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OPPORTUNITIES OF FRACTAL GRAPHICS IN THE CONTEXT OF DIGITIZATION

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Abstract: This article discusses the possibilities of digital education technologies and analyzes the works conducted by scholars on this topic. The article also explores the potential of fractal graphics in the context of digitization.
Keywords: digitization, artificial intelligence, Internet of Things (IoT), fractal graphics, fractal geometry, creative thinking, competence.

Today, advanced technologies like information and communication technologies (ICT), artificial intelligence, and the Internet of Things (IoT) are integrated into every aspect of life. In the future, these technologies will evolve and be widely applied across all sectors and aspects of social life, leading to the advent of the Industry 5.0 era, which will fundamentally transform the development of technology in society [1].

Therefore, it is essential to shape and develop future generations' competencies in digital technologies. To this end, it is vital to implement "equitable and individualized optimized learning" and "reform work methods in educational institutions" through the use of ICT. As technology continues to advance, research in education has shifted toward "learning based on digital technologies" in anticipation of Society 5.0 [2].

Improving the mechanisms of introducing digital technologies into the educational process is essential. Scholars from our country, the Commonwealth of Independent States (CIS), and abroad, such as G.C. Epgasheva [3], U.M. Mirsanov [4], H.I. Khanbabayev [1], H.R. Shodiyev [5], A.N. Gvintovkin [6], B. Dendeva [7], T.K. Klimenko [8], M.S. Luís [9], K. Peters [10], and A.B. Saleh [11], have conducted research in this field. According to them, the use of digital technologies in the educational process provides the following advantages:

Enhances students' engagement, motivation, and interest in the subject;

Facilitates ease of use, scenario modeling, and forecasting capabilities, complex sensory effects, enhanced audio-visual effects, and fosters information, research, and exploration skills;

Integrates traditional information sources with ICT tools to make the learning process vibrant, dynamic, non-traditional, and engaging;

Engages students in active collaboration, promoting individual and differentiated learning formats to increase student participation, resulting in conscious learning and cognitive activity that enhances and develops competency;

Conducts virtual experiments, enabling students to carry out laboratory activities in any place and time repeatedly, enhancing laboratory skills and promoting a culture of safety;

Improves the system of independent learning, allowing students to study independently the parts of a subject they have not mastered and to cover missed topics;

Provides a rapid feedback environment (educational interactivity);

Enhances the evaluation and control system, enabling students to independently assess their knowledge, skills, and competencies in the subject.

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Considering the advantages of digital technologies, it is advisable to use them actively in the educational process. Digital technologies are developing and improving rapidly, significantly affecting our lives, including how we work, spend leisure time, and, most importantly, access knowledge and information. Consequently, learners' perspectives shift as they encounter new approaches to learning.

In this regard, scholars such as X. Khanbabayev, I. Siddiqov, F. Shirinov, and M. Ikromova argue that students and young people are growing up in a world abundant with digital technologies. They appreciate learning with effective methodologies, cognitive theories, and emerging evidence-based data that help them understand and interpret our dynamic world and society in ways they recognize [12].

We believe that digital technologies, including digital educational technologies, foster students' creativity and creative thinking. Unlike traditional technical means, digital technologies not only enrich students with substantial, well-organized knowledge but also enhance their intellectual and creative abilities, allowing them to acquire new knowledge independently and develop the ability to work with various information sources.

Therefore, it is essential to develop effective ways of using digital educational technologies to enhance students' professional competencies. In creating digital educational technologies, computer graphics should be given special attention alongside subjects in the field of informatics, as computer graphics offer the potential to develop innovative and appealing educational resources.

As a result, the development of modern software tools, including graphic tools, is crucial in the context of advancing digital technologies. The development of graphic tools relies on computer graphics, defined as "a method of inputting, processing, and displaying graphic information." It encompasses processes for creating, storing, and processing models of objects and their images with the help of a personal computer (I.A. Konopleva et al.) [13].

The field of computer graphics has evolved alongside the development of informatics and information technologies. Today, computer graphics are highly advanced, and examples include three-dimensional moving objects, image-oriented hardware, and constantly emerging software.

Computer graphics have become a significant field within information technology, with distinct historical stages as researched by E.K. Henner. His research identifies three main stages in the development of computer graphics: pseudographic printing, using plotters to print graphic images on paper, and using graphical interfaces [15]. The last stage involves a transition from command interfaces to a user-friendly graphical interface, allowing for efficient and understandable interaction with graphical interface objects in an operating environment.

Analysis of educational literature from the 1980s and 1990s reveals that teaching computer graphics was generally associated with programming machine graphics algorithms [16]. In this period, computer graphics were recognized as machine graphics. Today, however, the field of machine graphics applications has expanded significantly.

In conclusion, the use of machine graphics reduces time spent on synthesizing, analyzing, and processing images. Consequently, teaching computer graphics should reflect these application areas. Studying machine graphics algorithms and methods involves solving problems through programming languages and environments [17].

Approaching computer (machine) graphics in this way is initially significant in terms of its content. The primary goal of teaching machine graphics is to study machine graphics algorithms, develop skills in solving geometric modeling problems, understand the role of machine graphics in engineering graphics,

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and more. In a machine graphics course, its mathematical foundations are explored, including geometric modeling; development of two- and three-dimensional algorithms such as the Sutherland-Cohen, Weiler-Atherton, Cyrus-Beck, and Sutherland-Hodgman algorithms; raster graphics algorithms, including Bresenham's line algorithm; methods for coloring and filling polygons to create circles; and algorithms for hidden line and surface removal [18]. To accomplish these tasks, fractal graphics are often used.

Fractal graphics are intriguing because they enable the creation of new types of objects and unusual properties through computer technology in artistic creation. In this, fractal geometry holds great significance. Currently, elements of fractal geometry are widely applied in many fields of human activity. Fractal methods for data compression and the fractal nature of communications are also common in information transmission [19]. Specialized programs and editors are being developed to work with fractals. Consequently, it is necessary to improve the teaching methodology for fractal graphics in today’s digital society, enhancing students’ logical, creative, and cognitive thinking and developing their competencies for working with fractal graphics.

In terms of research on this subject—namely, the theory and practice of teaching fractal graphics—research has been conducted by scholars such as E.S. Smirnova [20], V.A. Dalinger [21], and A.A. Babkin [22]. Specifically, E.S. Smirnova’s research justifies the use of teaching fractal geometry elements to foster future bachelor's scientific competence [20]. V.A. Dalinger’s work advocates using fractal graphics in undergraduate training within mathematics, natural sciences, and art, stating that applying fractal geometry contributes to the development of information-communication technology-related competence in specialists [21]. A.A. Babkin emphasizes the effectiveness of using fractal elements in integrating knowledge of geometry, mathematics, and informatics in the educational process of pedagogy colleges [22].

Furthermore, V.S. Sekovanov [23], E.S. Smirnova [24], and A.A. Babkin [25] have conducted research on the potential of fractal geometry. According to these researchers, fractal geometry can enhance students' interest in mathematics and informatics and foster research skills. Additionally, it provides the following opportunities:

Modeling complex processes and materials. For example, fractal modeling is useful for studying problems related to the distribution of galactic clusters across the Universe.

Accurate modeling of physiological processes such as human lungs, heartbeats, blood vessels, neurological systems, and many other complex processes.

Fractal algorithms allow for creating realistic representations of complex, highly irregular natural objects like mountainous terrains and intricate tree branches.

Fractal analysis simplifies calculations related to improving workplace safety, assessing promising resource development locations, and developing new structural materials.

In these areas, B. Mandelbrot has also conducted research and expressed the following view on fractal geometry: "Nature presents us with not only high but also perfect complexity on another level. The number of different scales, however close we come to describing them, is infinite. The presence of such structures brings challenges in solving existing problems because Euclid argued that there is no need to explore other shapes without using any rectitude. Mathematicians avoided this complexity and became increasingly distant from nature, inventing theories for things that have no emotional connection to what exists for our understanding.

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Consequently, it was discovered that nature's beauty can be created using fractals and fractal geometry" [26].

Thus, based on the above analysis, we can conclude that in the digital age, fractal graphics offer the following opportunities:

It enables students to study mathematics and geometry in greater depth.

It enhances students' logical and creative thinking related to programming and aids in developing their competencies.

It improves the ability to create various graphic projects.

It fosters students' research skills.

Given the opportunities that fractal graphics present, it is important to teach this field to students in higher education institutions. Therefore, this research holds significant relevance.

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