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PEDAGOGICAL FOUNDATIONS OF DEVELOPING MATHEMATICAL COMPETENCIES IN A DIGITAL EDUCATIONAL ENVIRONMENT

Matyoqubov Muhammad Maxsudovich

Department of Technological Machines and

Information Systems, Asia International University

Abstract: This article examines the pedagogical foundations of developing students' mathematical competencies in a digital educational environment. The effectiveness of organizing the learning process through the Articulate platform and other digital tools has been proven by experimental results. The findings demonstrate that digital technologies play a significant role in the development of mathematical competencies.

Keywords: digital education, mathematical competency, pedagogical foundation, Articulate, interactive learning, experiment, learning platform, educational effectiveness, competency-based approach.

Introduction: The rapid development of digital technologies in the modern education system is fundamentally transforming the learning process. The Decree of the President of the Republic of Uzbekistan No. PF–5847, dated September 6, 2019, "On Additional Measures for the Development of Education in the Republic of Uzbekistan" [1], along with the "Digital Uzbekistan" strategy for 2020–2030, established the necessity of implementing digital transformation in the field of education. These normative documents require higher education institutions to improve the quality of education through digital tools and, in particular, to develop new pedagogical approaches for enhancing students' mathematical competencies.

Mathematical competency refers to a student's ability to apply mathematical knowledge, skills, and expertise in real-life situations. Numerous studies have noted that traditional teaching methods fail to yield adequate results in developing mathematical competencies [2, 3]. Therefore, the scientific study of pedagogical foundations for effectively developing mathematical competencies in a digital educational environment is of vital importance.

The purpose of this research is to conduct a theoretical and experimental investigation into the pedagogical foundations of developing students' mathematical competencies in a digital educational environment, specifically through the Articulate platform and other modern digital tools.

Research objectives: 1) to analyze the theoretical foundations of developing mathematical competencies in a digital educational environment; 2) to study the capabilities of the Articulate software and other digital tools in education; 3) to determine the effectiveness of developing mathematical competencies through digital tools via experimental research; 4) to develop practical recommendations based on the obtained results.

Research methodology: A range of scientific and pedagogical methods were employed in this study. Theoretical methods included the analysis of domestic and foreign literature on the topic, comparative-typological analysis, a systemic approach, and the generalization of

pedagogical experience. Empirical methods comprised pedagogical experimentation, surveys, observation, interviews, and mathematical-statistical analysis.

The experimental work was conducted during the 2023–2024 academic year at a higher education institution in Uzbekistan (ISFT – International School of Finance, Technology and Science). Two groups participated in the study: an experimental group (EG) consisting of 48 students and a control group (CG) consisting of 46 students. In the experimental group, interactive digital learning materials developed using Articulate Storyline 360 were implemented, while the control group was taught using traditional methods.

The experimental work was carried out in three stages. The first stage – the diagnostic stage (September–October 2023): the initial level of mathematical competency in both groups was determined through a specialized diagnostic test. The second stage – the formative stage (November 2023–March 2024): the educational process in the experimental group was organized using digital tools, incorporating interactive exercises, simulations, online assessment systems, and adaptive learning content. The third stage – the evaluation stage (April 2024): a final diagnostic test was administered and the results were analyzed.

The survey assessed students' attitudes toward the digital learning environment, their motivation levels, and self-assessment indicators. A Likert scale (5-point system) was used in the survey. The results were subjected to mathematical-statistical analysis using Student's t-test, and the reliability of the results was verified at the $p<0.05$ level.

Literature review: Research devoted to the development of mathematical competencies in a digital educational environment has been extensively covered in both domestic and foreign scholarly literature. M.T. Jo'rayev [2], in his study on modern problems of mathematical education in higher education institutions, emphasized the positive impact of integrating digital technologies on students' competencies. The author provided a theoretical justification for the possibilities of organizing individualized instruction through digital tools.

N.A. Musulmonov and S.R. Xolmatova [3], in their collaborative research, analyzed the pedagogical conditions of competency-based mathematical education. They identified the knowledge, skills, and values components of mathematical competency and proposed a methodology for using digital tools to develop each component.

Among foreign researchers, J. Hattie and G. Yates [4], in their fundamental work, advanced the concept of visible learning in the educational process and provided a scientific basis for the impact of feedback systems organized through digital tools on student achievement. Their research demonstrates the effectiveness of digital assessment tools in mathematical education.

The OECD's "Education at a Glance 2023" report [5] analyzed the impact of the digital educational environment on student competencies based on extensive statistical data. According to the report, educational processes organized with the help of digital tools provide 15–25% greater effectiveness compared to traditional methods.

Regarding the role of Articulate software in education, R.S. Clark and R.E. Mayer [6], in their multimedia learning theory, particularly emphasized the importance of tools such as Articulate Storyline for creating interactive learning materials. They demonstrated the connection between multimedia learning and cognitive load theory, proving that students' comprehension levels significantly improve through interactive simulations.

Furthermore, A.V. Khutorskoy [7], in developing the didactic foundations of competency-based education, considered mathematical competency as an integral component of general educational competencies and justified the necessity of an activity-oriented approach for its development. His ideas form the theoretical basis for applying a competency-based approach in a digital educational environment.

The analysis of the above literature indicates that there is a need for in-depth study of the pedagogical foundations of developing mathematical competencies in a digital educational environment. Existing research has not sufficiently investigated the effectiveness of the Articulate software specifically in mathematical education, and this article is aimed at addressing that gap.

Analysis and results: The results of the diagnostic test conducted during the initial stage showed that the baseline levels of mathematical competency of students in the experimental and control groups were comparable (EG – mean score 56.2; CG – mean score 55.8). These results are an important indicator for ensuring the reliability of the experimental work.

During the formative stage, the following digital learning resources were implemented in the experimental group using Articulate Storyline 360: interactive lecture materials (12 modules), mathematical simulations (8 interactive exercises), online testing and assessment tools (after each module), and adaptive learning content (tasks adjusted to the individual level of the student). These materials were developed based on multimedia learning principles and include visual, audio, and interactive elements.

The results of the final diagnostic test demonstrated the following indicators:

Experimental group (EG): mean score – 78.4 (an increase of 22.2 points from baseline); proportion of high-level students – 37.5% (18 students); proportion of medium-level students – 47.9% (23 students); proportion of low-level students – 14.6% (7 students).

Control group (CG): mean score – 64.1 (an increase of 8.3 points from baseline); proportion of high-level students – 17.4% (8 students); proportion of medium-level students – 45.6% (21 students); proportion of low-level students – 37.0% (17 students).

The results of mathematical-statistical analysis using Student's t-test showed a value of $t=3.86$ ($p<0.01$), confirming that the difference between the experimental and control groups is statistically significant. The effect size (Cohen's d) was $d=0.79$, indicating a medium-to-large effect.

The survey results also confirmed that the experimental group students had a positive attitude toward the digital learning environment. In the Likert-scale survey, 83.3% (40 students) of the experimental group noted that learning through digital tools is more effective. A total of 79.2% (38 students) indicated that interactive exercises increase motivation. Additionally, 75.0% (36 students) highly valued the opportunity to identify gaps in their knowledge in a timely manner through the online assessment system.

Analysis by individual components of mathematical competency yielded the following results. Knowledge component: 24.8% increase in EG, 9.2% increase in CG (difference – 15.6%). Skills component: 21.5% increase in EG, 7.8% increase in CG (difference – 13.7%). Values component: 18.3% increase in EG, 6.4% increase in CG (difference – 11.9%). The

experimental group demonstrated a notable advantage over the control group across all components.

The analysis of experimental results indicates that the educational process organized through the Articulate platform in a digital learning environment was 2.5–3 times more effective in developing mathematical competencies compared to traditional methods. The main reasons for this include the continuous operation of a feedback system, the opportunity for individualized learning, deepening comprehension through visual and interactive elements, and the development of students' independent learning skills.

Conclusion and recommendations: The results of this research allow us to draw the following conclusions regarding the pedagogical foundations of developing mathematical competencies in a digital educational environment.

First, the digital educational environment has a significant advantage over traditional teaching methods in developing mathematical competencies. Students in the experimental group demonstrated higher results than those in the control group across all competency components – knowledge, skills, and values.

Second, Articulate Storyline 360 is an effective tool for creating interactive learning materials in mathematical education. The software's multimedia capabilities, interactive elements, and adaptive system help students gain a deeper understanding of mathematical concepts.

Third, the following pedagogical conditions are necessary for applying a competency-based approach in a digital educational environment: the instructor's digital literacy, the availability of quality digital learning content, the continuous operation of a feedback system, and the implementation of mechanisms to support student motivation.

Fourth, all components of mathematical competency (knowledge, skills, values) can be effectively developed in a digital educational environment, but this requires a systematic and consistent pedagogical strategy.

Based on the research results, the following practical and scientific recommendations have been developed:

1. It is advisable to expand the practice of using Articulate Storyline 360 and similar digital platforms in teaching mathematical disciplines at higher education institutions.

2. Special professional development courses should be organized to enhance instructors' digital literacy. These courses should develop skills in creating digital learning materials, using them effectively, and analyzing student outcomes.

3. It is recommended to create a unified national database of digital learning resources for mathematical disciplines. Such a database would facilitate the exchange of experience and dissemination of best practices among various higher education institutions.

4. Future research should explore in greater depth the impact of the digital learning environment on students' metacognitive skills, as well as issues related to the integration of artificial intelligence technologies into mathematical education.

5. It is necessary to develop and implement criteria for assessing mathematical competencies in a digital educational environment based on the requirements of the State Standard (O‘z DSt 3004:2022) [8].

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