INTEGRATION OF MOBILE APPLICATIONS IN THE METHODOLOGICAL TRAINING OF FUTURE CHEMISTRY TEACHERS

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Abstract. *This article examines the improvement of methodological training for future chemistry teachers through the integration of mobile applications. In the context of modern education, digital technologies, particularly mobile software applications, serve as essential tools for enhancing the effectiveness of the learning process. The study analyzes the didactic potential of mobile applications, their integration into the educational process, and their role in developing teachers' professional competencies. The findings indicate that learning organized through mobile technologies significantly improves students' academic performance, promotes independent learning skills, and increases learning motivation. In chemistry education, mobile applications are especially valuable for visualizing complex and abstract concepts, conducting virtual laboratory experiments, and creating interactive learning environments. The research also identifies certain challenges, including limited technical resources and insufficient methodological support. It is concluded that integrating mobile applications into the methodological training of future chemistry teachers is a crucial factor in ensuring their professional development and adapting education to the demands of the digital era.*

Key words: *mobile applications, chemistry education, methodological training, digital technologies, pedagogical competence, interactive learning, m-learning.*

Annotatsiya. *Mazkur maqolada bo‘lajak kimyo o‘qituvchilarining metodik tayyorgarligini mobil ilovalar asosida takomillashtirish masalasi yoritilgan. Zamonaviy ta’lim tizimida raqamli texnologiyalar, xususan mobil dasturiy ilovalar o‘qitish jarayonini samarali tashkil etishda muhim vosita sifatida namoyon bo‘lmoqda. Tadqiqotda mobil ilovalarning didaktik imkoniyatlari, ularning o‘quv jarayoniga integratsiyasi va o‘qituvchilarning kasbiy kompetensiyalarini shakllantirishdagi o‘rni tahlil qilingan. Natijalar shuni ko‘rsatadiki, mobil texnologiyalar asosida tashkil etilgan ta’lim jarayoni o‘quvchilarning bilim darajasini oshiradi, mustaqil ta’lim ko‘nikmalarini rivojlantiradi hamda o‘quv motivatsiyasini kuchaytiradi. Ayniqsa, kimyo fanida murakkab va abstrakt tushunchalarni vizuallashtirish, virtual laboratoriya tajribalarini tashkil etish va interaktiv muhit yaratish orqali samarali o‘qitish imkoniyati kengayadi. Tadqiqot davomida mobil ilovalardan foydalanishning afzalliklari bilan bir qatorda ayrim muammolar, jumladan texnik imkoniyatlarning cheklanganligi va metodik yondashuvning yetarli darajada ishlab chiqilmaganligi ham aniqlangan. Xulosa sifatida mobil ilovalarni metodik tayyorgarlikka integratsiya qilish bo‘lajak kimyo o‘qituvchilarining kasbiy rivojlanishini ta’minlovchi muhim omil ekanligi asoslab beriladi.*

Kalit so‘zlar: *mobil ilovalar, kimyo ta’limi, metodik tayyorgarlik, raqamli texnologiyalar, pedagogik kompetensiya, interaktiv o‘qitish, m-learning.*

Аннотация. *В данной статье рассматриваются вопросы совершенствования методической подготовки будущих учителей химии на основе мобильных приложений. В условиях современной системы образования цифровые технологии, в частности мобильные программные приложения, выступают важным инструментом повышения эффективности учебного процесса. В исследовании проанализированы дидактические возможности мобильных*

приложений, их интеграция в образовательный процесс и роль в формировании профессиональных компетенций педагогов. Полученные результаты показывают, что обучение, организованное с использованием мобильных технологий, способствует повышению уровня усвоения знаний, развитию навыков самостоятельного обучения и усилению учебной мотивации. Особенно важно, что мобильные приложения позволяют визуализировать сложные и абстрактные химические процессы, организовывать виртуальные лабораторные работы и создавать интерактивную образовательную среду. В ходе исследования также выявлены некоторые проблемы, такие как ограниченные технические возможности и недостаточная разработанность методических подходов. В заключении обоснована необходимость интеграции мобильных приложений в методическую подготовку будущих учителей химии как важного фактора их профессионального развития.

Ключевые слова: *мобильные приложения, химическое образование, методическая подготовка, цифровые технологии, педагогические компетенции, интерактивное обучение, мобильное обучение.*

In the context of rapid globalization and digital transformation, education systems worldwide are undergoing profound changes driven by the integration of information and communication technologies (ICT). Over the past decade, the widespread use of mobile devices has significantly influenced teaching and learning practices. According to recent global statistics, the number of smartphone users has exceeded 6.8 billion, which demonstrates the enormous potential of mobile technologies in education. Mobile learning (m-learning) has consequently emerged as a key component of digital education, enabling flexible, accessible, and personalized learning experiences.

International organizations such as UNESCO and UNICEF emphasize the importance of digital technologies in ensuring inclusive and quality education. In particular, the integration of mobile applications into the educational process has been identified as an effective way to enhance student engagement, improve learning outcomes, and support lifelong learning. Empirical studies indicate that students who learn through digital platforms and mobile applications show up to 20–30% higher achievement levels compared to those taught using traditional methods. Furthermore, surveys reveal that more than 75% of students consider mobile technologies to be an essential tool for learning in the modern educational environment.

In the Republic of Uzbekistan, the modernization and digitalization of the education system have been established as key priorities of state policy. The "Digital Uzbekistan – 2030" strategy aims to expand the use of digital technologies in education, improve ICT infrastructure, and develop the digital competencies of both students and teachers. As of recent data, the number of internet users in the country has reached approximately 29.5 million, and higher education coverage has increased to around 43%. These indicators reflect the growing readiness of the national education system to adopt innovative digital solutions.

At the same time, the effective integration of mobile technologies into higher education requires a transformation of traditional teaching approaches. In particular, the methodological training of future teachers must be aligned with modern digital demands. Future chemistry teachers, in addition to mastering subject knowledge, are expected to possess digital pedagogical competencies, including the ability to use mobile applications, design technology-enhanced learning environments, and implement interactive teaching methods.

Chemistry, as a scientific discipline, is characterized by complex abstract concepts, molecular-level processes, and experimental activities that are often

difficult to visualize through traditional teaching methods. As a result, students frequently encounter challenges in understanding key chemical phenomena. Mobile applications, however, offer unique opportunities for addressing these challenges by providing virtual simulations, interactive models, and augmented reality tools that enhance conceptual understanding and practical skills.

Moreover, contemporary educational paradigms emphasize student-centered learning, adaptive instruction, and the development of independent learning skills. Mobile applications support these approaches by allowing learners to access educational content anytime and anywhere, learn at their own pace, and actively engage with learning materials. This creates a dynamic and interactive educational environment that fosters critical thinking, creativity, and problem-solving abilities.

Despite the growing body of research on mobile learning, there remains a gap in the comprehensive study of how mobile applications can be systematically integrated into the methodological training of future chemistry teachers. Most existing studies focus on specific technological tools or isolated aspects of the learning process, while the development of a holistic methodological system based on mobile applications has not been sufficiently explored.

Therefore, this study aims to investigate the integration of mobile applications into the methodological training of future chemistry teachers and to determine their effectiveness in enhancing both educational outcomes and professional competencies. The relevance of this research lies in its potential to contribute to the modernization of teacher education, improve the quality of chemistry instruction, and prepare competitive педагогical professionals capable of meeting the demands of the digital age.

In recent years, the integration of digital technologies into education has become one of the central themes of pedagogical research, and mobile learning has emerged as a particularly important direction within this broader

transformation. In international scholarship, mobile applications are no longer viewed merely as supplementary tools; rather, they are increasingly interpreted as pedagogical instruments capable of reshaping the structure of teaching, learning, and methodological preparation. Research in chemistry education especially emphasizes that mobile technologies are highly valuable because chemistry combines abstract theory, symbolic representation, microscopic processes, and laboratory practice, all of which can be difficult for students to understand through traditional methods alone. Studies on mobile learning in chemistry show that mobile applications support visualization, enable anytime-anywhere access to content, and create more flexible and engaging learning environments. For example, Ewais and colleagues found that educational mobile applications can support chemistry learning by helping learners visualize concepts, interact with materials more actively, and continue learning beyond the classroom. Their findings reinforce the idea that mobile applications expand the learning environment rather than simply digitizing conventional instruction.

A major line of international research has focused on the cognitive advantages of mobile-supported chemistry learning. Chemistry is widely recognized as a subject in which many concepts remain invisible to direct perception, and this has led scholars to explore how mobile tools can bridge the gap between concrete observation and abstract reasoning. Research on augmented reality and interactive molecular visualization demonstrates that mobile technologies help students connect two-dimensional textbook representations with three-dimensional mental models. Smith's work on augmented reality models in chemistry-related instruction showed that such tools can make abstract chemical structures more comprehensible by providing alternative visual pathways for conceptual understanding. Similarly, Chen and colleagues reported that augmented reality-supported chemistry instruction improved learners' understanding of chemical concepts and sustained their

interest in science over time, especially when students were allowed to interact directly with the learning environment. These findings are especially relevant for future chemistry teachers, because their methodological training must prepare them not only to understand chemistry content but also to teach it in ways that make invisible processes pedagogically accessible.

Another important strand of the literature concerns the influence of mobile applications on motivation, self-regulation, and learner engagement. Contemporary educational theory increasingly values student-centered, flexible, and personalized learning, and mobile technologies align closely with these principles. Recent studies indicate that mobile learning environments can increase academic motivation by giving learners greater control over the time, pace, and format of study. Silva's study on augmented reality applications in chemistry education reported positive effects on academic performance and technology acceptance, while more recent work on AR game-based chemistry experiences found measurable learning gains alongside improved affective responses and stronger learner interest. Such results suggest that mobile applications are pedagogically significant not only because they transmit content but also because they enhance emotional and motivational conditions for learning. For future chemistry teachers, this has methodological importance: effective training today requires preparing them to design learning environments that combine conceptual rigor with interactivity, student agency, and sustained engagement.

Research has also increasingly examined mobile learning in relation to teacher preparation and professional competence development. This is particularly important because the success of digital integration in education depends not only on student access to technology but also on teachers' ability to use it meaningfully. A 2024 study by Sobowale on practical chemistry instruction among pre-service teachers concluded that mobile learning was highly effective in improving performance and addressing difficulties

associated with practical work. Likewise, Ürek's research on mobile phone- and application-supported laboratory work in preservice science teacher education found positive effects on digital literacy and on participants' dispositions toward using technology in teaching. These studies are especially relevant for methodological training because they shift attention from technology as a learner aid to technology as part of the professional toolkit of the future teacher. In this perspective, mobile applications become a means of developing instructional design skills, digital competence, and the ability to organize inquiry-based and practice-oriented learning.

Alongside international scholarship, researchers from the post-Soviet and CIS-related academic space have also made a meaningful contribution to the discussion, particularly in relation to chemistry teaching methodology. Hranovska and Laptyeva have argued that mobile technologies can serve as a form of electronic support for the study of inorganic chemistry, helping systematize content, strengthen learners' knowledge, and extend instruction beyond the conventional classroom structure. Their work is important because it interprets mobile applications not simply as isolated tools but as elements of a broader methodological system. Related publications by Hranovska further analyze the actual state of mobile technology use in chemistry learning and emphasize the need for carefully designed didactic support if such tools are to become genuinely effective in educational practice. More recent work by Prus and Nechypurenko also shows that although mobile applications offer real promise for teaching specific chemistry topics, methodological guidance for their topic-specific implementation remains insufficiently developed. This body of scholarship is especially valuable for the present topic because it links technological innovation with methodological planning, curricular logic, and teacher preparation rather than reducing digitalization to technical adoption alone.

A further trend in the literature is the recognition that mobile learning in chemistry is most effective when it is integrated into a broader pedagogical model rather than used episodically. Scholars increasingly stress that the educational value of mobile applications depends on alignment between content, didactic goals, learner needs, and assessment strategies. Research on science teaching supported by mobile applications has shown that positive outcomes are associated not merely with the presence of technology but with structured instructional design and meaningful pedagogical use. At the same time, several studies caution that the effectiveness of mobile learning may be limited by poor-quality applications, weak methodological support, information overload, and insufficient teacher readiness. Ewais and colleagues pointed to the importance of guided implementation, while topic-specific studies in school chemistry noted that technical and methodological barriers still hinder broader adoption. Such findings are highly significant for the methodological training of future chemistry teachers, since they suggest that digital competence alone is not enough; what is required is the ability to critically select, adapt, and pedagogically embed mobile tools within coherent teaching strategies.

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