



ЦИФРОВІ ТЕХНОЛОГІЇ ЯК ЗАСІБ АДАПТИВНОГО НАВЧАННЯ ЗДОБУВАЧІВ ВИЩОЇ ОСВІТИ ІНФОРМАТИЦІ ТА МАТЕМАТИЦІ

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DIGITAL TECHNOLOGIES AS A MEANS OF ADAPTIVE LEARNING FOR HIGHER EDUCATION INFORMATICS AND MATHEMATICS

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АНОТАЦІЯ

Формулювання проблеми. В умовах онлайн/змішаного навчання актуальність дослідження щодо використання цифрових технологій як засобу адаптивного навчання здобувачів вищої освіти інформатиці та математиці незаперечна. Реалізація засад адаптивного навчання за допомогою цифрових технологій надає значні можливості для індивідуалізації й диференціації освітнього процесу відповідно до когнітивних особливостей та освітніх потреб кожного випускника.

Матеріали і методи. Дослідження опирається на праці вітчизняних і зарубіжних науковців. Використані теоретичні та практичні методи. За допомогою методів системного аналізу і теоретичного узагальнення проведено дослідження впровадження системи адаптивного навчання в умовах дистанційного навчання у Вінницькому державному педагогічному університеті імені М. Коцюбинського.

Результати. Обґрунтовано, що з розвитком електронного навчання стало можливим ефективно забезпечення адаптивності процесу навчання здобувачів вищої освіти інформатиці та математиці. Адаптація передбачає аналіз індивідуальних особливостей і початкового рівня підготовки здобувачів освіти, впровадження процесу інтерактивного навчання, оцінку критеріїв успішності для переходу на наступний рівень навчання тощо. Розглянуто методичні аспекти адаптивного навчання в інформаційній навчальній системі закладу вищої освіти.

Висновки. Система адаптивного навчання математики та інформатики забезпечує оптимальну адаптацію освітнього процесу до індивідуальних особливостей і персональних уподобань студента, сприяє активізації їхньої пізнавальної діяльності, підвищує мотивацію до навчання, надає можливість здійснювати моніторинг навчання і його коригувати для досягнення запланованих індивідуальних результатів. Адаптивна система навчання має потенціал для забезпечення повного залучення студентів у процес побудови власної індивідуальної освітньої траєкторії, розвитку їхньої активності, удосконалення індивідуалізації освітнього процесу тощо.

ABSTRACT

Formulation of the problem. In the context of online / blended learning, the relevance of research on the use of digital technologies as a means of adaptive learning for higher education in computer science and mathematics is undeniable. Implementation of the principles of adaptive learning with the help of digital technologies provides significant opportunities for individualization and differentiation of the educational process in accordance with the cognitive characteristics and educational needs of each graduate.

Materials and Methods. The study is based on the work of domestic and foreign scientists. Theoretical and practical methods are used. Using the methods of system analysis and theoretical generalization a study of the implementation of adaptive learning in distance learning at Vinnitsya Mykhailo Kotsiubynskiy State Pedagogical University.

Results. It is substantiated that with the development of e-learning it became possible to effectively ensure the adaptability of the learning process of higher education in computer science and mathematics. Adaptation involves the analysis of individual characteristics and the initial level of training of students, the implementation of the process of interactive learning, evaluation of success criteria for the transition to the next level of education and more. Methodical aspects of adaptive learning in the information educational system of a higher education institution are considered.

Conclusions. The system of adaptive teaching of mathematics and computer science provides the optimal adaptation of the educational process to individual characteristics and personal preferences of students, promotes their cognitive activity, increases motivation to learn, provides monitoring of learning, and adjusts it to achieve planned individual results. The adaptive learning system has the potential to ensure the full involvement of students in the process of building their individual educational trajectory, development of their activity, improving the individualization of the educational process, and more.

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КЛЮЧОВІ СЛОВА: адаптивне навчання; цифрові технології; освітній процес; здобувач вищої освіти; навчання математиці та інформатиці.

KEYWORDS: adaptive learning; digital technologies; educational process; higher education seeker; teaching mathematics and computer science.

INTRODUCTION

Formulation of the problem. The introduction of online/blended learning and the widespread use of e-learning technologies encourage higher education institutions to move to a new quality level of educational services. The introduction of innovative technologies and distance learning in higher education is one of the operational goals, the objectives of which are "to create an industry of innovative technologies and teaching aids that meet the world scientific and technical level; digitalization of all processes in the higher education system; standardization of distance learning as a form of higher education" (Strategy for the development of higher education in Ukraine for 2021-2031, 2020). Due to quarantine restrictions, the main priorities, which include the organization of the educational process regardless of the time and location of its participants, providing interactive work of students with educational content, adapting the learning process to individual characteristics, needs and characteristics of students, use of e-learning tools and services of wide practical significance. There are changes in teaching methods and technologies, in particular regarding the role and place of teachers (Titiun & Soia, 2018). From traditional teaching, broadcasting, transfer, and control of knowledge, the functions of research and teaching staff are transformed and focused on the creation and functioning of the educational environment and its management with the widespread use of digital technologies in full-time, part-time, dual, and mixed forms of learning and active student participation. ; self-education, internships, advanced training, participation in grant programs and other projects, etc.

Thus, new requirements are set for educational institutions that must prepare responsible individuals for adult life who can adapt to modern society. Hence one of the main goals – is to create conditions for each graduate to receive the level of education that corresponds to his abilities, interests, and capabilities. According to the principles of adaptive learning, teachers should focus their efforts on providing students with individualization of the pace of study, differentiated complication of educational material, and development of individual tasks taking into account the interests of students and by the profile of the educational institution. To implement adaptive learning, it is necessary to take into account the individual characteristics of students in the organization of their educational activities, which will allow students to build their educational trajectory, taking into account individual pace of learning, depth of learning, and educational needs. The effectiveness of such training will increase significantly with the use of digital and information and communication technologies, which will provide significant opportunities for expanding the individualization and differentiation of the educational process by the cognitive characteristics of students.

An analysis of recent research. A significant number of scientific works of philosophers are devoted to the problems of adaptation in education, including vocational education (V. Andrushchenko, H. Vasianovych, I. Ziaziun, V. Kremen), teachers (V. Bondar, S. Honcharenko, R. Hurevych, A. Dontsov, N. Kuzmina, V. Krutetskyi, O. Liashenko, L. Mitina, T. Opaliuk) and psychologists (L. Vyhotskyi, H. Kostiuk, S. Maksymenko, S. Rubinshtein) (Opaliuk, 2015).

In the article scientists (Mubaraka & Hamada, 2016) propose a new adaptive learning framework that classifies learners based on individual preferences in terms of understanding and processing information.

The authors of the article (Zweig & Chechik, 2017) claim that the exchange of information between several training agents can speed up learning. It could be particularly useful if learners operate in continuously changing environments because a learner could benefit from previous experience of another learner to adapt to their new environment. Such group-adaptive learning has numerous applications, from predicting financial time-series, through content recommendation systems, to visual understanding for adaptive autonomous agents.

The monograph (Bondar et al., 2018) highlights the theoretical and practical issues of content and methods of teacher training for the implementation of adaptive learning of students of general secondary education from the standpoint of the modern professional and personal paradigm of competitiveness.

The reports of the participants of the Sixth All-Ukrainian Scientific Forum with International Participation "Adaptive Processes in Education" (Yelnykova & Rostoka, 2021) highlighted current issues of the formation and development of adaptive processes in the national education system of Ukraine and revealed the methodological aspect of adaptive processes in education; adaptive technologies in the preparation of masters in the management of educational institutions; information analytics as a tool for regulating adaptive processes in education and the organization of scientific research; intensification of adaptive processes in the training of highly qualified specialists; adaptive management in education; adaptive education in preschool and general secondary education institutions; adaptive processes in the educational activities of domestic and foreign higher education institutions, appropriate decisions have been made.

The authors (Joo et al., 2021) study the types of visual presentations and tips; offer learning strategies for multi-representative adaptive learning; argue that visually adaptive learning should include individualized self-explanations; show that streamlining visual presentations by increasing their accuracy in learning materials and offering vanishing support for tips adapted to learning progress are two effective and additional ways to provide individual learning.

The author of the article (Kosovets, 2020) notes that the adopted curriculum of the discipline and the adapted content of education not only provide for the availability of educational topics and text presented in different forms but also offers other options that can help a particular student.

The analysis of the works shows that the main requirements for the implementation of the principle of adaptation are the flexibility of the educational process in educational institutions and the focus on students taking into account their educational characteristics.

The goal of the article. To substantiate expediency and methodical bases of the complex introduction of adaptive training of applicants of higher education to informatics and mathematics on use of digital technologies, to describe features of realization of the system of adaptive training in Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University.

RESEARCH METHODS

Our research is based on the work of domestic and foreign scholars, educators, and specialists who study the theoretical and methodological foundations of fundamental and modern provisions of pedagogical theory to implement the principles of adaptive learning in higher education, problems, and prospects of digital technology in education. The process of innovative learning tools and technologies in the system of adaptive learning. To achieve the goal of the research, theoretical methods (analysis of scientific and methodological sources, synthesis, comparison) and practical methods (observations, surveys, testing, etc.) were used. The method of logical generalization was used for theoretical substantiation of the significance of the tasks and clarification of key research concepts. Using the methods of system analysis and theoretical generalization a study of the implementation of adaptive learning in distance learning at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University.

RESEARCH RESULT AND DISCUSSION

With the development of e-learning, it has become possible to effectively ensure the adaptability of the learning process of higher education in informatics and mathematics: a wide range of digital technologies opens new learning opportunities, monitoring the pace of educational activities and learning levels of each student. Verification of results provides an opportunity for the teacher to analyze the situation, if necessary, change the criteria, methods, technologies, and algorithms of teaching. Today, adaptive learning is a modern automated version of personalized learning. In particular, the adaptation involves the analysis of individual characteristics and the initial level of training of students, the process of interactive learning, evaluation of success criteria for the transition to the next level of education. This is a system of adaptive learning aimed at improving the quality of students' learning. It consists of adaptive planning, adaptive testing, and/or adaptive presentation of educational content, in particular with the use of digital technologies.

Information learning systems are elements of adaptation and modeling of student activities, as adaptive learning systems must build the educational strategy of the learner about personalization. Usually, personalization involves adaptive interaction, adaptive access to the course, adaptive content of educational material, adaptive support for cooperation. The origins of adaptation technologies used in adaptive learning systems come from the field of information learning systems (adaptive planning, data mining, support for interactive tasks, support for ready-made tasks, and support collaboration) or from the field of adaptive hypermedia systems that correspond to three criteria: the hypermedia system must be hypertext or hypermedia, have a user model and adapt its hypermedia space using this model.

In the scientific and pedagogical literature (Rohrkemper & Corno 1988) the concept of "adaptive learning" is formulated as a set of forms, methods, tools, technologies, and approaches to learning, which provides an alternative and flexible concept that expands students' self-control and allows them to actively respond to educational material with the possibility of its further adaptation in the learning process.

The main didactic principles of adaptive learning in the modern information system are the principles of activity – implies that the activities of students based on adaptive technology should promote the development of not only the ability to solve problems according to a given algorithm, but also build algorithms for creative tasks; independence – is expressed in the fact that students develop the ability to navigate independently in new sections and topics, to think independently and find algorithms for new tasks; individuality – provides individualized ways of interaction between student and teacher, which contributes to the formation of students with a high level of intellectual development; systematicity and consistency – involves the logical, consistent formation of general and professional competencies in each topic, and the logical connection between different topics.

The principle of adaptability of education in computer science and mathematics is aimed at building individual educational programs, aimed at psychological correction of the stereotype of the individual, his thinking, and implementation mechanisms (Pryima, 2012).

Information training system for adaptive teaching of computer science and mathematics should: provide conditions for achieving educational goals; combine different types of presentation of educational materials, taking into account the individual characteristics of students in terms of perception of the material (visual, audio, or kinesthetic); be adapted to different forms and methods of teaching (Ohneviuk, 2004).

The inclusion of information systems in adaptive learning is based on the following models: *the information-educational model* is aimed at acquiring new knowledge, formation of skills, application of innovative pedagogical technologies, self-knowledge; *control-corrective and diagnostic model* involves the use of knowledge control tools, expert training systems, dialogic solution of practical problems; the *research model* is related to the formation of research abilities of students and is aimed at gaining research experience; *the communicative model* is aimed at regulating the choice of modes of communication and interaction (Pryima, 2012).

These models are interconnected and meet the requirements of adaptive learning.

When organizing the educational process based on an individual-oriented approach, it is recommended to use a set of adaptation criteria that complement each other and/or take into account different aspects of learning, namely: individual characteristics of different categories of students; different levels of their education; multilevel training of pedagogical and scientific-pedagogical workers; the possibility of creativity by all participants in the educational process; regional features of learning conditions; career guidance; features of the labor market, especially in specialized training in computer science and mathematics; flexibility of the system, which allows you to use a nonlinear method of obtaining the final result.

Scientists (Osadcha et al., 2021) specify the purpose of adaptive systems of individualization and personalization of professional training of future professionals in blended learning in the following tasks: 1) to implement technologies of adaptive learning in higher education: adaptation of teaching materials, adaptation control), adaptation of devices, adaptation of face-to-face classes; 2) to introduce an individual approach to the process of professional training in the system of distance and full-time learning through the study of individual qualities of students, support and support of individual educational program, individualization of the learning process, development of individual characteristics of students and formation of new

characteristics; 3) to organize a personal educational environment for professional training of future specialists, including electronic; 4) to implement the systematic use of modern information and communication technologies and modern technical means of education to ensure the training of future professionals in a blended learning environment; 5) monitor the formation of professional competence of future professionals in the adaptive system of higher education institutions.

The Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University has implemented a learning management system LMS "Collaborator" (hereinafter Collaborator) for the organization of distance learning of students. Collaborator corresponds to the described models of inclusion of information systems in adaptive learning and fully allows to implement of the tasks of adaptive systems. This is an internal university system of adaptive learning, which is accessed through pre-registration through the system administrator.

After successful registration, teachers can work in two modes: "Tutor" and "User". In the "Tutor" mode, the teacher has the opportunity to add adapted teaching material of relevant disciplines, which corresponds to individual educational characteristics and to control the knowledge of students. In the "User" mode, the teacher looks at the form in which the student will receive the sent study material.

To create the *information-learning model* of adaptive learning in Collaborator, the teacher places learning materials in the "Tutor" mode using the command of the main menu of **Resource Management** in the **Resources** section.

This section displays downloaded files of lectures, practical and laboratory work in pdf, docx, pptx, etc. (Figure 1).

Added teaching materials should be divided into separate **Topics**, such as lectures, laboratory tests, etc. This can also be done with the **Resource Management** command of the main menu of the system. For ease of searching for topics and resources, you should set a label, such as a specialty code or group number, that allows you to quickly search and sort by the label.

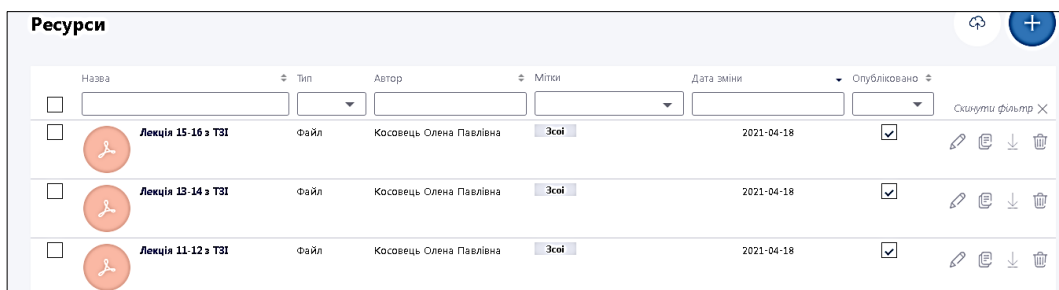


Figure 1. Adding training materials to the Collaborator

We recommend combining the grouped topics from the respective discipline into the **Curriculum** – this is the Collaborator section, in which the teacher places the work program of the discipline and combines all created topics with teaching materials, which ultimately give the full scope of the discipline. The teacher in the settings for individual topics can specify the date when to start training and sets the mode of access to educational materials of the discipline (go to the next topics when passed the previous task or completed the previous task, or completed all previous tasks) (Figure 2).

The next step in providing a control-corrective and diagnostic model of adaptive learning is the **Task Management** section. The developers of Collaborator stipulate that the teacher creates and sends tasks to the selected group of students for execution. To do this, you need to create **Tasks** based on added resources in the main menu of **Task Management** (pre-upload a file with a description of laboratory work in pdf format to the resources). The created task is displayed in the general list with parameters of editing, deletion. Also, use the **Assign** command button.

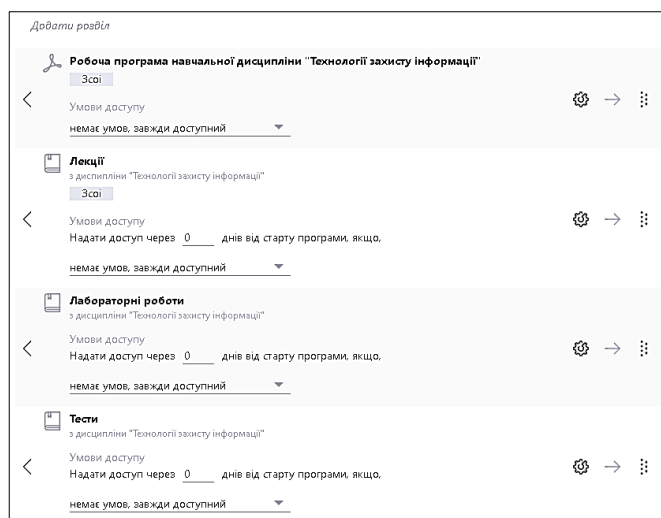


Figure 2. Creating a section of the Curriculum Collaborator

In the assignment window, you need to specify groups of students by department or label, select individual students to whom to send tasks to be performed using the **Assign Tasks** command. Students can be sent laboratory and practical

assignments, tests, etc. In response, the student sends a comment explanation or attaches a file with the completed task for assessment.

To implement the communicative model of adaptive learning, Collaborator has modern forms of communication and interaction between participants in the educational process at the **Forum** and in **Chats**. Chats can be group or personal. In the process of analyzing the submitted works of the student, the teacher has the opportunity to write questions, recommendations for feedback.

After the evaluation of the works, the **Training Reports** and **System Reports** are formed. In the study reports, the teacher receives a graphical and percentage report on the development of theoretical teaching material in the discipline, a report on laboratory (practical) group work, a test report, a report on individual student achievement (student learning history), and a consolidated report. Different forms of reports allow to fully assess the student's performance and monitor the formation of professional competence of future professionals in the adaptive system of higher education (Figure 3).

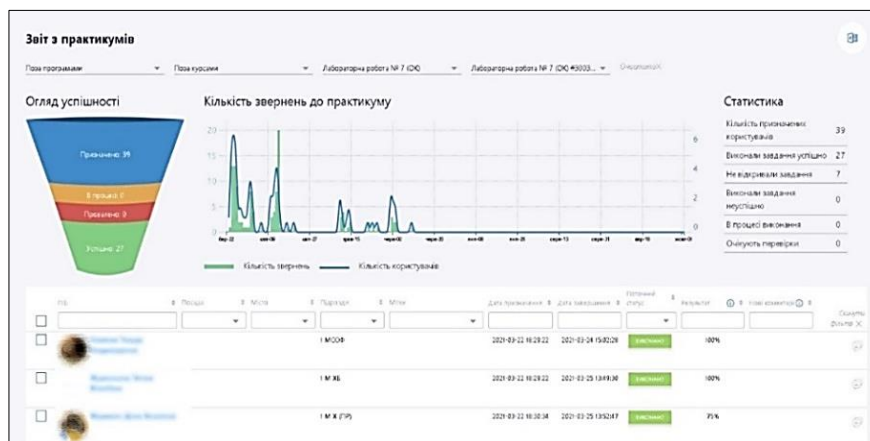


Figure 3. Collaborator Workshop Report

Let's compare Collaborator with the popular educational platform Moodle. Educational platforms Moodle and Collaborator provide an opportunity for teachers to create authors' distance learning courses in the curriculum of the discipline. Students receive many opportunities for remote access to educational materials, download files with completed tasks, tools for testing and communication, tools for group work (forums, chats, webinars, seminars, etc.), viewing the results of the training course, test results, etc. Students have access to a distance course on the Moodle and Collaborator platforms upon registration.

Adaptive learning technologies in Moodle are implemented by additional plug-ins that allow you to apply adaptive behavior to the learning trajectory of an individual student: adaptive Quiz, adaptive adapted for code runner, adaptive mode (multi-part questions), domoscio, and others.

In the absence of skills on the Moodle platform, the teacher has problems with content formats for creating and placing educational materials for the lesson. It is not always clear which element of the educational platform is best used to create a task. Designing one module of a distance course requires a lot of time, special knowledge, and skills to work with the platform.

Unlike Moodle Collaborator, it has an easy-to-use interface with intuitive menus and commands. You can master the basic principles of work in the educational system with the help of educational videos with short explanations, which are aimed at ordinary users of modern digital technologies and do not require special technical knowledge.

Disadvantages of Collaborator include the lack of grouping of student assignments by discipline, creating assignments and sending them to students is not convenient.

The lecturer of Vinnytsia Mykhailo Kotsiubynskiy State Pedagogical University using digital technologies to create conditions for adaptive learning through Collaborator provides the implementation of the above tasks of adaptive systems with the following tools: available in the system section Resources allows sections of the Program and Topics give the chance to organize an individual educational trajectory of the student; sections Tasks and Tests are designed to send tasks to selected groups of students, taking into account their individual qualities and special educational needs and the creation of test control of varying complexity; to monitor the formation of professional competencies of higher education students will help reports on the implementation of educational programs, reports on the implementation of laboratory and practical work, test reports, individual reports of individual student learning.

Given the capabilities of the described tools, Collaborator fully ensures the implementation of the main functions of the adaptive approach to learning: motivational function based on restructuring stereotypes of personality, understanding the active role of teachers in choosing strategies and methods of work; organizational and target, which is expressed in the approximation of the goals of those who participate in the educational process, taking into account the individual characteristics of students; content-design, which involves the selection of educational information, variability of curricula and programs, construction of new educational models; technological and managerial, which involves modeling, use of multilevel and differentiated learning, which includes a choice of forms and methods of teaching and changing socio-educational orientations.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The main purpose of implementing an adaptive education system in higher education is to use a flexible educational environment that provides teachers and students with different individual characteristics and personal preferences, modern digital tools to improve training. An important aspect of such a system of education is the focus of students on self-awareness,

analysis, and understanding, and not just on listening to and replicating educational material in the process of their professional training in higher education institutions. Under the conditions of work in the system of adaptive learning, each student can study independently at a pace that corresponds to his psychological characteristics in solving educational problems, turning to the teacher if necessary for advice or assistance. Compared to other educational platforms, such as Moodle, LMS Collaborator has a simple and clear interface that does not require special knowledge and skills. It is worth noting that the Collaborator has certain shortcomings in the organization of learning tasks that students receive. Despite the shortcomings, the Collaborator educational platform is easy to use and fully meets the needs of the organization and implementation of adaptive learning. Thus, the system of adaptive learning provides the optimal adaptation of the educational process in higher education institutions to individual characteristics and personal preferences of students, promotes their cognitive activity, increases motivation to learn, and provides the opportunity to monitor learning and adjust the learning content to achieve planned individual results. The adaptive learning system has the potential to fully involve all students in the process of building their individual educational environment, developing their activities, improving the individualization of the educational process in one lesson, one educational program, and the entire higher education institution.

REFERENCES (TRANSLATED AND TRANSLITERATED)

1. Bondar, V. I., Shaposhnikova, I. M., Opaliuk, T. L., & Franchuk, T. Y. (2014). *Adaptyvne navchannia studentiv profesii vchytelia: teoriia i praktyka [Adaptive learning of students of the teaching profession: theory and practice]*. Kyiv: National Pedagogical Dragomanov University. (in Ukrainian).
2. Djananjay, P., & Ajay, B. (2019). A Declarative Approach for an Adaptive Framework for Learning in Online Courses. *43rd Annual Computer Software and Applications Conference (COMPSAC)*. <https://doi.org/10.1109/COMPSAC.2019.00039>.
3. Ibrahim, M. S., & Hamada, M. (2016). Adaptive Learning Framework. *16th International Conference on Information Technology Based Higher Education and Training (ITHET)*. <https://doi.org/10.1109/ITHET.2016.7760738>.
4. Joo H., Park, J., & Kim, D. (2021). Visual representation fidelity and self-explanation prompts in multi-representational adaptive learning. *Journal of Computer Assisted Learning*, 37, 4, 1091-1106. <https://doi.org/10.1111/jcal.12548>.
5. Kosovets, O. P. (2020). Kompleksna adaptatsiia metodychnoi systemy navchannia informatyky uchniv v inkluzyvykh hrupakh [Comprehensive adaptation of the methodological system of teaching computer science to students in inclusive groups]. *Academic notes. Series: Pedagogical Sciences*. Kropyvnytskyi: EPC of Volodymyr Vynnychenko Central Ukrainian State Pedagogical University, 191, 105–108. <https://doi.org/10.36550/2415-7988-2020-1-191-105-108>. (in Ukrainian).
6. Opaliuk, T. L. (2015). *Dydaktychni umovy realizatsii adaptyvnoi funktsii navchannia studentiv u protsesi profesiinoi pidhotovky vchytelia [Didactic conditions of realization of adaptive function of training of students in the course of professional training of the teacher] : the dissertation author's abstract ... the candidate of pedagogical sciences* : 13.00.09. Ternopil, 20. (in Ukrainian).
7. Osadcha, K. P., Osadchyi, V. V., Spirin, O. M., & Kruhlyk, V. S. (2021). Kontseptualni zasady rozrobky adaptyvnoi systemy indyvidualizatsii ta personalizatsii profesiinoi pidhotovky maibutnikh fakhivtsiv v umovakh zmishanoho navchannia [Conceptual principles of development of adaptive system of individualization and personalization of professional training of future specialists in the conditions of blended learning]. *Pedagogy of creative personality formation in higher and general education schools*, 74, 65-70. (in Ukrainian).
8. Pryima, S. M. (2012). Osoblyvosti funktsionuvannia intelektualnykh adaptyvnykh navchalnykh system vidkrytoi osvity doroslykh [Features of functioning of intellectual adaptive educational systems of open adult education]. *Herald of National Academy of the State Border Guard Service of Ukraine named after Bohdan Khmelnytskyi*. Series: Pedagogical Sciences. Khmelnytskyi, 3. http://nbuv.gov.ua/UJRN/Vnadps_2012_3_21 (in Ukrainian).
9. Rohrkemper, M., & Corno, L. (1988). Success and Failure on Classroom Tasks: Adaptive Learning and Classroom Teaching. *The Elementary School Journal*, 88(3), 296-312.
10. *Stratehiia rozvytku vyshchoi osvity v Ukraini na 2021-2031 roky. (2020). [Strategy for the development of higher education in Ukraine for 2021-2031]*. Kyiv, 71. <https://mon.gov.ua/storage/app/media/rizne/2020/09/25/rozvitku-vishchoi-osviti-v-ukraini-02-10-2020.pdf> (in Ukrainian).
11. Tiutiun, L. A. & Soia, O. M. (2018). Zabezpechennia E-learning za dopomohoiu personalnogo сайту bykladacha [Providing e-learning through the teacher's personal website]. *Proceedings of the 2nd International Scientific and Practical Conference: Suchasni informatsiini tekhnologii ta innovatsiini metodyky navchannia: dosvid, tendentsii, perspektyvy - Modern information technologies and innovative education methods: experience, trends, perspectives/ Ternopil*, 247-249. (in Ukrainian).
12. Vanbecelaere, S., Van den Berghe, K., Cornillie, F., Sasanguie, D., Reynvoet, B., & Depaepe, F. (2020). The Effectiveness of Adaptive Versus Non-Adaptive Learning With Digital Educational Games. *Journal of Computer Assisted Learning*. <https://doi.org/10.1111/jcal.12416>.
13. Vinothini, K., Aida, M., & Imran, M. (2017). Adaptive learning system for higher learning. *International Conference on Information Technology (ICIT) on May 17*. <https://doi.org/10.1109/ICITECH.2017.8079975>.
14. Yelnykova, H. V., & Rostoka M. L. (ed.). (2021). Adaptyvni protsesy v osviti [Adaptive processes in education]. *Collection of materials of the 6th All-Ukrainian Scientific Forum with international participation*. Kharkiv, 3, 160. (in Ukrainian).
15. Zweig, A., & Chechik, G. (2017). Group online adaptive learning. *Machine Learning*. <https://doi.org/10.1007/s10994-017-5661-5>

