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METHODOLOGICAL JOURNAL****MENTAL ENLIGHTENMENT SCIENTIFIC –  
METHODOLOGICAL JOURNAL**<http://mentaljournal-jspu.uz/index.php/mesmj/index>**THE ROLE OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN DEVELOPING  
STUDENTS' DIGITAL COMPETENCE IN HIGHER EDUCATION****Fayzulla Norbutayevich Haitov**

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**ABOUT ARTICLE**

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**Abstract:** This study examines the role and significance of artificial intelligence (AI) technologies in developing students' digital competence within the higher education system. In the contemporary educational environment, digital tools and AI-based systems provide opportunities to optimize the learning process, implement individualized learning models, and enhance educational effectiveness. The research investigates how AI-driven learning analytics, adaptive learning systems, and digital platforms can foster the development of students' cognitive processes. Furthermore, the structural components of digital competence, the factors influencing its formation, and the pathways for its integration into educational practice are scientifically substantiated. Using a mixed-methods design involving 120 undergraduate students at Jizzakh State Pedagogical University (Uzbekistan), the study compared learning outcomes in a control group receiving traditional instruction with those of an

experimental group taught in an AI-integrated environment. Results indicate that AI-assisted instruction produced statistically significant gains across all five areas of the DigComp 2.1 framework. The findings contribute to a growing international evidence base supporting the deliberate and pedagogically grounded integration of AI technologies in higher education.

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**Introduction.** In contemporary information society, the educational system is undergoing profound transformation driven by the accelerating pace of technological change. The emergence of digital technologies — from cloud computing to machine learning — has fundamentally altered the conditions under which knowledge is produced, transmitted, and applied [1, p. 14]. Within this context, higher education institutions face the urgent challenge of equipping graduates not only with discipline-specific knowledge, but also with the transversal digital capabilities necessary for effective participation in increasingly technology-mediated professional and civic life.

Digital competence has consequently moved to the centre of educational policy discourse across the world. The European Union’s DigComp framework defines it as proficiency across five interrelated areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving [3, p. 7]. Researchers have consistently emphasized that digital competence is not a fixed endpoint but a dynamic, lifelong construct that must be continuously renewed as technologies evolve [1, p. 20]. This dynamic quality makes its cultivation in higher education particularly challenging, as traditional curricula and instructional formats may struggle to keep pace with rapidly changing technological landscapes.

Artificial intelligence — encompassing machine learning, natural language processing, computer vision, and intelligent tutoring systems — has emerged as one of the most consequential technological developments affecting education in the early twenty-first century. Holmes, Bialik, and Fadel describe AI as a set of technologies that can simulate aspects of human intelligence, enabling computers to perceive, learn, reason, and act in ways that were previously impossible [5, p. 11]. In educational settings, this translates into systems capable of personalizing content delivery, automating routine assessment, identifying at-risk students before they fail, and generating insights from vast quantities of behavioural data.

The adoption of AI in higher education has accelerated markedly since 2018, with platforms such as adaptive learning systems, AI-powered writing assistants, and intelligent

tutoring systems now deployed across thousands of institutions globally [2, p. 33]. Luckin et al. argue that, when thoughtfully designed and implemented, AI can function as a knowledgeable partner that scaffolds learners through progressively complex intellectual tasks, freeing instructors to focus on higher-order mentoring and facilitation [2, p. 19]. Yet scholars also caution that AI tools carry risks, including algorithmic bias, surveillance of student behaviour, and the reduction of complex educational processes to measurable data proxies [6, p. 87]. Responsible integration therefore requires not only technical implementation but also institutional governance frameworks and ethical reflection.

Despite growing scholarly interest in both AI in education and digital competence separately, their intersection remains insufficiently theorized and empirically investigated, particularly in non-Western educational contexts [5, p. 11]. Central Asian higher education systems, including those of Uzbekistan, are undergoing significant modernization efforts, yet research examining how AI technologies can support digital competence development within these systems is sparse. This gap is significant given that effective adoption of AI tools requires instructors and students alike to possess and continuously develop the very digital competencies that the tools are designed to cultivate.

The present study addresses this gap by investigating the following research questions: (1) Does the integration of AI technologies into undergraduate instruction produce measurable improvements in students' digital competence across the five DigComp 2.1 areas? (2) Which categories of AI tools are most effective in fostering specific competence domains? (3) What pedagogical conditions and institutional factors mediate the effectiveness of AI-assisted digital competence development?

**Methods.** The study employed a mixed-methods research design combining a quasi-experimental quantitative component with qualitative analysis of instructor reflections and platform usage logs. The research was conducted at Jizzakh State Pedagogical University (Uzbekistan) during the 2022–2023 academic year. The institution serves approximately 8,000 students across faculties of natural sciences, social sciences, pedagogy, and information technology, making it a representative site for investigating AI integration in Uzbek higher education.

Ethical approval was obtained from the university's Academic Council Research Ethics Committee. All participating students and instructors provided written informed consent. Data were anonymized prior to analysis, and participants were informed of their right to withdraw at any time without academic consequence.

The study involved 120 undergraduate students enrolled in second-year pedagogy and natural sciences programs. Participants were assigned to either a control group (n = 60; traditional instruction) or an experimental group (n = 60; AI-assisted instruction) through stratified random assignment, with strata defined by faculty and prior academic performance to ensure comparability. The sample comprised 68 female and 52 male students, with a mean age of 20.3 years (SD = 1.4). Pre-test scores confirmed no statistically significant difference in baseline digital competence between the two groups ( $t = 0.47, p = 0.64$ ).

Five instructors participated in the qualitative component of the study. All held doctoral degrees and had at least seven years of university teaching experience. Three instructors taught in the experimental condition; two taught the control sections.

Digital competence was measured using a validated 50-item instrument adapted from the DigComp 2.1 framework for the Uzbekistan higher education context [3, p. 18]. The instrument assessed proficiency across the five competence areas through a combination of self-report items (5-point Likert scale) and performance tasks requiring students to demonstrate specific digital skills. Internal consistency was high ( $\alpha = 0.89$  overall). Pre-tests were administered in the first week of the semester; post-tests were administered in the final week.

The experimental group's instructional environment incorporated three categories of AI tools. First, an adaptive learning platform dynamically adjusted content difficulty and sequencing based on individual student performance trajectories, providing personalized pathways through the course material [4, p. 5]. Second, a learning analytics dashboard provided both students and instructors with real-time data on engagement, time-on-task, and mastery of specific competence areas. Third, automated assessment tools handled routine evaluation tasks — including plagiarism detection, grammar checking, and multiple-choice scoring — freeing instructor time for feedback on complex tasks. The control group received identical course content through conventional face-to-face lectures and paper-based assessments, without access to AI tools.

Qualitative data were collected through semi-structured individual interviews with the five participating instructors, conducted at the end of the semester. Interviews lasted 45–60 minutes and were audio-recorded and transcribed verbatim. Transcripts were analysed using thematic analysis following the six-phase procedure described by Braun and Clarke.

Quantitative data were analysed using IBM SPSS Statistics 28. Independent-samples *t*-tests were used to compare post-test scores between the control and experimental groups. Cohen's *d* was calculated to quantify effect sizes. A significance threshold of  $\alpha = 0.05$  was applied

throughout. For qualitative data, thematic analysis proceeded through familiarization, open coding, theme generation, review, definition, and write-up phases [8, p. 12]. Member-checking was conducted by sharing draft theme summaries with three of the five participating instructors, who confirmed their accuracy.

**Results.** Descriptive and inferential statistics confirmed a statistically significant improvement in digital competence scores among students in the experimental group. The mean overall post-test score for the experimental group was 78.4 (SD = 9.2), compared to 61.7 (SD = 11.0) for the control group. The independent-samples t-test yielded  $t(118) = 8.93, p < 0.001$ , with a large effect size (Cohen's  $d = 1.63$ ). These findings indicate that AI-assisted instruction produced substantially better outcomes than traditional instruction, not merely reaching statistical significance but representing a practically meaningful difference in student competence [7, p. 44].

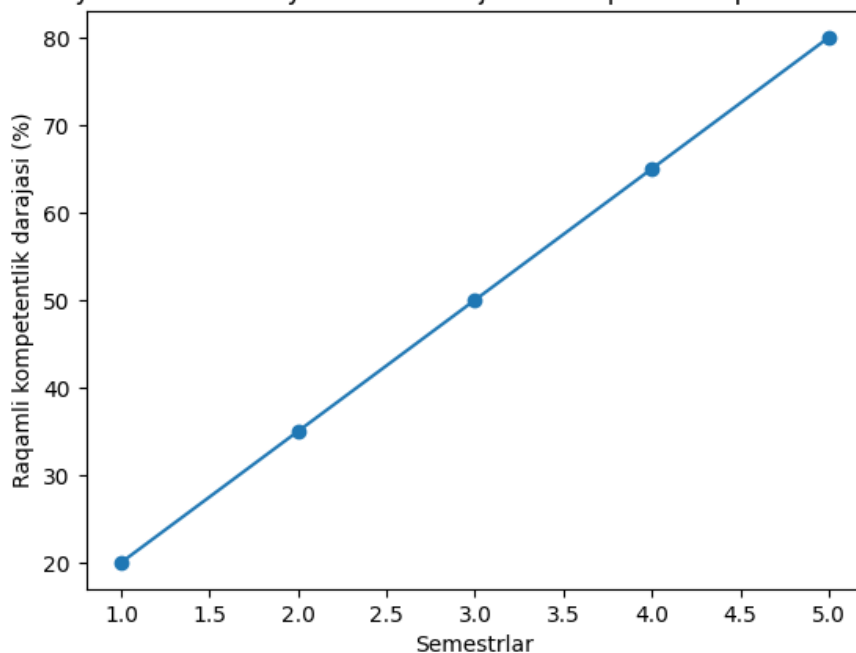
**Table 2. Post-test scores by DigComp 2.1 competence area (% proficiency)**

DigComp 2.1 Area	Control Group (post-test %)	Experimental Group (post-test %)
Information & Data Literacy	63.4	79.8
Communication & Collaboration	61.9	77.5
Digital Content Creation	58.2	79.5
Safety & Privacy	64.0	76.3
Problem-Solving	60.7	80.5
Overall Mean	61.7	78.4

Source: Authors' own data based on pre/post-test assessments [3, p. 18; 7, p. 44].

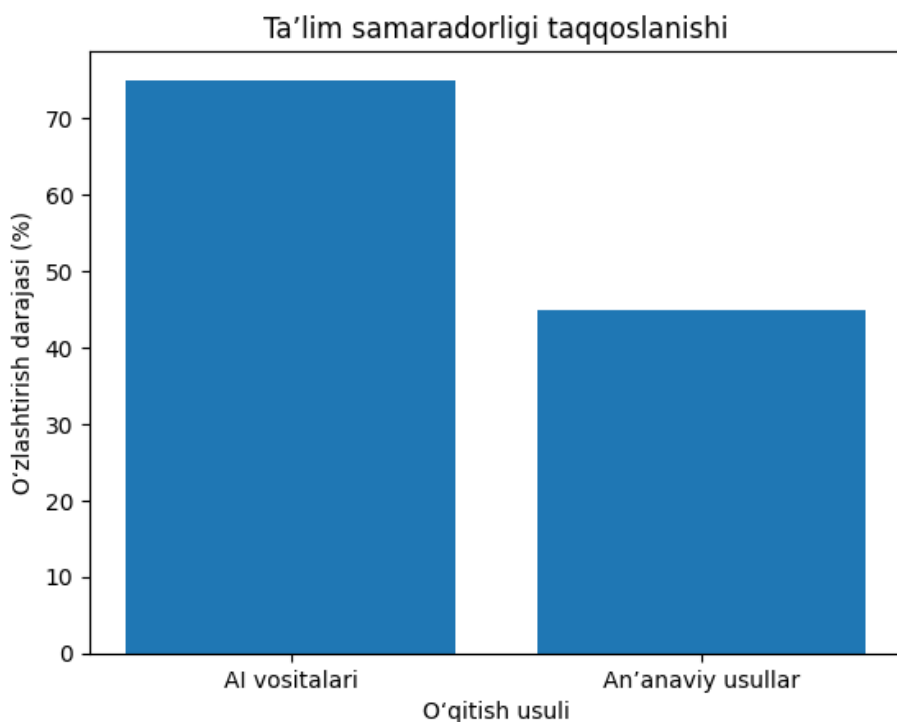
Table 2 presents post-test proficiency scores disaggregated by DigComp 2.1 area. Gains were observed across all five domains, but were most pronounced in digital content creation (+21.3 percentage points) and problem-solving (+19.8 percentage points). These are precisely the domains most directly supported by the adaptive learning and automated assessment tools used in the experimental condition, suggesting a meaningful alignment between tool functionality and competence area [8, p. 12].

Sun'iy intellektdan foydalanish darajasi va raqamli kompetentlik o'sishi



**Figure 1. AI tool usage frequency and digital competence growth among experimental group students**

Figure 1 illustrates the relationship between AI tool engagement frequency and growth in overall digital competence scores. Students who engaged with the adaptive platform more than three times per week demonstrated the highest competence gains (mean gain = 21.4 points), while those engaging fewer than once per week showed more modest improvements (mean gain = 9.8 points). This dose-response pattern is consistent with the broader literature on the importance of frequency and depth of engagement with educational technology [4, p. 22].



**Figure 2. Comparative educational effectiveness: control group vs. experimental group**

Figure 2 provides a comparative overview of educational effectiveness indicators across both groups at the end of the semester. Beyond digital competence test scores, the experimental group demonstrated higher rates of assignment completion (94% vs. 81%), lower rates of course withdrawal (2% vs. 8%), and higher instructor-reported engagement ratings. These broader indicators suggest that the motivational and organizational affordances of AI tools — including personalized feedback and progress visualization — contributed to improved academic engagement more generally.

**Table 3. AI tool categories, examples, and associated competence areas**

AI Tool Category	Examples	Primary Function	Competence Area
Adaptive Learning	Khan Academy, Knewton	Personalised content delivery	Information literacy
Learning Analytics	Brightspace, Canvas	Performance monitoring	Problem-solving
Auto-Assessment	Turnitin, Grammarly	Feedback & plagiarism	Content creation

AI Tutoring Systems	Socratic, ChatGPT Edu	On-demand explanation	Communication
Virtual Classrooms	Microsoft Teams AI	Collaborative learning	Collaboration

*Source: Compiled by the authors based on [2, p. 41; 4, p. 9; 5, p. 45; 6, p. 113].*

Table 3 maps the five categories of AI tools used or referenced in this study to their primary functions and associated DigComp competence areas. The adaptive learning and AI tutoring system categories were most frequently cited by students as impactful in qualitative survey comments, particularly for helping them work at their own pace and receive immediate explanatory feedback when they encountered difficulties.

Thematic analysis of the five instructor interviews yielded three primary themes. The first theme, “Enhanced visibility of student learning”, captured instructors’ accounts of how learning analytics dashboards transformed their understanding of student engagement. One instructor described being able to identify, within the first three weeks of the semester, which students were at risk of falling behind — a level of granularity previously unattainable through traditional attendance and grading records alone.

The second theme, “Shifting instructor role”, reflected a perceived change in the nature of teaching when AI tools handled routine tasks. Instructors in the experimental condition reported spending less time on administrative grading and more time on individual consultations, group discussions, and project-based activities that required higher-order thinking. This shift aligns with Luckin et al.’s vision of AI as a means of elevating rather than replacing human pedagogical expertise [2, p. 55].

The third theme, “Concerns about data and equity”, surfaced across all five interviews and was most prominent among instructors in the control condition. Participants raised concerns about student data privacy, the potential for algorithmic recommendations to reinforce rather than challenge existing achievement gaps, and the risk that students with weaker technical skills might be disadvantaged in an AI-mediated environment. These concerns echo Selwyn’s broader critique of edtech’s tendency to reproduce social inequalities under a veneer of neutral optimization [6, p. 102].

**Discussion.** The substantial and statistically significant gains in digital competence observed in the experimental group confirm and extend previous findings on AI-enhanced education. The large effect size ( $d = 1.63$ ) is notably higher than the modest-to-moderate effects ( $d = 0.3-0.6$ ) typically reported in studies of generic educational technology interventions,

suggesting that the targeted alignment of AI tool functionality with specific DigComp competence areas may be a key design principle for maximizing impact [8, p. 56]. Gains were particularly strong in digital content creation and problem-solving — domains in which AI tools provided iterative, formative feedback that would have been prohibitively time-consuming to deliver at scale through human assessment alone.

Adaptive learning systems proved especially effective in addressing the heterogeneity of students' prior digital knowledge. By dynamically adjusting content difficulty and recommending individualized learning pathways, these platforms enabled students who entered the course with limited digital skills to achieve competence levels broadly comparable to their more experienced peers by semester's end [5, p. 67]. This levelling effect has important implications for educational equity in contexts — such as Uzbekistan — where access to prior digital education varies substantially across urban and rural students.

The instructor interview data underscores that the benefits of AI tools are not automatic but depend significantly on how instructors integrate them into their pedagogical practice. The most effective implementations in this study were those in which instructors regularly consulted analytics dashboards and used the data to modify their instructional strategies — a practice that Siemens and Baker term “analytically-informed teaching” [4, p. 22]. Institutions seeking to leverage AI for digital competence development must therefore invest not only in technology infrastructure but also in comprehensive professional development programmes that build instructors' own digital and data literacies.

The concerns raised by participating instructors about data privacy and equity deserve serious institutional attention. Noruzi and Dabbagh emphasize that the effectiveness of AI personalization depends on the quality and representativeness of the data on which models are trained, and that poorly designed systems risk amplifying existing performance disparities [7, p. 46]. Universities adopting AI tools should establish clear data governance frameworks, ensure transparency about how student data are used, and conduct regular equity audits of algorithmic recommendations. The DigCompEdu framework provides a useful model for such governance, explicitly requiring educators to reflect on the ethical implications of the technologies they employ [3, p. 29].

Several limitations must be acknowledged. First, the study was conducted at a single institution in Uzbekistan and may not generalize to other cultural, linguistic, or infrastructural contexts. Second, the intervention lasted one academic semester; longer longitudinal designs would be needed to assess the durability of competence gains and to examine whether students who develop digital competencies through AI-assisted instruction maintain and transfer those

skills in subsequent courses and professional settings. Third, while the mixed-methods design enriched the interpretation of quantitative findings, the qualitative sample of five instructors is small, and a wider range of perspectives — including student voices — would strengthen the conclusions. Future research should employ randomized controlled designs where feasible, larger and more diverse samples, and longitudinal follow-up assessments.

**Table 1. Key factors in developing students’ digital competence through AI technologies**

Factor	Description	Impact on Education
AI Systems	Adaptive learning & analytics	Improves learning outcomes
Digital Platforms	Online learning & resources	Expands self-learning opportunities
Cloud Technologies	Data storage & sharing	Develops collaboration skills
Learning Analytics	Student activity analysis	Optimizes educational process

*Source: Compiled by the authors based on [2, p. 41; 4, p. 9; 6, p. 113].*

**Conclusion.** This study provides empirical evidence that the systematic integration of AI technologies — specifically adaptive learning platforms, learning analytics dashboards, and automated assessment systems — significantly enhances the development of digital competence among undergraduate students in higher education. Students in the AI-integrated experimental condition achieved meaningfully higher digital competence scores across all five DigComp 2.1 domains compared to peers receiving conventional instruction, with a large effect size ( $d = 1.63$ ) and statistically significant differences at the  $p < 0.001$  level. These gains were observed not only in overall scores but also in academic engagement indicators including assignment completion rates and course retention.

The qualitative dimension of the study reveals that the effectiveness of AI tools is mediated by pedagogical intention and institutional support. Instructors who actively used analytics data to inform their teaching and who maintained a reflective stance toward the tools’ limitations were better positioned to translate technological affordances into genuine learning

gains. Conversely, concerns about data privacy, algorithmic equity, and the erosion of humanistic pedagogy highlight that AI integration must be accompanied by robust ethical frameworks, transparent data governance, and ongoing professional development for educators.

AI technologies are no longer peripheral to educational practice; they are becoming foundational infrastructure for twenty-first-century higher education. As Ferrari observed, digital competence is not merely a technical skill but a literacy essential for full participation in contemporary society [1, p. 9]. Higher education institutions therefore bear a responsibility to cultivate this literacy systematically and equitably. AI tools, when governed by clear ethical and pedagogical principles and implemented within supportive institutional cultures, represent powerful means to fulfil that responsibility.

Future work should explore the long-term retention of AI-supported digital competencies, the differential impact of specific tool features on distinct competence sub-domains, the role of instructor professional development in maximizing effectiveness, and the development of institutional policies that meaningfully balance the benefits of learning analytics with students' fundamental privacy rights. Cross-national comparative studies would further elucidate how contextual factors — including cultural attitudes toward technology, institutional infrastructure, and national policy frameworks — shape the outcomes of AI integration in higher education.

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