakes – with the aim of developing "geometric thinking" in future teachers. This shows that even if the course is not strictly "projective," methods aimed at developing spatial, logical, abstract thinking, and visualization can be very useful and applicable in the more general context of geometry. The use of projective geometry as a tool for developing critical and spatial thinking – not only as "mathematics for mathematicians," but as a powerful pedagogical resource [9-13].

Despite some successful examples, there are not many works devoted specifically to the method of teaching projective geometry in higher education institutions. Research is needed to test the long-term effect: not just "improved performance now," but "improved geometric thinking, the ability to abstract, and apply design ideas in new situations." Methodological recommendations and training programs need to be developed that take into account the cognitive characteristics of students when transitioning from Euclidean to projective geometry.

Materials and Methods

Let's start describing the teaching materials we have developed with the creation of Projective Geometry lecture complex. It includes a lecture course on 30 basic and additional topics.

When compiling and delivering lectures, various methods and technologies are used, as well as creative approaches aimed at developing students' creative thinking. For example, problem-based learning. The use of problem situations in lectures can contribute to a creative approach to problem solving [8]. This approach involves presenting students with problem situations or tasks that do not have a single obvious solution. For example: "What if...?": studying how geometric properties or theorems change when axioms or conditions change (for example, what happens to parallel lines in projective space). Or tasks with missing or redundant data: students must determine for themselves what information is needed or unnecessary to solve a specific projective task. Other methods and technologies (Table 1) were also used in lectures to develop students' creative and innovative abilities.

Table 1. Methods and technologies used to develop creative thinking

Topics	*Proposed methods for developing creative thinking*	*Technologies and creative approaches in teaching*
Incidental	*The "Six Thinking Hats" method or brainstorming, where participants are asked to consider a problem from different perspectives (emotional, critical, optimistic, etc.).*	*Facilitation techniques, visual tools, digital platforms*
Projective straight line	*Synectics (direct, personal, symbolic analogies): Searching for analogies in nature, art, or technology to understand abstract concepts of projective geometry*	*Creative journal: Sketch your ideas about how one projection is related to another, or how isometry transitions into perspective.*
Projections	*Six Thinking Hats Method (De Bono): Study projections and perspectives from different "points of view" (emotions, facts, criticism, positivity) for a comprehensive analysis.*	*SketchUp, GeoGebra*
Homography	*TIPS (Theory of Inventive Problem Solving): Applying the principles of contradictions and ideal end results to find new ways of projecting, solving problems with constraints, and "improving" geometrical constructions*	*Project-based and problem-based learning (PBL): Solving real-world problems (architecture, design, graphics), creating 3D models from 2D sketches, or vice versa.*
Duality	*Brainstorming and mind maps: Generating a multitude of ideas related to projections, shadows, perspectives, and visualizing them to find connections.*	*Interactive diagrams.*
Conics	*Random word/picture method: Linking concepts being studied (e.g., points, lines, planes, perspectives) to a random object to generate unusual metaphors and associations.*	*Augmented (AR) and virtual (VR) reality: Immersion in a three-dimensional space that allows you to "touch" and "enter" geometric figures and see their transformations in real time.*
Axiomatics	*Brainstorming: Mass generation of ideas without judgment.*	*3D modeling and parametric design*
Desargues' theorem, Pappus' theorem	*Constructivist learning: Students don't just acquire knowledge, they "build" it by manipulating objects in GeoGebra and discovering patterns.*	*GeoGebra*

Thus, the application of creative thinking methods in lectures when studying the Projective Geometry course contributes to the formation of in-depth knowledge in students, combined with the development of interest and motivational aspects in the learning process. Therefore, is received with interest by students, reveals their creative abilities, which in turn contributes to a deep understanding of the topic and is an effective way of teaching.

During practical classes, students offered their ideas on the problem at hand and considered various methods of solving the problem. To enhance creative thinking, we used various creative approaches in practical classes. For example, the Ames room can be viewed as the result of a projective transformation of space that is close to affine but not affine. Students interpret the image assuming a standard perspective, and the brain "imposes" a Euclidean model where a projective one works. In essence, the Ames room is an optical illusion based on the principles of projective geometry (in particular, perspective distortion). The students created a three-dimensional embodiment of projective transformations in the form of a model (Fig. 1) where objects are projected onto a plane (eye retina), and the brain tries to restore their three-dimensional dimensions based on incorrect assumptions. The Ames room is constructed so that from the front it looks like a normal cubic room with a back wall and two side walls parallel to each other and perpendicular to the horizontal planes of the floor and ceiling. However, the true shape of the room is trapezoidal: the walls are sloped, the ceiling and floor are also sloped, and the right corner is much closer to the observer entering the room than the left, or vice versa. As a result of an optical illusion, the snowman (assyk, Christmas tree, and Santa Claus, headphones) standing in one corner appears to the observer to be a giant, while the second object standing in the other corner appears to be a dwarf. The illusion is so convincing that the observer thinks that the object changes size when it moves. We also tried to depict the Ames room in the GeoGebra program (Fig. 2).

Figure 1. Three-dimensional embodiment of projective transformations in the form of a model

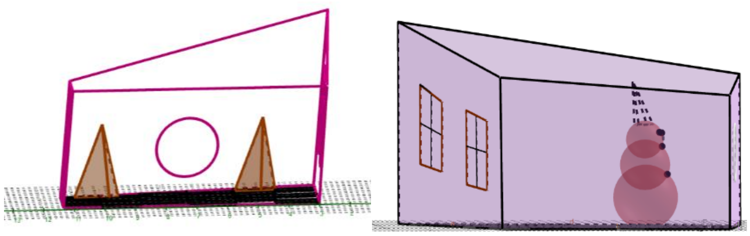

Figure 2. Ames room in the GeoGebra program

During practical classes, students demonstrated their creative abilities and creative approach by applying linear perspective, theory of shadows, and Desargues' configuration in painting, design, and architecture by making figures (Fig. 3). They also tried to make models of the room (Fig. 4) with the effect of depth and space, which is achieved by converging lines leading to a single vanishing point. The task set for the students was to create a space that would then go beyond the existing one. Models in projective geometry and perspective are closely related: perspective is a method of central projection that imitates how we see objects on a plane using vanishing points and the horizon line, and is the basis for constructing realistic models (figures, drawings) of buildings, cities, and objects, transforming the 3D world into a 2D image using the principles of projective geometry. Projective geometry studies how shapes change when projected, and perspective is the practical application of these rules, especially linear (one, two, three vanishing points), to create the illusion of depth and volume in a model.

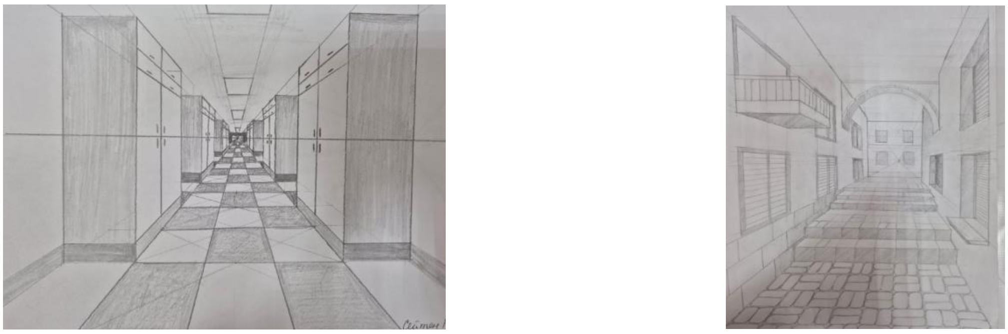

Figure 3. Students' work

Figure 4. Room models with the effect of depth and space

Using the Compass 3D and GeoGebra programs allows you not only to visualize points at infinity and directions, but also to explore projective invariants (collinearity, dual relation); model central and parallel projections; dynamically verify theorems (when changing the configuration); and develop research skills in students. This is especially important because intuition plays a key role in projective geometry, particularly when considering topics in second-order surface theory.

For example, constructing and rotating 3D models of surfaces (ellipsoids, hyperboloids, paraboloids, cylinders) based on their equations helps students understand their spatial arrangement (Figure 5). Constructing cross-sections of surfaces with planes (parallel to the axes or arbitrary) to see how second-order curves (ellipses, hyperbolas, parabolas) are formed.

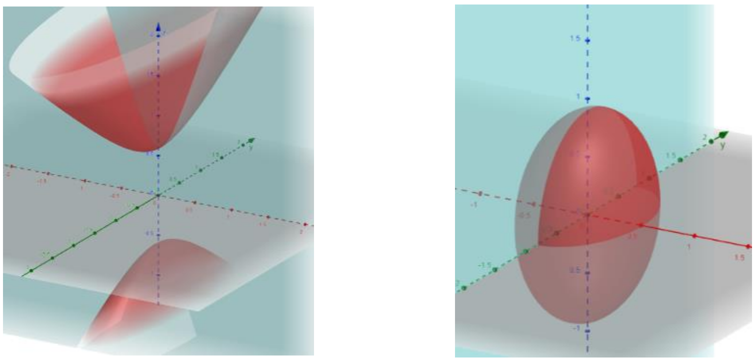

Figure 5. Three-dimensional surface models

The dynamic environment of GeoGebra allows for the effective use of an experimental approach when studying the theorems of Desargues and Pappus-Pascal, forming students' intuitive understanding of projective invariants and preparing them for the perception of rigorous proofs (Fig. 6). When proving Pappus-Pascal and Desargues' theorems, students develop their geometric imagination and rely on complex configurations of points and lines, formulate hypotheses for collinearity, observe the stability of the result, and realize which properties are projective invariants.

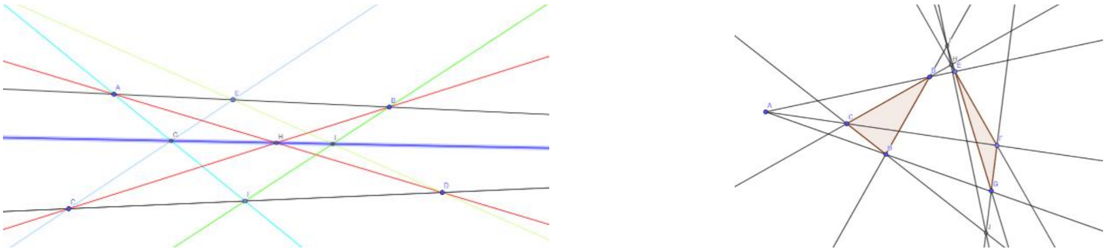

Figure 6. Students' work in GeoGebra

Students begin to understand that in projective geometry, the same "transformation" can be applied to the text of any theorem. After all, on a projective plane, unlike a Euclidean plane, there are no parallel lines. The condition and conclusion mainly involve collinear triples of points (three points are incident to one line) and competitive triples of lines (three lines are incident to one point).

By the end of the semester, students knew the basic methods for constructing perspective images of geometric figures; the basic rules for applying perspective projections in figures and performing analysis of perspective images; and solved problems involving the construction of shadows from objects in perspective at various positions of the light source.

Results and discussion

During the study, we developed a model, indicators, and control and measurement materials for diagnosing the level of research skills of future mathematics and physics teachers [7].

The study was conducted at Margulan University among students majoring in Mathematics Teacher Training while studying the Projective Geometry discipline. A total of 42 second-year students were involved, with Russian and Kazakh as their languages of instruction.

In the course of studying the discipline and observing students in lectures and practical classes, as well as analyzing their written creative works, we determined the following levels: high, sufficient, threshold, low, critical [7]. We did not divide the groups into control and experimental groups, as we diagnosed the qualities of developing creative abilities and creative thinking before and after the application of the teaching materials we had developed. The initial study was conducted after the students had completed traditional practical work on projective geometry. Next, according to our plan of experiment, the students began learning using the teaching materials we developed.

The problem of determining the levels of development of creative abilities was considered in the dissertation research of Bibikova N.V., Vishnevaya N.E., Klevtsova V.L., and Gin S.I. Theoretical analysis of their work and our own research on the problem allowed us to identify the following criteria for assessing the levels of development of students' creative abilities

The criteria on the basis of which it is possible to determine the levels of creative abilities are given in Table 2. The final diagnosis of the level of creative thinking was carried out according to the criteria, by checking written works and personal interviews with students.

At the beginning of the educational process, students did not show very high results. They did not know how to find and work with information, did not show persistence in solving problems, did not know how to analyze and correctly formulate solutions and the main points of research, etc.

Table 2. Criteria for assessing the level of creative abilities

Criterion	Level and score of creativity development				
	Critical /1	Low /2	Threshold /3	Sufficient/4	High/5
A. Cognitive-emotional criterion	Doesn't show interest in upcoming work	Takes a passive approach to tasks Afr aid to speak in public	Engages as necessary Involved in teamwork	Thinks outside the box, shows emotionality in creative tasks	Generates many ideas Is active and proactive
B. Personal-creative criterion	Not active	Afraid to express his/her point of view, prefers to work under the template	Only shows up in group work	Able to use his/her imagination	Criti cally evaluates ideas, tends to act independent ly
C. Moti vational-value criterion	Does not seek to participate in creative activities	Lea rning creative activities is extremely slow	Participates in creative activities as part of a team	Understands and recognizes the value of his/her own and others' creativity	Gen erates a large number of ideas. Demonstrat es originality and independen ce
D. Acti vity-process criterion	Does not demonstra te independe nce skills	Does not demonstrat e independen t creative activity	Demon strates creative skills in group work	Perfor ms work well, expresses emotional satisfaction with the results of his/her activities	Strives to achieve goals and obtain specific results from his/her activities
E. Refl ective criterion	Does not demonstra te analysis of activities	Does not demonstrate liveliness and emotionality in self- reflection	Adequ ate in self-assessment. Strives for self-education	Conducts self-analysis and self-reflection, sees his/her strengths and weaknesses	Striv es for self-developmen t, objective criticism of his/her own and others' achievemen ts

Given that the maximum score is 5 and the minimum is 1, we converted the obtained indicators into scores.

$$X = \frac{A + B + C + D + E}{5}$$

Then, analyzing the results at the initial stage of the study, where the level of development of creative skills and abilities had low indicators, we saw that threshold and low scores prevailed. At the final stage of the study, a repeat diagnosis of the level of development of students' research skills and abilities was carried out using the same method.

After conducting a statistical analysis using Wilcoxon rank sum test and determining whether there was a significant shift in indicators in this direction, we observed a statistically significant positive shift: the indicators of the level of development of creative skills and abilities at the final stage increased compared to the same indicators at the initial stage.

The study on the formation of creative thinking in the study of the module of Projective Geometry discipline showed positive statistics.

It should be noted that students with a relatively low creative flexibility coefficient are by no means considered by us to be uncreative. In this case, we adhere to the point of view of V.N. Druzhinin, who believes that a person who gives an original, creative answer obviously possesses creativity. But even if a person does not give a creative answer in a free situation, this is not evidence of a lack of creativity. With the help of creativity tests, we can identify creative people, but we cannot accurately identify non-creative people. The reason for this is the spontaneity of manifestations of creativity and the insubjectivity of these manifestations to external and internal regulation [1].

Conclusions

Analysis of the results of our study on the formation of creative thinking in students has shown how, through the competent construction of logical chains, it is possible to lead students to solve problems of any complexity, while developing their creative thinking. The completion of spatial figures accompanying the reasonings given, develops spatial thinking as well. All this enriches the student's intellect and thinking culture, which is so necessary for their project and research activities.

This study aims to ensure that future mathematics and physics teachers master the theoretical foundations of creative activity through the development of their creativity and the organization of special training for students to carry out creative activities in geometry lessons.

Список использованных источников

[1] Дружинин, В.Н. Психология общих способностей [Текст] / Дружинин В.Н. // СПб.: Питер, 2002, 3-издание, 359с. URL:https://krh–school2.ucoz.com/dokumenty/obrazovanie/psikhologija_obshhikh_sposobnostej_druzhinin.pdf

[2] Proshkin, V., Astafieva, M., and Radchenko, S. Formation of critical thinking of future mathematics teachers by means of geometry. Educological discourse, 2018, № 1(20–21) DOI: 10.28925/2312–5829.2018.1–2.1416

[3] Jafaruddin, M., Chen, Wen–Haw. Fostering Ethnomathematics in Projective Geometry: A Hypnoteaching Framework for Effective Distance Learning, Southeast Asian Mathematics Education Journal, 2023, Vol.13, №2. DOI: https://doi.org/10.46517/seamej.v13i2.240

[4] Lucas, Cunha Bastos. Projective Geometry: A Historical Overview and Perspectives for Education. The Global GeoGebra Journal. – 2023. – Vol.11 – №1. https://mathed.miamioh.edu/index.php/ggbj/article/view/206

[5] Ravshanova, O'g'ilshod Abdurashid kizi. The application of projective geometry in elementary geometry problems, International Journal of Artificial Intelligence, 2025, Vol. 5, No.08, p.196–199. https://www.academicpublishers.org/journals/index.php/ijai/article/view/6051

[6] Кокеш, А.Н. Калимбетов, Б.Т. Мадияров, Н.К. Цифрлық технологияларды қолданып болашақ математика мұғалімдерін геометриялық фигураларды кескіндеуге оқыту әдістері, Gumilyov journal of pedagogy, 2025, Том 150, № 1, p.248–266. https://doi.org/10.32523/3080-1710-2025-150-1-248-266

[7] Irina, B. Shmigirilova. Alla, S. Rvanova. Advancing future mathematics teachers' geometric thinking through a Van Hiele–based elementary geometry course, Journal on Mathematics Education, 2025, Volume 16, No.3, pp. 799–818 https://doi.org/10.22342/jme.v16i3.pp799–818

[8] Zhunussova, R., Kireyeva, A. Development of students' research competencies when studying analytical and projective geometry //Bulletin of Abai KazNPU. Series of Physical and Mathematical sciences, 2025, Vol. 91, No.3, p.111–120. DOI:https://doi.org/10.51889/2959–5894.2025.91.3.010.

[9] Thom, J.S, McGarvey, L.M. and Markle, J. Projective geometry and spatial reasoning for STEM learning, European Journal of Mathematics Education, 2024, 9, p.1–5. DOI: 10.3389/feduc.2024.1312845

[10] Kim, J., & Park, H. Visualization of Cross–Ratio Concepts Through Interactive Geometry Software, Education Studies in Mathematics, 2024, Volume 45, https://doi.org/10.1016/j.edurev.2024.100639

[11] Hamdi, M. N. H., Handayani, R. D., & Supriadi, B. Student's perspective: Mathematical reasoning ability and correlations between mathematics and physics, Journal of Environment and Sustainability Education, 2024, 2(1), p. 53–60. doi: 10.62672/joease.v2i1.31

[12] Delan, Serhang & Bnar, Karim. Teaching euclidean geometry and introducing some non–euclidean geometries: enhancing high school student engagement, 2024, 15-noyabr, Session 1, Part 1. DOI: 10.5281/zenodo.14235584

[13] Майер, В.Р. Крум, Е.В. Информационные технологии в обучении проективной геометрии будущих учителей математики, 2014, №1(27). URL: https://cyberleninka.ru/article/n/informatsionnye–tehnologii–v–obuchenii–proektivnoy–geometrii–buduschih–uchiteley–matematiki (дата обращения: 08.12.2025).

References

[1] Druzhinin, V.N. Psixologiya obshhix sposobnostej, SPb.: Piter, 2002. – 3 – izdanie, 359s. URL:https://krh–school2.ucoz.com/dokumenty/obrazovanie/psikhologija_obshhikh_sposobnostej_druzhinin.pdf

[2] Proshkin, V., Astafieva, M., and Radchenko, S. Formation of critical thinking of future mathematics teachers by means of geometry. Educological discourse, 2018, № 1(20–21) DOI: 10.28925/2312–5829.2018.1–2.1416

[3] Jafaruddin, M., Chen, Wen–Haw. Fostering Ethnomathematics in Projective Geometry: A Hypnoteaching Framework for Effective Distance Learning, Southeast Asian Mathematics Education Journal, 2023, Vol.13, №2. DOI: https://doi.org/10.46517/seamej.v13i2.240

[4] Lucas, Cunha Bastos. Projective Geometry: A Historical Overview and Perspectives for Education. The Global GeoGebra Journal. – 2023. – Vol.11 – №1. https://mathed.miamioh.edu/index.php/ggbj/article/view/206

[5] Ravshanova, O'g'ilshod Abdurashid kizi. The application of projective geometry in elementary geometry problems, International Journal of Artificial Intelligence, 2025, Vol. 5, No.08, p.196–199. https://www.academicpublishers.org/journals/index.php/ijai/article/view/6051

[6] Kokesh, A.N. Kalimbetov, B.T. Madiyarov, N.K. Sifrlyq tehnologialardy qoldanyp bolaşaq matematika mūğalımderın geometrialyq figuralardy keskındeuge oqytu ädısterı, Gumilyov journal of pedagogy, 2025, Том 150, № 1, p.248–266. https://doi.org/10.32523/3080-1710-2025-150-1-248-266

[7] Irina, B. Shmigirilova. Alla, S. Rvanova. Advancing future mathematics teachers' geometric thinking through a Van Hiele–based elementary geometry course, Journal on Mathematics Education, 2025, Volume 16, No.3, pp. 799–818 https://doi.org/10.22342/jme.v16i3.pp799–818

[8] Zhunussova, R., Kireyeva, A. Development of students' research competencies when studying analytical and projective geometry //Bulletin of Abai KazNPU. Series of Physical and Mathematical sciences, 2025, Vol. 91, No.3, p.111–120. DOI:https://doi.org/10.51889/2959–5894.2025.91.3.010.

[9] Thom, J.S, McGarvey, L.M. and Markle, J. Projective geometry and spatial reasoning for STEM learning, European Journal of Mathematics Education, 2024, 9, p.1–5. DOI: 10.3389/feduc.2024.1312845

[10] Kim, J., & Park, H. Visualization of Cross–Ratio Concepts Through Interactive Geometry Software, Education Studies in Mathematics, 2024, Volume 45, https://doi.org/10.1016/j.edurev.2024.100639

[11] Hamdi, M. N. H., Handayani, R. D., & Supriadi, B. Student's perspective: Mathematical reasoning ability and correlations between mathematics and physics, Journal of Environment and Sustainability Education, 2024, 2(1), p. 53–60. doi: 10.62672/joease.v2i1.31

[12] Delan, Serhang & Bnar, Karim. Teaching euclidean geometry and introducing some non–euclidean geometries: enhancing high school student engagement, 2024, 15-noyabr, Session 1, Part 1. DOI: 10.5281/zenodo.14235584

[13] Majer, V.R. Krum, E.V. Informacionny`e texnologii v obuchenii proektivnoj geometrii budushhix uchitelej matematiki // Vestnik KGPU im. V.P. Astaf`eva, 2014, №1(27). URL: https://cyberleninka.ru/article/n/informatsionnye–tehnologii–v–obuchenii–proektivnoy–geometrii–buduschih–uchiteley–matematiki (data obrashheniya: 08.12.2025).