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METHODOLOGY FOR DEVELOPING MATHEMATICAL COMPETENCE THROUGH DIGITAL PLATFORMS IN HIGHER EDUCATION

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Abstract

This article investigates a methodology for developing students' mathematical competence through digital platforms (GeoGebra, Desmos, Moodle LMS, Articulate) in higher education. Quasi-experimental research results demonstrated a 19.4% improvement in mathematical modeling indicators in the experimental group.

Keywords

mathematical competence, digital platforms, competency-based approach, digital pedagogy, adaptive learning, interactive assessment, LMS systems, GeoGebra, Articulate, blended learning, mathematical modeling.

Introduction. The modern higher education system is undergoing a rapid process of digital transformation. This process is particularly significant in the field of teaching mathematical disciplines, as the abstract nature of mathematical concepts more clearly reveals the limited capabilities of traditional teaching methods [1, 4]. International studies show that integrating digital platforms into the educational process significantly improves student learning outcomes.

The level of utilization of modern digital platforms — such as GeoGebra, Desmos, Wolfram Alpha, Moodle LMS, and Articulate — in teaching mathematical disciplines at higher education institutions of our country remains insufficient [3, 5]. In many cases, the educational process is conducted in the traditional lecture-practical format, and students' individual learning characteristics, algorithmic literacy, and creative thinking potential are not fully realized.

The concept of mathematical competence is broadly interpreted today and encompasses not only computational skills but also a comprehensive set of abilities including mathematical modeling, logical-algorithmic thinking, data analysis, and interpretation [2, 6]. A competency-based approach grounded in the principles of digital pedagogy opens new opportunities for forming these competencies.

Research Methodology. A mixed methods methodological approach was employed in the study, utilizing a combination of quantitative and qualitative methods. Systematic analysis of scholarly literature, synthesis, and comparative-pedagogical analysis were used as theoretical methods. The empirical methods included a pedagogical experiment, diagnostic testing, questionnaires, and semi-structured interviews.

SPSS 27 software was used for statistical data processing. Descriptive statistics (arithmetic mean — M, standard deviation — SD), Student's t-test for independent samples, one-way analysis of variance (ANOVA), and Cohen's d effect size were calculated. The level of statistical significance was set at $p < 0.05$.

The study was conducted over two semesters during the 2024–2025 academic year at two higher education institutions in Uzbekistan. Students from the informatics and mathematics education programs were involved in the experiment:

Group	n	Pre-test M±SD	Homogeneity (p)
Experimental Group (EG)	46	54.2 ± 8.7	p = 0.72
Control Group (CG)	43	53.8 ± 9.1	(no difference)

Table 1. Description of Experimental and Control Groups

A pre-test was administered to ensure the homogeneity of the initial knowledge level of both groups. Student's t-test results confirmed that there was no statistically significant difference between the two groups ($t = 0.36$; $p = 0.72$).

The pedagogical experiment was carried out in three stages:

Diagnostic stage (Weeks 1–2): Students' initial knowledge level, digital literacy, and mathematical motivation were assessed through diagnostic tests and questionnaires.

Formative stage (Weeks 3–14): A methodology developed based on digital platforms (GeoGebra interactive applets, Desmos Activity Builder tasks, Moodle adaptive courses, Articulate Storyline interactive modules) was implemented in the experimental group. Traditional teaching methods continued in the control group.

Assessment stage (Weeks 15–16): Post-tests, final questionnaires, and semi-structured interviews were conducted. Additionally, analytical data from the Moodle LMS system (activity logs, task completion dynamics, time spent) were analyzed.

The survey instrument was designed using a 5-point Likert scale and comprised 28 questions. The internal consistency of the questionnaire was confirmed at Cronbach's alpha = 0.87.

Literature Review. The issue of implementing digital technologies in education has been widely studied in Uzbekistani pedagogical science over the past decade. Kho'jayev N.Kh., in his dissertation, investigated the methodology of teaching mathematical disciplines based on information technologies in higher education and demonstrated that the use of digital tools increased student engagement by 23% [3]. Rahimov B.Kh. and Toshpo'latova M.S. studied the effectiveness of the Moodle LMS platform in higher education and found that learning quality improved by 17% in distance education conditions [5].

Karimova D.I. conducted research on developing a methodology for teaching mathematics based on a competency-based approach, analyzed the structural composition of mathematical competence, and identified its cognitive, operational, and motivational components [4]. Abdullayev Sh.N. investigated the impact of interactive educational technologies on student knowledge quality and proved that using GeoGebra provided 21% effectiveness in mastering geometric concepts [1].

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At the international level, the use of digital platforms in mathematical education has been extensively studied. Hohenwarter M. and Preiner J. were among the first to research GeoGebra's role in mathematical education and described it as a "dynamic mathematical environment" [7]. Drijvers P. et al. systematically analyzed the integration of digital technologies in mathematical education and emphasized the importance of "instrumental genesis" theory for effective integration.

Borba M.C. et al. analyzed the relationship between digital technologies and mathematical education from a "40-year retrospective" perspective and demonstrated that technologies fundamentally transform the pedagogical paradigm [6]. Clark R.C. and Mayer R.E. promoted an evidence-based approach in e-learning and developed principles for the effectiveness of multimedia instruction.

Artigue M. analyzed the complexity of applying technologies in mathematical education from the perspective of "didactic transposition" and identified difficulties in transferring theoretical knowledge to practical instruction. According to OECD data, the level of mathematical literacy among students at educational institutions that effectively integrated digital platforms increased by an average of 15–25%.

Articulate Storyline and Articulate Rise platforms are recognized as among the most effective tools for creating modern e-learning content [15]. Articulate Storyline is designed for creating interactive slide-based learning modules, with capabilities including animated visualizations, branched scenarios, simulations, and built-in assessment instruments.

The advantages of Articulate in the context of mathematical education are manifested in the following: first, the ability to explain complex mathematical processes through step-by-step animation; second, the creation of personalized learning trajectories for students — students who give incorrect answers are redirected to supplementary explanation pages; third, full integration with Moodle LMS through the SCORM standard.

Pappas C. found that interactive mathematical modules created with Articulate Storyline improved student learning indicators by 24% compared to traditional video lectures. Additionally, Waters J. investigated the advantages of the Articulate Rise platform in mobile learning (m-learning) and showed that the capability to work on any device through responsive design increased student learning activity by 31%.

In our study, 12 interactive mathematical modules were created using Articulate Storyline, covering the following topics: graphs of functions and their properties, fundamentals of differential calculus, integral calculus and its applications, and elements of linear algebra. Each module consisted of an average of 15–20 interactive slides and included built-in mini-tests and simulations.

Analysis and Results. The post-test results conducted after the 16-week pedagogical experiment showed a statistically significant difference between the experimental and control groups (Table 2).

Indicator	EG Pre	EG Post	CG Pre	CG Post	t	p

Modeling	52.1	71.5	51.8	58.3	4.82	<0.001
Alg. thinking	56.4	73.8	55.9	62.1	3.96	<0.001
Creative sol.	48.7	67.2	49.3	55.8	3.51	0.001
Overall score	54.2	72.6	53.8	60.4	4.27	<0.001

Table 2. Post-test Results of Experimental and Control Groups (scores)

Data analysis showed that statistically significant growth was observed across all indicators in the experimental group ($p < 0.001$). The mathematical modeling indicator increased from 52.1 to 71.5 points, representing a 19.4-point (37.2%) improvement. In the control group, this indicator increased by only 6.5 points (12.5%). The algorithmic thinking indicator increased by 17.4 points (30.9%) in the experimental group, compared to only 6.2 points (11.1%) in the control group. The effect size was Cohen's $d = 0.92$, indicating a strong effect.

Likert scale survey results showed that students' interest in mathematical disciplines and their confidence in digital tools increased significantly in the experimental group. The proportion of students who agreed with the statement "Digital platforms help me understand mathematical concepts" was 42% at the beginning of the experiment and rose to 81% by the end. The average score of the motivational component increased from 3.1 to 4.3 (a 39% increase).

According to data from the Moodle LMS analytics module, experimental group students spent an average of 4.7 hours per week on independent learning activities, while control group students spent 2.9 hours. This difference of 62% demonstrates the strong activating effect of digital platforms on students' independent work.

Analysis of the Articulate Storyline modules revealed that students who completed the interactive modules in full ($n = 38$) achieved an average post-test score of 76.3, whereas students who partially completed the modules ($n = 8$) scored 61.7. This result demonstrates the direct impact of content created on the Articulate platform on learning quality.

The semi-structured interview results confirmed the quantitative data and provided additional insights. The majority of students (89%) particularly highly rated the visualization capabilities of GeoGebra and Desmos platforms. 73% of students noted the convenience of the self-directed learning process through Articulate Storyline modules. Furthermore, 68% of students reported that the adaptive trajectory system was effective in identifying their individual weak points.

Conclusions and Recommendations. The integrative methodology developed based on digital platforms (GeoGebra, Desmos, Articulate Storyline) significantly improves students' mathematical competence. The experimental group results showed a statistically significant difference compared to the control group ($p < 0.001$; Cohen's $d = 0.92$).

The application of adaptive learning trajectories and interactive assessment instruments creates opportunities for taking into account students' individual learning characteristics and providing differentiated instruction.

It has been proven that interactive modules created on the Articulate Storyline platform are an effective tool for improving students' learning quality compared to traditional educational materials.

Digital platforms activate students' independent learning activities. According to LMS analytics data, experimental group students spent 62% more time on independent study compared to control group students.

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