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## Digitalisation of higher education: a methodology for applying modern technology to science teaching

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### Abstract

**Relevance.** When investigating the peculiarities of social relations formation in the 21st century, it should be noted that to a greater extent they are formed under the influence of such phenomenon as digitalisation. Undoubtedly, this factor is also reflected in the educational environment, as evidenced by a number of government programs and plans to modernise this sphere. Thus, the relevance of the issue under study is extremely significant today; in particular, its results are a priority source for further research.

**Purpose.** The aim of this paper is therefore to investigate methods and approaches to introduce digital technologies and tools in the process of research in the field of science.

**Methodology.** Of course, this issue is broad enough in its content that a number of methodological tools must be used. In particular, the functional and methodological approaches, and the methods of analysis and synthesis, comparison, deduction, and generalisation.

**Results.** The research resulted in a several important conclusions, among which are both theoretical and practical foundations, which are the basis of the topic in question. Accordingly, the theoretical part analysed the general concepts that form the object of this study and reveal its internal structure. In the practical part, specific digital ways and tools that can be used to implement the learning process in higher education institutions have been studied.

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**Conclusions.** The study highlighted that digitalisation is the key to the successful development of the whole educational environment and to improving the quality of educational services in higher education institutions. The practical value of the work is revealed in the fact that it can be used both for the development of curricula in universities and as a source for further scientific developments. In particular, a priority issue for consideration in future research is the analysis of the main ways of involving artificial intelligence in the study of narrow disciplines.

**Keywords:** students; higher education institutions; educational process; innovative programmes; informatisation.

## **Introduction**

Currently, society is characterised by dynamic changes in all its spheres, in particular, scientific, technical, social and economic, cultural, and informational, which certainly affects the formation of global transformations not only in Kazakhstan, but around the world. Undoubtedly, it should be agreed that the process of digitalisation characterises such a feature of modern society as its adaptability to information and virtual technologies. The category “digital university” is now increasingly common in various state programmes and curricula, which demonstrates its priority as well as revealing the main directions of higher education development. Nevertheless, the particular attention to the issue of updating and modernising higher education institutions has been given as a direct result of the spread of the COVID-19 pandemic and the introduction of a number of quarantine restrictions, as they have all led to the transition of a number of public spheres to a distance mode [1].

As for the concept of “digitalisation of higher education”, when examining it, it should be noted that they are broader, both in scope and content, as opposed to the concept of “application of innovative information and communication technologies” to the educational activities of higher education institutions. Thus, a modernised digital university is a thoroughly reformed educational institution, both in structure and content, characterised by developed approaches to administration. In addition, an important feature of this category is the modernisation of human capital, and the development of the scientific activities of the subjects of the educational process [2]. When considering digitalisation in the context of science subjects, it should be noted that it is a priority in this process. This is due to the fact that the introduction of modernised approaches and innovative tools into the learning activities of students and teachers provides a number of positive changes. Among them, an increase in the level of digital literacy of all subjects of the learning process, the formation and improvement of several cognitive capabilities of digital universities, and an in-depth study of a particular discipline. At the same time, analysing the system of science disciplines, it should be noted that they are characterised by a number of complex features that the student must necessarily master, respectively, to accelerate and facilitate this process will be effective application of digital tools [3].

Thus, the transition from the foundations on which traditional universities are based to digital foundations results in both a quantitative increase in technical means and a reform of the aims, objectives, system ideology, starting principles and methods, and also the internal structure of the institution. In addition, there is an increasing tendency for certain digital universities to be cooperated into comprehensive educational institutions that operate without regard to political boundaries or

geography. It should, however, be understood, that changes are also reflected in the rules and requirements for the subjects of such learning activities. On this basis, it can be established that the change of traditional principles of organisation and provision of higher education institutions to digital ones, provokes a number of changes in areas such as normative, organisational, financial, social and economic, and ideological [4]. As for the starting point of digitalisation of higher education, they are enshrined in the Decree of the Government of the Republic of Kazakhstan No. 988 “On approval of the State Program for the Development of Education and Science of the Republic of Kazakhstan for 2020-2025” [5], and also in the State Programme “Digital Kazakhstan” [6]. Accordingly, these acts regulate the essence of the implementation of digitalisation, define the main tools for its implementation, and describe its main directions [7].

Thus, the main purpose of this research paper is to study the process of digital transformation of higher education in Kazakhstan, based on the analysis of priority ways and approaches for students to study science disciplines. For this purpose, the article performed a number of tasks. In particular, it established the essence of the concept of digitalisation and science disciplines and also considered their features and properties, and investigated the relationship between them. In addition, it studied various digital tools and approaches to enhance the learning process in the context of learning science disciplines.

## **Materials and Methods**

Studying the digitalisation of higher education in the context of the use of modern technologies and tools for the study of science disciplines is a rather complex and multidimensional process. This is explained by the fact that it includes a number of parts, each of which needs to be studied both separately and in general. Moreover, in order to obtain thorough results, the whole object of study should be analysed, its features examined, and the factors that influence it identified. Hence, the article used a functional methodological approach, the role of which is certainly of utmost priority for this work. Accordingly, it provided the basic organisational framework, including the aim and objectives, and also the research plan. Equally important is the dialectical approach, as it allowed the whole process of studying the topic to be divided into several stages. As a result, the whole range of necessary elements was organically considered, while this process allowed the main properties of the research object to be established.

As for the general methods for the research, they take the lead in this study. In particular, the method of analysis and synthesis were most responsible for shaping the theoretical part of the study. Consequently, the main concepts related to the issue under study, namely digitalisation and science disciplines, were studied on their basis. Moreover, both the specificities of each of them and

the interrelations between them were considered in the paper. In addition, a comparison method was used in the article, which formed the basis of the practical part of the work. Thus, it was used to compare a number of digital tools and approaches, in particular, to analyse their effectiveness and to identify the most effective among them. In addition, the different factors affected by the digital transformation were considered through the comparison method. The logical structure of this research study is largely developed on the basis of the method of deduction. Based on this, it can be established that the course of the research is revealed from its general aspects to specific ones. Accordingly, the general theoretical concepts and their specificities were studied at the beginning of the article, while the next part directly analysed a certain range of digital tools and approaches.

In order to draw conclusions and examine the results of the study, a synthesis method was used. It was also used to identify priority areas for future research work. The study was carried out in three phases. The first stage defined the basic organisational framework, including the aim and objectives of the work. In addition, the theoretical part of the paper was initiated. The second stage focused on the practical foundations of the topic under study, in particular analysing common digital tools, including games, prioritised for science learning. The third step reviewed the results and drew conclusions based on them.

## Results

Digitalisation is undoubtedly the main feature of a modernising society, as it is reflected in a number of social and economic spheres, including education. Accordingly, every developed state, including Kazakhstan, seeks to improve the social conditions that are the basis for the lives of its citizens. This can be explained by the fact that it is on the basis of digitalisation that the entire sphere of education is digitised, and it is especially important for higher education institutions, since it is this link that is responsible for training specialists in various specialties, i.e. increases the capacity of the state. Thus, the comprehensive implementation of digital technologies is usually based not only in the context of the implementation of changes in educational process equipment, but also relates to the development and integration of research activities of the subjects of the educational process. It should be noted that the digitalisation process in higher education institutions should not only change the understanding and perception of digitalisation, but also change the entire algorithm of the educational process and the corresponding provision of educational services to students. Thus, currently, the concept of digitalisation should be understood as the introduction of digital technologies and approaches to a certain area of social life, with the aim of its comprehensive and accelerated development.

As far as educational institutions are concerned, in this context, digital transformation is a specific mechanism for the multidimensional modernisation of the entire higher education environment, and for increasing the level of adaptability of the educational process. In addition, digitalisation creates opportunities for the rapid exchange of both experience and skills of the actors involved in the learning process, which is particularly relevant for science disciplines. Moreover, the essence of digital

transformation in the educational environment is revealed in the fact that it increases the adaptability of students and teachers to the implementation of online learning, which is necessary in the context of the COVID-19 pandemic. At the same time, when characterising the concept of digitalisation of the learning environment, it should be emphasised that it certainly increases the range of opportunities that individuals can obtain in the study of a number of disciplines, including science. Based on the main properties of the category in question, it can be established that through the use of digital tools and approaches in higher education institutions, it is possible to fully globalise the scientific environment, while increasing the efficiency of educational services provided, which undoubtedly has a positive impact on the social and economic level of the country. Modernisation of higher education institutions is therefore not a recommendation, but a prerequisite for a developed society, since it is an opportunity to provide students with quality knowledge and opportunities for successful future professional activity. Accordingly, all this is only possible through a logically structured strategy and also a well-established developments aimed at the development of both learning and research activities of the subjects of the learning process.

Analysing the regulatory documents related to the implementation of digitalisation in the public sphere, including education, it should be noted, that the main among them are the programs for the period from 2020 to 2025 [5], and also the State Programme “Digital Kazakhstan” [6]. The essence of the first is the implementation of digital technologies, directly aimed at updating and improving the scientific infrastructure. As for the State Programme “Digital Kazakhstan” [6], it is a comprehensive system of measures aimed at the development of social and economic conditions of the population, including through the attraction of digital funds. Having analysed the content of these documents directly in the context of higher education development, it can be established that they enshrine a number of changes and directions in which it should take place. In particular, special attention is paid to the fact that it is important not only to introduce digital tools into the educational process, but also to enhance the digital capacity of educational personnel in order to ensure effective communication between students and teachers. In addition, there is a general idea in these documents to replace the standard system of theoretical teaching materials with special online products, as this will not only help to modernise the information and quality of educational services, but also increase the number of teaching hours, both in the learning and research context of the actors in the learning process [8].

Thus, based on the content of the programmes evoked, it can be established that the process of digital transformation should take place in the form of modification of information resources and human potential, in particular teachers and their level of professional competence, modernisation of a comprehensive educational culture, socialisation of higher education subjects, communication between different educational institutions, optimisation of algorithms of the educational process implementation. Based on this, it can

be emphasised that, at the moment, the policy of digital transformation of education in Kazakhstan ensures and complies with a range of special principles, among which is the principle of urgency, timeliness, and quality of decision-making. That is, this process should be reflected in the high level of adaptability of the university to the specific target audience, which is especially important for students mastering scientific disciplines. Moreover, the implementation of this approach will allow the institution to increase its level of competitiveness, not only in the national but also in the international market of educational services [9].

Regarding the internal goals of digitalisation of higher education institutions, they are more focused on increasing both the level of efficiency and the quality of communication between both the student and teacher and the student and student from different higher education institutions. This aspect is extremely important, since it is the internal structure of the learning process and environment that needs to be primarily introduced in order to achieve the desired results in the external dimension, in particular through global innovative reforms and transformations [10]. The main feature of digital transformation of higher education is the implementation of compulsory and continuous monitoring of the educational and professional market, the result of which should be taken into consideration in the development of curricula and direct learning activities. This feature derives from the fact that the main purpose of digitalisation is to update a particular environment, in this case the educational one. Thus, in order for students in Kazakhstan to receive quality knowledge and be able to implement it effectively in their future professional activities, higher education institutions need to organise the educational process based on the requirements coming from a number of priority competencies of digitalisation [11; 12].

Based on the above analysis of the concepts of digitalisation and transformation of higher education in Kazakhstan, it can be argued that such educational institutions currently face a number of challenges that require the introduction of significant changes in the established algorithms of the learning process. Among them, the following can be highlighted, in particular the selection of the optimal way of digitalisation by each higher education institution, in the context of their profile; the obligation to develop and consolidate a rational structure and mechanism for the operation of the higher education institution; consideration of possible ways to cooperate such approaches to form a single effective learning system which will be the basis for the digital university. In addition, educational institutions in the context of digitalisation should consider how to effectively and optimally integrate elements of information and communication technology into the learning process, and this should be done separately for each particular university. Thus, the above processes confirm that digital transformation is an extremely complex and multidimensional mechanism, while its effectiveness is quite high, which obliges advanced higher education institutions to shift their activities from traditional principles and tools to digital ones, in order to meet the educational and professional interests and needs of students at a high level [13; 14].

## **Discussion**

Having studied the theoretical framework of the issue under study and having analysed the essence and purpose of digitalisation in higher education, it would be useful to consider in a specific way its implementation in the educational process, in the context of the study of science disciplines. First of all, it is necessary to consider statistical data that allow determining the priority of such a direction for the development of the Kazakhstani educational environment. Thus, the level of digital provision of higher education institutions in Kazakhstan is already 100%. To a greater extent, this indicator was influenced by the fact that in the period from 2019 to 2021 the entire educational process was implemented in a distance learning format, which in turn obliged all educational institutions to solve the problem of digital provision and digital competence of teaching staff. Accordingly, all higher education institutions are equipped with the necessary digital infrastructure, which certainly differs in its efficiency, depending on the particular university. Thus, currently 100% of higher education institutions have access to LMS (learning management system) platforms, of which 44% belong to Platonus, 10% to Univer, 35% to Moodle, and 11% to several others, including Classroom.

At the same time, it should be noted that a significant number of universities have formed and implemented individual learning platforms that are private and accessible only to students of a particular institution and also universal. Al-Farabi Kazakh National University is an example of this approach, as its specialists have developed a Kazakh mechanism called Jinalysroom, which is an analogue of well-known platforms such as Zoom and Teams. Already now, some 12626 accounts use this programme to organise online sessions [15].

An equally common digital tool in Kazakh universities is the electronic document management system, which is actively used in 83% of universities. In addition, as a rule, developed educational institutions allow students to use materials placed in digital libraries, which greatly facilitates the learning process and optimises it. As for the administration of higher education institutions and the educational environment, it is also subject to active digitalisation, in particular, online registrars are increasingly appearing in such institutions, online dean's office, or rector's office, which certainly has a positive impact on the speed of decision-making and also the communication of subjects of the educational process [16-18].

Equally important for this study is the analysis of statistics on examinations through digital means and methods, as this process in the educational environment is basically essential. In this case, it is about the implementation of proctoring system, which in turn is not only about examinations, but also about the verification of the student's identity and monitoring of his/her behaviour when completing the test work online. Accordingly, currently the most common system among universities in Kazakhstan is such as SEB (safe exam browser), which is an integrated proctoring system based on such mechanisms as LMS Platonus, Sirius, Moodle, Univer, Aero, Examus, Proctopus, Oqylyq, OES, Hesperus [19].

Based on the above statistics, it can be established that one of the main objectives of the digitalisation of higher

education in Kazakhstan has already been achieved, in particular the development and implementation of digital infrastructure. Thus, a number of innovative technologies and programmes have been installed in all higher education institutions, which are the basis of the educational process at the moment, and the capacity of the servers on which the above-mentioned platforms operate has been increased. Moreover, the development of digital infrastructure is also manifested in the increase in the speed of the Internet, and the development of teachers' digital capacity [20-22]. Considering the digitalisation process specifically in the context of students' study of science disciplines, it is worth noting that these include physics, chemistry, biology, astronomy, geography, geology, and ecology. Based on this list it is necessary to mention that each of them has some peculiarities that play an important role in the process of their mastering, mainly caused by the necessity of practical and laboratory works. Thus, students have to carry out learning activities in specially equipped rooms and laboratories, using a number of tools and elements. For this reason, during the digitalisation of higher education institutions in Kazakhstan, more than 7000 virtual laboratories have been created. In addition, a large number of online courses and also student self-testing have been developed to deepen knowledge in these disciplines [23].

Accordingly, in order to ensure that students have unhindered access to the science system, a number of changes have been introduced in higher education institutions. In particular, the capacity of servers responsible for virtual platforms, which host simulators and additional teaching material, has been increased; the purchase of a number of additional both computer and other digital equipment necessary for online laboratory work has been made. In addition, special attention should be paid to the process of development and establishment of virtual laboratories and tools necessary for students to perform science works, as they are responsible for organising the study of science disciplines online or in real life with the use of digital technology. It should be also focused on the fact that, to a greater extent, the educational process has been transformed from the traditional to the cloud environment, allowing the development and use of hybrid services. At the same time, there is an increase in the dynamics of both input and output channel of communication between students and teachers, which is a necessary element in the study of science disciplines [24; 25].

Studying the process of teaching and mastering science disciplines in higher education institutions, it should be noted that for its quality and effective implementation, with the help of digital tools and approaches, it is necessary that they should meet a set of requirements. Thus, such exercises and digital programmes should clearly touch the fundamentals of both science and engineering disciplines so that their role in the learning process is basic and reveals their essence, while allowing students to master the chosen one in depth. In addition, digital tools should be equipped with features that allow the student to use them to deepen the understanding and essence of a number of key and complex concepts underlying a particular science discipline. Consequently, digital transformation should help students to solve complex problems both in individual and several subject areas, which is certainly a priority

during the study of complex academic disciplines [26]. Particular attention should be paid to the fact that the teacher's selection of exercises and digital tools for organising the learning process should be based on the specific interests and views of a particular category of persons, in particular the study group. In doing so, priority should be given to the selection of digital tools which link students' learning activities to their life experiences. In this case, it is intended to optimise the learning process, which will form a more comfortable environment for the student and, as a result, will be reflected in the level of his or her knowledge, in a particular science discipline [27].

When focusing on specific tools and exercises for studying science disciplines, it should be noted that their range is extremely wide, and they differ both in their direction and in the way they are used. First of all, such digital tools as virtual reality glasses should be highlighted, as through their use students have the opportunity to carry out learning activities in special laboratories, while following the processes which cannot be reproduced in real life [28; 29]. Besides, due to specialised software, students can not only observe but also perform realistic virtual experiments themselves, including participation in collective projects. It should be noted that by applying innovative learning tools, in particular digital microscopes, students are able to interact with macro- and micro-objects, modify their structures accordingly, and reflect the results obtained. In the mathematical sciences, such approaches are revealed in the fact that students, through interactive whiteboards and projects, can shape mathematical objects, while defining features of their form and properties. Hence, based on this, digitalisation plays an important role not only during the learning process, but is also a necessary tool for engaging in research and scientific activities. Thus, it should be noted, that digital transformation effectively affects the entire educational environment, as it allows its dynamic development [30-32].

Based on the listed conditions and tools through which the digital transformation of higher education can be implemented, in the context of studying science disciplines, it is possible to form a list of exercises that allow to implement this process in game form. In particular, interactive quizzes used in 43% of Kazakh higher educational institutions. Their priority for the learning process is revealed in the fact that it can not only to check the already acquired knowledge of a student, but also to expand it. In this case, the use of special digital platforms or an interactive whiteboard is necessary in order to visualise this process and bring it closer to reality [33; 34]. In addition, the organisation of team competitions among groups of students, which is also a fairly common tool in 67% of higher education institutions, can be highlighted, consisting of their development of certain natural or mathematical virtual objects. This approach will allow the individual to discover his or her own potential and also to work in a group, dividing the roles between each other independently. Particular attention in this process should be paid to the fact that this process should necessarily be combined with the teacher, since it is in the course of such a game activity, he or she will be able to establish the strengths and weaknesses of each student, based on which an individual approach to each will be selected. Also, a popular phenomenon, especially when

studying science disciplines, in 34% of Kazakh universities is the use of digital platforms, where students can study an object in depth, in particular bring it closer and compare its features with other phenomena. In this case, both natural and mathematical categories are involved, especially those that cannot be reflected and analysed in real life.

The gamification process is becoming increasingly popular, as it is more connected with digital tools and instruments than anything else, which is characteristic of the approaches of 51% of higher education institutions in Kazakhstan. Accordingly, teachers can use specialised programmes consisting of special tasks and quests for students to organise the learning process. This approach is rather informal, which in turn allows making the learning environment comfortable, giving it a playful form. Such programmes can be included into the list as Kahoot, Mentimeter, and Socrative, in which one can choose a specific learning activity among the range of science disciplines. Based on the analysed frameworks and digital ways of organising the educational process in higher education institutions, it can be established, that they require not only normative, i.e. governmental changes, but also personal ones. In particular, this applies to the staffing of universities, since it is this factor that determines the efficiency and appropriateness of the digital transformation. Therefore, an equally important process is the qualitative training of both future pedagogical specialists and current educational personnel, in particular by means of special programmes and courses. As a result of the cooperation of high professional capacity with quality digital tools, a dynamic improvement of students' learning performance is expected, directly in the context of their mastery of science disciplines [35].

## **Conclusions**

As a result of the research, a range of theoretical and practical bases have been uncovered concerning the issue of digital transformation in general and directly in the context of science studies. Accordingly, in the theoretical

part, the concept of digitalisation and its dimensions in the educational environment was studied in depth. The main features and characteristics of this process were established, and also the factors affecting it. At the same time, the signs of digitalisation in Kazakhstan higher education institutions were considered, and the main provisions on which this process takes place were analysed. In addition, several digital tools and approaches have been studied and their impact on the learning environment and on the direct process of science learning has been established. In doing so, a number of conditions that effective digital tools have to meet were formed. They were also prioritised for both students and teachers.

Moreover, the paper has established a range of exercises through which traditional learning activities can be integrated into the digital transformation process and be more playful in nature. Accordingly, the advantages of this approach and its current relevance for Kazakhstan have been established. In addition, the paper looked at statistics on the percentage of higher educational institutions that meet the basic requirements of the digital society. It also analysed the frequency of use of a certain number of platforms and programmes aimed at improving the learning process, including the study of the system of science disciplines. Hence, based on this, digitalisation is the key to the successful development of the whole educational environment and to improving the quality of educational services in higher education institutions. Therefore, it is a priority for the forthcoming research to identify ways and tools to engage the mechanism of artificial intelligence in the process of mastering highly specialised disciplines by the students of higher education institutions of Kazakhstan.

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## **Conflict of Interest**

None.

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## **Цифровізація вищої освіти: методологія застосування сучасних технологій у викладанні природничих наук**

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### **Анотація**

**Актуальність.** Досліджуючи особливості формування суспільних відносин у 21 столітті, слід зазначити, що більшою мірою вони формуються під впливом такого явища, як цифровізація. Безперечно, цей чинник відбивається і на освітньому середовищі, про що свідчить низка державних програм і планів модернізації цієї сфери. Таким чином, актуальність досліджуваного питання є надзвичайно важливою на сьогоднішній день; зокрема, її результати є пріоритетним джерелом для подальших досліджень.

**Мета.** Таким чином, метою цієї статті є дослідження методів і підходів до впровадження цифрових технологій та інструментів у процес досліджень у сфері науки.

**Методологія.** Звичайно, це питання досить широке за своїм змістом, тому необхідно використовувати низку методичних засобів. Зокрема, функціонально-методологічний підходи, методи аналізу та синтезу, порівняння, дедукції та узагальнення.

**Результати.** У результаті дослідження було зроблено кілька важливих висновків, серед яких як теоретичні, так і практичні основи, які є основою розглянутої теми. Відповідно, у теоретичній частині проаналізовано загальні поняття, що утворюють об'єкт даного дослідження та розкривають його внутрішню структуру. У практичній частині вивчено конкретні цифрові способи та інструменти, які можна використовувати для реалізації процесу навчання у вищих навчальних закладах.

**Висновки.** Дослідження підкреслило, що цифровізація є запорукою успішного розвитку всього освітнього середовища та підвищення якості освітніх послуг у вищих навчальних закладах. Практична цінність роботи виявляється в тому, що вона може бути використана як для розробки навчальних програм у ВНЗ, так і як джерело для подальших наукових розробок. Зокрема, пріоритетним питанням для розгляду в майбутніх дослідженнях є аналіз основних шляхів залучення штучного інтелекту до вивчення вузьких дисциплін.

**Ключові слова:** студенти; вищі навчальні заклади; навчальний процес; інноваційні програми; інформатизація.