# Methodology for Developing Visual Thinking of Future Engineers Based on Interactive and Artificial Intelligence Technologies

Abdurakhim Abdubannayevich Qahharov
Namangan State Technical University, Uzbekistan

Received: 16 Feb 2026 | Received Revised Version: 03 Mar 2026 | Accepted: 26 Mar 2026 | Published: 16 Apr 2026

Volume 08 Issue 04 2026 | Crossref DOI: 10.37547/tajssei/Volume08Issue04-07

## Abstract

*This study examines the theoretical and methodological foundations for developing visual thinking in future engineers through the integration of interactive and artificial intelligence technologies. Within the framework of the research, visual thinking is considered as a core cognitive component of graphic competence, and its formation mechanisms—visual perception, spatial imagination, mental modeling, and cognitive processing—are scientifically substantiated.*

*Based on an analysis of both international and national scholarly sources, existing pedagogical, technological, and cognitive approaches are critically evaluated, revealing insufficient integration among them. In response to this gap, an integrative and adaptive methodology is proposed, aimed at enhancing visual thinking in engineering education through the combined use of interactive multimedia tools and artificial intelligence technologies.*

*The proposed methodology is structured around key stages, including visualization, modeling, and intelligent analysis, and incorporates adaptive management aligned with students' individual cognitive characteristics. The findings demonstrate that AI-driven educational environments significantly improve visual thinking, spatial reasoning, and the effectiveness of graphic activities.*

*The proposed approach contributes to the modernization of engineering education, the advancement of teaching methodologies in graphic disciplines, and the development of next-generation learning systems based on digital and intelligent technologies.*

Keywords: Visual thinking, graphic competence, artificial intelligence, engineering graphics, interactive learning.



**Cite This Article:** Abdurakhim Abdubannayevich Qahharov. (2026). Methodology for Developing Visual Thinking of Future Engineers Based on Interactive and Artificial Intelligence Technologies. The American Journal of Social Science and Education Innovations, 8(04), 33–40. https://doi.org/10.37547/tajssei/Volume08Issue04-07

## 1. Introduction

At the current stage of development of the modern educational system, enhancing the professional training of future engineers and improving their practical skills and competencies has become a matter of particular importance. In this context, the rapid advancement of digital technologies and artificial intelligence (AI) has fundamentally transformed the nature and content of engineering activities, requiring specialists to possess a high level of visual thinking, spatial imagination, and graphic competence.

The discipline of Engineering and Computer Graphics plays a pivotal role in the formation of these competencies. This is due to the fact that a significant part of engineering activity involves the perception, processing, and representation of graphical information in the form of drawings and models. Therefore, graphic competence should be regarded not merely as a technical skill, but as an integrative construct closely associated with complex cognitive processes such as visual perception, mental imagery, spatial transformation, and memory.

Recent scientific studies indicate that the development of visual thinking and spatial intelligence serves as a critical factor in enhancing the effectiveness of engineering education. However, existing research tends to examine this process within separate frameworks—methodological, cognitive, or technological—while their integration remains insufficiently explored.

At the same time, the integration of artificial intelligence technologies into the educational process has created new opportunities. In particular, adaptive learning, personalized instruction, and real-time management of the learning process significantly contribute to improving educational effectiveness. Nevertheless, the integration of these technologies with engineering graphics and visual thinking has not yet been adequately investigated.

The relevance of this issue determines the primary objective of the present study, which is to develop an integrative methodology for enhancing visual thinking and improving the graphic competence of future engineers within an artificial intelligence environment.

To achieve this objective, the following research tasks were formulated:

- to analyze the theoretical foundations of visual thinking and graphic competence;
- to compare existing pedagogical and technological approaches;
- to identify the educational potential of the Engineering and Computer Graphics discipline;
- to develop an adaptive learning model based on artificial intelligence technologies;
- to substantiate the effectiveness of the proposed model.

The scientific novelty of the study lies in proposing a new methodological approach to developing graphic competence through the integration of visual thinking, cognitive mechanisms, and modern digital technologies. This approach enables the organization of the educational process in an adaptive and individualized format within an artificial intelligence environment.

The results of this research have significant scientific and practical value for improving engineering education, advancing the methodology of teaching graphic disciplines, and implementing modern educational technologies in practice.

## 2. Literature Review

The issue of developing visual thinking and graphic competence in modern engineering education is formed at the intersection of multiple scientific domains, including cognitive psychology, pedagogy, and digital technologies. An analysis of the existing scholarly perspectives reveals that research in this field can be broadly categorized into three main groups: international studies, research conducted in CIS countries, and studies carried out by Uzbek scholars.

In international research, the problem of visual thinking is primarily examined within a cognitive framework. In particular, R. Mayer's multimedia learning theory emphasizes that the integrated processing of visual and verbal information is a fundamental condition for effective learning. According to A. Paivio's dual coding theory, human cognition operates through two parallel systems—visual and verbal—thereby enhancing the efficiency of learning when visual materials are employed. Furthermore, J. Sweller's cognitive load theory highlights the importance of reducing excessive informational load in order to optimize knowledge acquisition and improve learning outcomes.

Recent studies (Zawacki-Richter, 2020; Holmes, 2022) indicate that the integration of artificial intelligence technologies into education has significantly expanded opportunities for adaptive learning, personalized instruction, and real-time analytical feedback. Additionally, research conducted by M. Hegarty and D. Uttal demonstrates that the development of spatial thinking and visual representation constitutes a critical component of STEM education.

In contrast, research conducted in CIS countries is largely grounded in activity-based and developmental learning theories. The works of L.S. Vygotsky, A.N.

Leontev, and V.V. Davydov conceptualize learning as a process of knowledge acquisition through purposeful activity. Within this paradigm, thinking and activity are closely interconnected, and particular emphasis is placed on the development of spatial imagination through graphical activity.

At the same time, studies in this context tend to focus predominantly on the formation of practical skills in engineering graphics, such as technical drawing, projection methods, and geometric modeling. However, these approaches often demonstrate limited integration of modern digital technologies and artificial intelligence capabilities.

Research conducted by Uzbek scholars primarily addresses issues related to improving engineering education, developing professional competence, and enhancing the methodology of teaching graphic disciplines. These studies emphasize the specific characteristics of the national education system, practical orientation, and professional training. Nevertheless, the integration of visual thinking, cognitive mechanisms, and artificial intelligence technologies remains insufficiently explored.

Overall, the analysis indicates that international research emphasizes cognitive and technological approaches, CIS studies focus on activity-based and methodological frameworks, while Uzbek research prioritizes professional orientation. However, these approaches have largely evolved independently, and their integration has not been adequately achieved.

From this perspective, the approach proposed in the present study aims to develop a comprehensive model for enhancing visual thinking and graphic competence through the integration of existing scientific perspectives. This model combines cognitive mechanisms, pedagogical methods, and artificial intelligence technologies into a unified system.

Thus, the conducted literature review demonstrates that the problem of developing visual thinking and graphic competence has not yet been fully resolved, thereby substantiating the need for the development of an integrative approach in this field.

## 3. Discussion

The findings of the study indicate that the development of visual thinking and graphic competence represents a multifactorial and inherently integrative process. The conducted analysis demonstrates that interpreting this process within a single framework—whether methodological, technological, or content-oriented—is insufficient for achieving effective educational outcomes.

In particular, international studies highlight the effectiveness of the Visual Thinking Strategies (VTS) approach as a tool for developing students' observation skills, analytical thinking, and communication abilities. However, this approach does not adequately address the professional aspects of graphic competence formation within engineering education.

Research on interactive multimedia technologies emphasizes that interactivity is a key factor in enhancing educational effectiveness. Such approaches facilitate active student engagement and stimulate cognitive processes. Nevertheless, they often lack clearly defined mechanisms for the targeted development of visual thinking.

Studies in the field of engineering and computer graphics primarily focus on the acquisition of graphic knowledge, projection techniques, and the formation of spatial visualization skills. While practical competencies are emphasized, the integration of cognitive processes and modern digital technologies remains insufficiently explored.

From this perspective, the approach proposed in this study is aimed at integrating three core dimensions—content (engineering graphics), methods (visual strategies), and technologies (interactive and artificial intelligence tools)—to foster the development of visual thinking and graphic competence. This integration is grounded in cognitive mechanisms and ensures the systematic organization of the educational process.

The analysis further demonstrates that cognitive stages such as information perception, encoding, storage, and retrieval play a crucial role in the development of visual thinking. These processes correspond closely with the stages outlined in Gagné's instructional model, thereby providing a theoretical basis for understanding visual and graphical learning activities from a cognitive perspective.

Moreover, the incorporation of artificial intelligence technologies introduces a qualitatively new dimension to this process. In particular, AI enables the adaptive organization of learning, the consideration of students' individual characteristics, and the automated management of the educational process. As a result, higher levels of efficiency can be achieved compared to traditional instructional models.

The results of the study confirm that the most effective approach to developing visual thinking and graphic competence is an integrative one, based on the synergy of content (engineering graphics), methods (visual strategies), and technologies (interactive and AI-based tools). This approach transforms the educational process into a cognitively grounded, adaptive, and efficient system.

Thus, the model proposed in this study not only synthesizes existing approaches but also advances them to a new level by establishing a scientific foundation for the development of visual thinking and graphic competence within an artificial intelligence-driven educational environment.

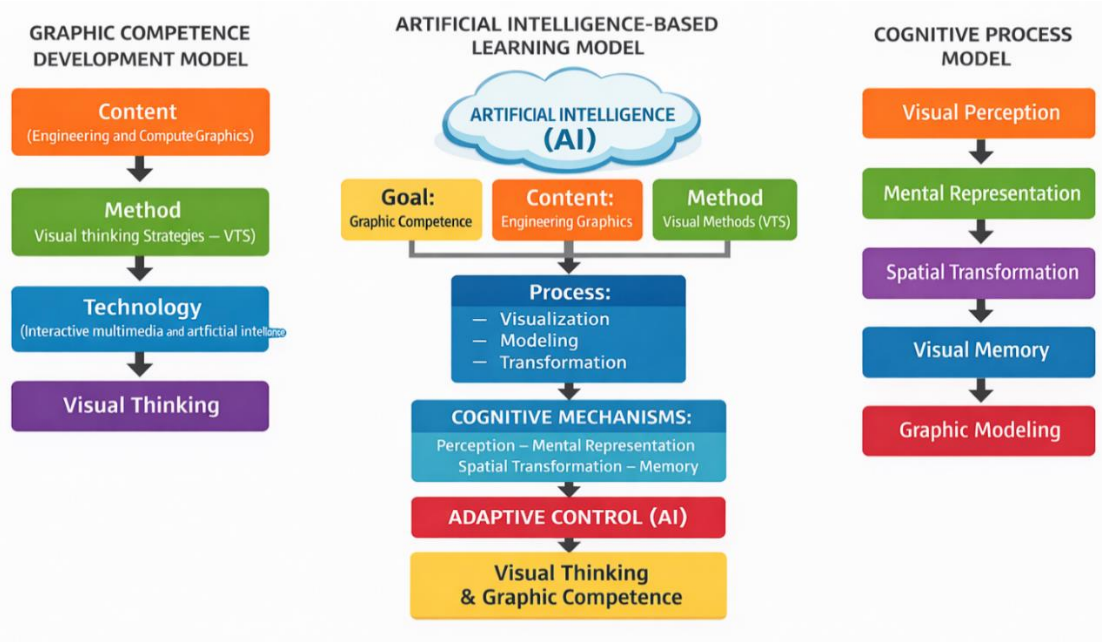


**Figure 1. Integrative approach model**

**Scientific and Analytical Foundations of the Model System**

Within the framework of this study, the developed system of visual models represents the process of developing graphic competence in future engineers based on a systematic and integrative approach. This system consists of three interrelated models: the graphic competence development model, the artificial intelligence-based learning model, and the cognitive process model.

The first model—the graphic competence development model—is constructed based on the integration of three key components of the educational process: content, methodology, and technology. The content component encompasses the theoretical and practical foundations of engineering and computer graphics. The methodological component includes pedagogical strategies aimed at developing visual thinking, particularly Visual Thinking Strategies (VTS). The technological component supports the learning process through interactive multimedia tools and artificial intelligence systems. The integration of these three components leads to the formation of visual thinking, which in turn contributes to the development of graphic competence.

The second model—the artificial intelligence-based learning model—reflects a more complex and structured representation of the educational process. In this model, artificial intelligence functions as a central control element that coordinates the goal, content, and methodological components. The learning process is implemented through stages such as visualization, modeling, and transformation. These stages ensure the perception, processing, and transformation of graphical information into new knowledge by students.

A distinctive feature of this model is the выделение of cognitive mechanisms as a separate component. Processes such as perception, mental representation, spatial transformation, and memory form the psychological foundation of graphical activity. AI-based adaptive control enables the personalization of these processes, taking into account individual student characteristics and cognitive abilities. As a result, the effectiveness of the learning process is significantly enhanced.

The third model—the cognitive process model—describes the mechanism of visual thinking development in a sequential manner. It includes stages ranging from visual perception to mental representation, spatial transformation, visual memory, and graphic modeling. These stages are consistent with Gagné's instructional model and explain the process from knowledge acquisition to its practical application.

The integration of these three models demonstrates that the development of graphic competence cannot be achieved solely through technical or methodological approaches, but rather through the комплексное взаимодействие of cognitive, pedagogical, and technological factors. In particular, the application of artificial intelligence technologies transforms this process into an adaptive, flexible, and personalized system.

Thus, the proposed system of models provides both theoretical and practical foundations for the development of visual thinking and graphic competence in future engineers. This approach can serve as an effective methodological basis for improving modern engineering education.

The proposed approach is based on the integration of the following components: engineering graphics (content), visual methods (VTS), and interactive and AI-based technologies.

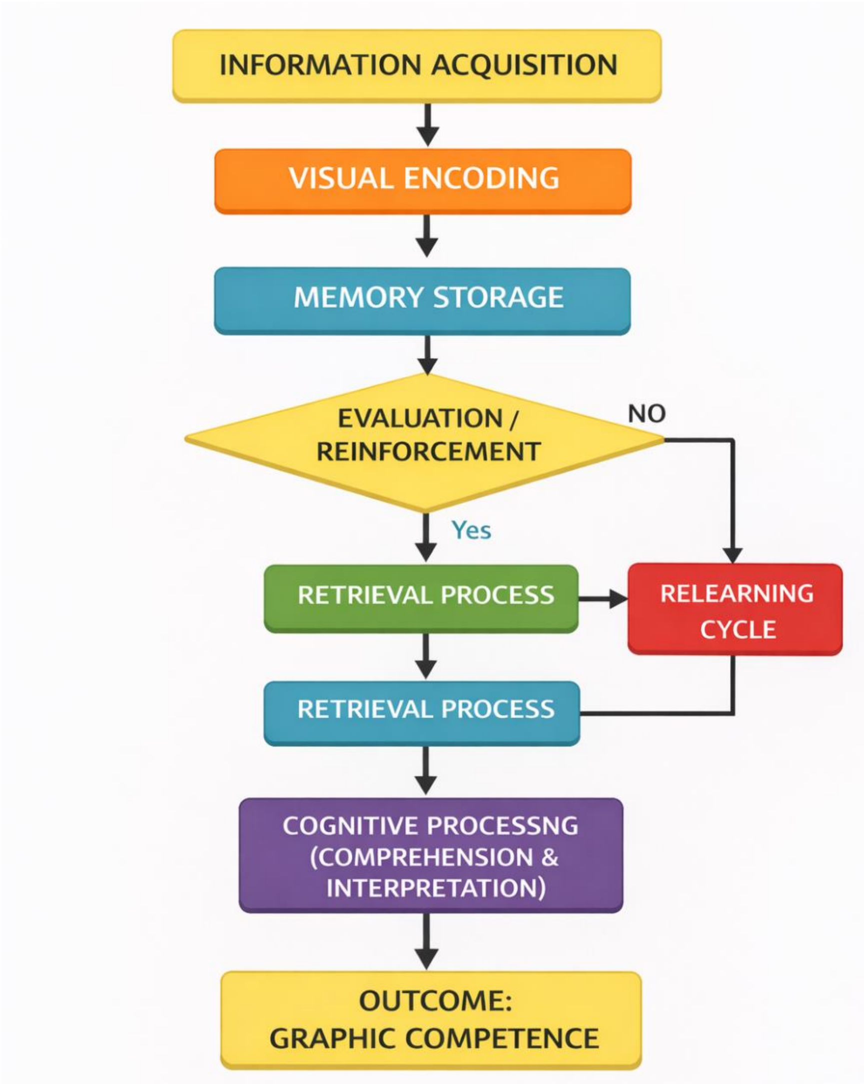


**Figure 2. Author's model**

**Model for Developing Visual Thinking and Graphic Competence Based on Cognitive Processes**

The proposed model systematically represents the process of developing visual thinking and graphic competence from the perspective of cognitive psychology. It encompasses stages ranging from information perception to processing, storage, and practical application.

The first stage—information perception—involves the reception of visual and graphical data from the external environment. At this stage, students perceive information through drawings, diagrams, and visual objects, which activates visual perception processes.

The next stage—visual encoding—involves the transformation of perceived information into meaningful cognitive structures. During this process, students convert graphical representations into mental models, which plays a crucial role in the development of visual thinking.

The third stage—storage (memory)—involves retaining encoded information in both short-term and long-term memory. At this stage, reinforcement, repetition, and the formation of cognitive connections are essential.

An important stage in the model is the verification (repetition) process. At this stage, students assess their level of understanding and mastery of the material. If the knowledge is insufficiently formed, the system automatically returns to the learning stage, ensuring the adaptive nature of the educational process.

During the retrieval stage, students activate stored information from memory. This process plays a key role in applying graphical knowledge in practice. Retrieval strengthens knowledge and enables its transfer to new contexts.

This is followed by the stage of comprehension and interpretation, where students deeply analyze information and integrate it with existing knowledge. This stage requires higher-order cognitive processes.

The final stage of the model is the outcome (graphic competence), which reflects the formation of visual thinking, spatial imagination, and graphical skills. This stage serves as a key indicator of professional preparedness in engineering education.

Thus, the proposed model reflects a step-by-step cognitive mechanism of information processing and provides both theoretical and practical foundations for the development of visual thinking and graphic competence. The integration of this model with artificial intelligence technologies enables the organization of the learning process in an adaptive and personalized manner.

## 4. Conclusion

The results of the conducted study indicate that the process of developing graphic competence in future engineers is inherently multifactorial and integrative in nature. Its effective implementation requires a coherent integration of content, methodology, and technology. Within this framework, visual thinking and spatial intelligence occupy a central position, forming the cognitive foundation of graphical activity.

The analysis confirms that methodological approaches aimed at developing visual thinking—particularly those based on visual discussion and interpretation strategies—play a significant role in enhancing students' analytical thinking and communication skills. At the same time, interactive multimedia technologies promote active student engagement, stimulate cognitive processes, and contribute to the durable acquisition of knowledge.

The content analysis of engineering and computer graphics demonstrates that projection techniques, modeling, and the development of spatial imagination are key factors in the formation of graphic competence. However, existing research in this area reveals a недостаточная интеграция of cognitive mechanisms, pedagogical methods, and modern digital technologies.

From this perspective, the integrative approach proposed in this study is aimed at addressing these limitations by unifying engineering graphics content, visual thinking-oriented methodologies, and interactive technologies based on artificial intelligence into a single system. This enables the transformation of the educational process into a cognitively grounded, adaptive, and effective system.

From the standpoint of Gagné's instructional model, the development of visual thinking is scientifically substantiated as a process involving stages such as attention activation, information perception, encoding, storage, and retrieval. The integration of these stages with engineering graphics activities ensures the systematic formation of students' graphic skills.

The findings also demonstrate that the incorporation of artificial intelligence technologies into the educational process significantly enhances the effectiveness of developing visual thinking and graphic competence. In particular, adaptive learning, personalization, and automated analysis create a learning environment that aligns with students' individual cognitive characteristics.

Based on the proposed model, an adaptive methodology for developing graphic competence has been designed. This methodology focuses on the step-by-step formation of visual thinking, the application of interactive technologies, and the personalization of the learning process through artificial intelligence.

In conclusion, the theoretical and practical approaches proposed in this study establish a scientific foundation for improving engineering education through the integration of visual thinking, cognitive mechanisms, and modern technologies. This approach can serve as an effective tool for developing the professional competence of future engineers.

## References


1. Mayer R. E. Multimedia Learning. – 2nd ed. – Cambridge: Cambridge University Press, 2009. – 304 p.
2. Paivio A. Mental Representations: A Dual Coding Approach. – Oxford: Oxford University Press, 1986. – 322 p.
3. Sweller J. Cognitive Load Theory. – New York: Springer, 2011. – 274 p.
4. Gardner H. Frames of Mind: The Theory of Multiple Intelligences. – New York: Basic Books, 1983. – 440 p.
5. Norman D. A. Things That Make Us Smart. – Reading: Addison-Wesley, 1993. – 271 p.
6. Zawacki-Richter O., Marín V. I., Bond M., Gouverneur F. Systematic Review of Research on Artificial Intelligence Applications in Higher Education // International Journal of Educational Technology in Higher Education. – 2020. – Vol. 17.
7. Holmes W., Tuomi I. State of the Art and Practice in AI in Education. – Luxembourg: Publications Office of the European Union, 2022. – 180 p.
8. Hegarty M. Spatial Thinking in STEM Education // Educational Psychology Review. – 2021.
9. Uttal D. H., Cohen C. A. Spatial Thinking and STEM Education // Psychology of Learning and Motivation. – 2020.
10. Sorby S. A. Developing Spatial Thinking in Engineering Students // Engineering Education. – 2020.
11. Выготский Л. С. Мышление и речь. – Москва: Педагогика, 1982. – 287 с.
12. Леонтьев А. Н. Деятельность. Сознание. Личность. – Москва: Политиздат, 1975. – 304 с.
13. Давыдов В. В. Теория развивающего обучения. – Москва: Интор, 1996. – 544 с.
14. Занков Л. В. Обучение и развитие. – Москва: Педагогика, 1975. – 320 с.
15. Bertoline G. R., Wiebe E. N. Technical Graphics Communication. – New York: McGraw-Hill, 2012. – 640 p.
16. Zeid I. CAD/CAM Theory and Practice. – New York: McGraw-Hill, 2009. – 944 p.
17. Ching F. D. K. Engineering Drawing and Design. – New York: Wiley, 2015. – 688 p.
18. Kahharov, A. A. (2021). Developing students' spatial imagination in teaching descriptive geometry and engineering graphics using computer technologies. International Journal of Education Research.
19. Kahharov, A. A. (2021). Intensive methods of developing students' spatial imagination in graphic sciences. Annals of the Romanian Society for Cell Biology, 25(4), 11885–11892.
20. Suzuki, K. (2014). Traditional descriptive geometry education in the 3D-CAD/CG era. Journal for Geometry and Graphics, 18(2), 249–258.
21. Suflyaeva, N. E. (2014). Modern aspects of teaching graphic disciplines in technical universities. Geometry and Graphics, 2(4), 28–32.
22. Khamrakulov, A. K. (2020). Implementation of computer technologies in teaching graphic disciplines. Universum: Psychology and Education, 6(72), 11–14.
23. Abdubannaevich, K. A., & Sharifjanovna, Q. M. (2023). Tools for developing students' design skills in technical education. International Journal of Research in Commerce, IT and Social Sciences, 17(8), 1–6.
24. Madumarov, K. K., & Qosimjonov, N. (2025). Using artificial intelligence technologies in modern self-directed learning environments. Latin American Journal of Education, 5(5), 413–416.
25. Inamidinova, D. K. (2025). Application of interactive and innovative technologies in engineering education. Economics and Society, 6(133), 310–314.
26. Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial intelligence in education: Promises and implications for teaching and learning. Center for

Curriculum Redesign.
**27.** Luckin, R. (2018). Machine learning and human intelligence: The future of education for the 21st century. UCL Institute of Education Press.
**28.** Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education. International Journal of Educational Technology in Higher Education, 16(39), 1–27.
**29.** Holmes W., Bialik M., Fadel C. Artificial intelligence in education: Promises and implications for teaching and learning. – Boston: Center for Curriculum Redesign, 2019.
**30.** Luckin R. Machine learning and human intelligence: The future of education for the 21st century. – London: UCL Institute of Education Press, 2018.
**31.** Zawacki-Richter O., Marín V.I., Bond M., Gouverneur F. Systematic review of research on artificial intelligence applications in higher education // International Journal of Educational Technology in Higher Education. – 2019. – Vol. 16. – Article 39.