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ORIGINAL

Digital transformation of education as a space for supporting learners with special needs — challenges and prospects for inclusion

La transformación digital de la educación como espacio de apoyo a los alumnos con necesidades especiales: retos y perspectivas para la inclusión

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ABSTRACT

Introduction: digital technologies and processes of digitalization of education have contributed to the realization of the principle of equal access to education. This study focuses on the implementation of inclusive education within the framework of digital transformation as a response to the special educational needs of perfectly integrated students.
Method: the following methods were used in the study: a questionnaire, a pedagogical experiment, a comparative analysis of graduates' educational outcomes before and after the use of educational technology, and mathematical data processing according to Pearson's criterion.
Results: a systematic categorization of traditional and digital models of inclusion in inclusive pedagogy was conducted, and the prospects for using proactive digital inclusion approaches in pedagogical practice were explored. A system of criteria and sub-criteria for self-analysis of the effectiveness of digital inclusive methods in modern education has been developed. The conclusions of the self-analysis indicate the inadequacy of the didactic capabilities of educational resources, low flexibility of interfaces of educational platforms, inadequate service support, insufficient qualifications of teachers in inclusive education, as well as inadequate targeting systems in the process of integrated learning. A statistical study of the effectiveness of the use of modern educational technologies in teaching children with special needs has shown positive dynamics in the essence of educational achievements of a significant number of students.
Conclusions: the use of advanced technologies provides broad prospects for the organization of integrated learning and involves the development of complex hardware, methodological and technological solutions for this category of students.

Keywords: Inclusive Education; Digitalization; Ensuring Accessibility of Education; Students with Special Needs.

RESUMEN

Introducción: Las tecnologías digitales y los procesos de digitalización de la educación han contribuido a hacer realidad el principio de igualdad de acceso a la educación. Este estudio se centra en la implantación de la educación inclusiva en el marco de la transformación digital como respuesta a las necesidades educativas especiales de los alumnos perfectamente integrados.
Método: en el estudio se utilizaron los siguientes métodos: un cuestionario, un experimento pedagógico, un análisis comparativo de los resultados educativos de los graduados antes y después del uso de la tecnología educativa y el procesamiento matemático de datos según el criterio de Pearson.
Resultados: se ha llevado a cabo una categorización sistemática de los modelos tradicionales y digitales de inclusión en la pedagogía inclusiva y se han explorado las perspectivas de utilización de enfoques proactivos de inclusión digital en la práctica pedagógica. Se ha desarrollado un sistema de criterios y subcriterios para el autoanálisis de la eficacia de los métodos digitales de inclusión en la educación moderna. Las conclusiones del autoanálisis indican la inadecuación de las capacidades didácticas de los recursos educativos, la escasa flexibilidad de las interfaces de las plataformas educativas, el inadecuado apoyo de los servicios, la insuficiente cualificación de los profesores en educación inclusiva, así como los inadecuados sistemas de orientación en el proceso de aprendizaje integrado. Un estudio estadístico de la eficacia del uso de las modernas tecnologías educativas en la enseñanza de niños con necesidades especiales ha mostrado una dinámica positiva en la esencia de los logros educativos de un número significativo de estudiantes.
Conclusiones: el uso de tecnologías avanzadas ofrece amplias perspectivas para la organización del aprendizaje integrado e implica el desarrollo de soluciones complejas de hardware, metodológicas y tecnológicas para esta categoría de estudiantes.

Palabras clave: Educación Inclusiva; Digitalización; Garantizar la Accesibilidad de la Educación; Estudiantes con Necesidades Especiales.

INTRODUCTION

Innovative pedagogical practices are gaining momentum to ensure equal access to education for all social categories, as well as inclusive solutions. The digitalization of education opens up opportunities for special education institutions beyond the university level. With the help of digital inclusive tools, people with disabilities can use technology on an equal footing with others and actively participate in the learning process.[1] Advances in information and communication technologies and artificial intelligence are opening up new opportunities for students with disabilities.[2]

Virtual assistants, automatic subtitles, and educational platforms improve accessibility for people with hearing, visual, and musculoskeletal disabilities.[3]

At the same time, there is a need to develop appropriate methods and pedagogical models that would ensure the effective implementation of digital solutions in inclusive education. The key challenges of digital inclusion include: limited compliance of educational platforms with international accessibility standards; insufficient preparation of teaching staff to work with certain special categories of students; social exclusion of students from education who study under inclusive models; and the need for developed logistical support for the educational process.[4] Digital tools used in inclusive education make it possible to adapt the learning environment to the unique needs of each student. At the same time, there is still a need to develop specialized educational content and digital tools for use in inclusive education to adapt flexible approaches to teaching and learning.[5]

The purpose of the article is to determine the effectiveness of digital transformations on the learning outcomes of students with special educational needs through the prism of inclusive technologies.

Technological progress does not stand still; today, numerous digital platforms with automation for education are being actively developed to create equal opportunities for access to educational services, especially for students with special educational needs.

Aydin and Kaya[6] created a system of tools using artificial intelligence and identified their potential benefits for the implementation of inclusive education. The publication by Aung and Kham[7] focuses on identifying the main negative and positive aspects of the use of artificial intelligence in inclusive educational institutions. In this review, the authors also analyze the national legislation of Ukraine on digital transformation in education and its current problems, as well as offer recommendations for building a sustainable digital education system. The study by Gurenko et al.[8] explores new educational vectors and ways of effective digitalization in the context of sustainable development of society. The authors focus on the growing number of students with disabilities in higher education institutions, which complicates the implementation of innovative approaches to

learning, such as the flipped classroom model or dual education.

The responses of the higher education system to the COVID-19 pandemic crisis are described in terms of analyzing barriers, solutions, and adaptation to new functional operating conditions.[9] Grindei et al.[10] study the case of Hassan II University (Morocco), which highlights the transition from face-to-face to distance learning using the i-UH2C platform, as well as outlines the main milestones of the digital transformation of university education and provides suggestions for further development.

Current trends in higher education demonstrate an inclusive approach, emphasis on multiculturalism, civic engagement, achieving equal access for all, as well as cultural diversity, sustainable development and integration of technologies in an interdisciplinary context. It is known that Goldie[11] described the eSGarden project in his article within the framework of the Erasmus+ initiative and strategic partnerships in education, under the influence of the Erasmus+, Supporting Innovative Action program.

Research related to the development of information and communication technologies in education, as well as the application of modern pedagogical requirements to the forms of the educational process of outline documents in accordance with national education priorities in accordance with the Global Sustainable Development Goals – A, is a key prerequisite for the formation of integrated digital systems for the technological transformation of the educational process. At the same time, there are a number of problems in Ukraine that impede the implementation of advanced technological solutions in educational processes, which, in turn, negatively affects the level of the education system. This is due to the political regulation of the introduction of digital ICT technologies and the financing of digital resources in Ukraine, which do not meet the changed needs.[12]

Experts point to the need to improve the system of evaluation and accreditation of higher education institutions to fully implement environmental and digital transformations in their processes. Emphasis is placed on developing a more comprehensive understanding of educational impact, including sustainable development and a focus on humanistic values.[13]

It was noted that the lack of diversity and existing inequalities are most pronounced in the fields of science, technology, engineering and mathematics (further – STEM). In this regard, studies have been conducted on the current state of teaching computational thinking and programming in terms of inclusiveness.

In particular, Myhovych[14] analyzes this problem and proposes a learning model based on inclusive collaboration. The use of digital educational technologies has great prospects for higher education institutions due to its ability to contribute to the creation of a positive learning environment adapted to the individual needs of students. Such an environment is functional only if teachers are properly trained to work in the framework of digital inclusion.

METHOD

In the context of the current development of society and the pandemic, special attention should be paid to analyzing the effectiveness of inclusive education as a modern method of organizing the education of children with special educational needs. To this end, authors organized a research work that included such procedures as a questionnaire, a comparative analysis of educational achievements, a pedagogical experiment, as well as calculations related to the actual data collected during the experiment. A large amount of empirical material was obtained from: Khortytsia National Educational and Rehabilitation Academy, O. Honchar Dnipro National University and Sumy State Pedagogical University.

The study aimed at solving theoretical and practical problems by developing traditional and digital models of inclusive education and implementing digital inclusive practices in the educational process. The work was carried out in two stages. At the first stage, a system of effectiveness and sub-effectiveness criteria was developed and substantiated, including monitoring and self-diagnosis of pedagogical activities, as well as methodologies for theoretical and practical approaches to the application of digital inclusive approaches to education.

During the academic year, the class with special educational needs was supported by 28 teachers who taught at their level. To obtain the primary data for the first stage of the study, a questionnaire was developed (annex 1) with a 10-point rating scale (0 – no effect, 10 – maximum effect). The collected data was converted into a percentage scale for further analysis. The second stage of the study during the 2023-2024 academic year evaluated the effectiveness of implementing inclusion in digital methods based on the learning activities of students with special needs.

This study involved 86 university students with special educational needs. Of these, 43 formed the control group, where the training was conducted using traditional inclusive teaching methods. The other 43 participants made up the experimental group, where classical and digital inclusive teaching tools were used. Students were selected into the groups by random sampling. The European Credit Transfer and Accumulation System (further – ECTS system) was used to assess academic performance.

To test the hypothesis of increasing the effectiveness of the educational process when using digital inclusive

pedagogical tools, Pearson's chi-square (x^2) was used, which allowed for a statistical analysis of the effectiveness of educational tools adapted to the educational needs of students with Special Educational Needs (further – SEN). The pedagogical experiment is focused on finding a link between the effectiveness of traditional teaching approaches and new digital technologies.

The second stage of the study was implemented in a practical context: the control group studied only according to the classical inclusion scheme, while the experimental group combined traditional theses with modern digital forms. Authors will analyze this part of the work in detail in the next section.

The use of traditional inclusive approaches relies on universal design in education, self-directed learning through individual programs, cooperative learning, mentoring, active learning, psychosocial support, and other forms of assistance. The digital component was implemented through the creation of personalized software, adaptive educational platforms, virtual and augmented reality (further – VR/AR), distance learning, digital adaptation of educational materials, and interactive and computer games to increase student engagement.

RESULTS

Providing all students of higher education institutions with free access to education at the university level, taking into account disabilities, socioeconomic status and psychological characteristics, is the basis for implementing a systematic approach to inclusion in education. With the rapid development of digital technologies, inclusive educational strategies are also transforming.[15]

Table 1 presents a comparison between classical inclusive approaches and modern digital solutions used to provide accessible education to students with special educational needs. The table highlights key aspects such as accessibility, resources, individualization, socialization, and technical support.

Table 1. Comparison of classical and digital strategies for inclusive education for students with special needs

Strategies	Classical	Digital
Accessibility	Physical access to classrooms	Online platforms with adaptive interfaces
Learning resources	Printed materials and notebooks	Interactive e-textbooks, video and audio content
Individualization	Personal consultations with teachers	Automated recommendations and adaptive learning paths
Socialization	Group lessons in the classroom	Virtual classes, forums, collaborative projects in cloud services
Technical support	Assistant or tutor	Platforms with built-in support tools (chatbots, glossaries, subtitles)

The use of digital technologies in the field of inclusive education can significantly expand access to quality educational resources. Thanks to interactive platforms, multimedia content, and automated adaptation tools, students with special needs are able to learn the material at their own pace and according to their capabilities. Virtual interaction promotes the development of social skills and engagement in the learning process, which has a positive impact on their academic performance and psychological well-being.

Among the most common methods of active learning are case studies and interactive discussions. The support of course participants and the teacher in the context of a one-to-one relationship creates a comfortable learning environment for both people with disabilities and all erudite students. The use of specialized software, such as screen readers (NVDA, JAWS) or speech recognition systems (Dragon NaturallySpeaking), provides resources for modifying learning material.

Distance learning systems implement systems that meet the specific educational needs of students. Elements of virtual and augmented reality are used to create an inclusive educational environment optimally adapted for people with limited activity. Digital learning tests and materials with easy adaptation through subtitles or sign language can be accessible to everyone. Therefore, the use of modern digital inclusive formats is a well-proven method of implementing the principles of accessibility in education for people with special educational needs.

Digital inclusion in higher education involves a systematic approach that includes needs analysis, development of accessible content, and the formation of an institutional environment that supports equal opportunities. Figure 1 shows the cycle of digital transformation of inclusive education, which is implemented at all levels of interaction between students, teachers and digital tools.

In the process of integrating inclusive digital technologies into the educational activities of higher education

institutions, it is important to identify the individual characteristics of students with special educational needs at the initial stage. At the same time, it is necessary to identify all systems that will facilitate the use of accessible, inclusive approaches. One of the key aspects is the development of specialized training materials and the design of courses in accordance with the requirements of Web Content Accessibility Guidelines (further – WCAG) accessibility standards.

Figure 1. Digital transformation cycle of inclusive education in higher education institutions

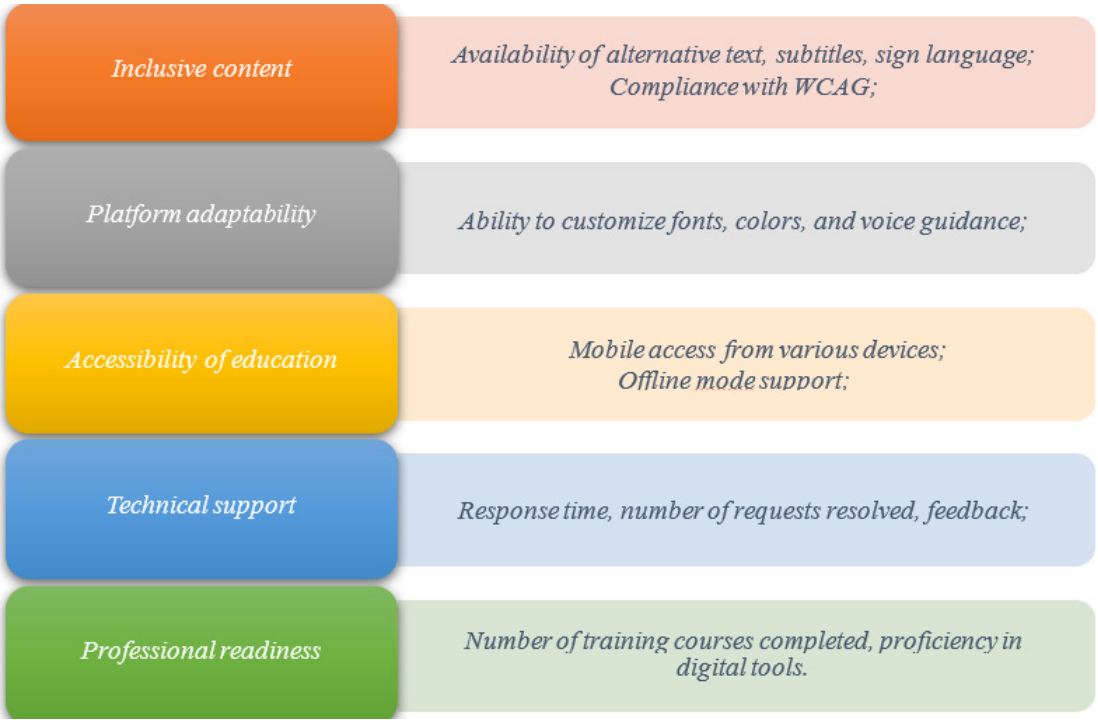


Figure 2. Key indicators of the effectiveness of digital inclusive education in the higher education system

It is also important to organize training for teachers and other employees through thematic courses, methodological seminars and workshops.

There is a need to organize the testing of digital learning tools and the development of courses using inclusive technologies. Based on academic work and feedback from students and teachers, it is advisable to introduce elements of continuous improvement. Successful practices can be widely disseminated through networking and professional exchange.[16]

Figure 2 presents an updated model for evaluating the effectiveness of digital inclusive practices in higher education. The proposed system of criteria allows for a qualitative self-analysis of the work of an educational institution in the context of accessibility and inclusiveness of digital learning. The definition of technology assessment for the implementation of inclusive digital teaching methods and the teacher survey yielded almost similar results. The results of the assessment within the criteria that were formed on the basis of the data (annex 1) are presented in table 2 on a 10-point scale.

After the implementation of the digital inclusive approach, most participants in the experimental group noted a significant improvement in access to educational content, increased interaction with teachers, and higher motivation for self-study. The use of multimedia and adaptive resources contributed to an increase in the overall level of involvement of students with SEN in the learning process. This indicates the effectiveness of using digital solutions as a tool for implementing the principles of inclusion in higher education (table 2).

Table 2. Self-assessment of the impact of digital educational tools on inclusive education of students with special needs (10-point scale)

	Before the implementation of the digital solution	After implementation of the digital solution
Flexibility of forms of access to learning content	4	9
Interactivity and visual support of the material	5	8
Student-teacher interaction through digital channels	3	8
Participation of students with SEN in group activities	4	7
Motivation for independent learning	4	9

The next stage was the assessment of the academic achievements of students with special educational needs, which was carried out before and after the introduction of digital inclusive tools.

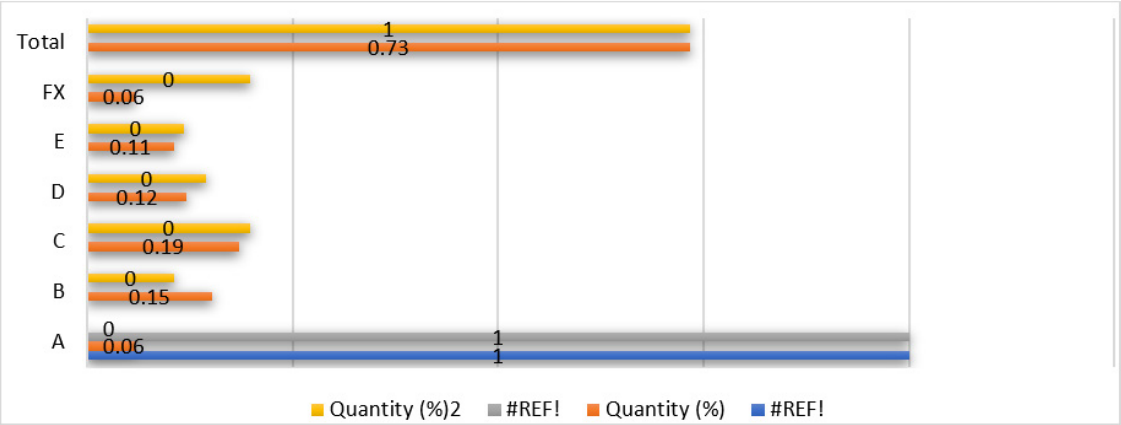
The next step was to assess the learning achievements of students with special educational needs before and after the introduction of digital inclusive tools. Figure 3 and figure 4 show the quantitative and percentage indicators of ECTS scores obtained by students of the control (CG) and experimental (EG) groups before and after the introduction of innovative methods. This allows us to track the dynamics of changes in learning outcomes and the effectiveness of digital inclusive solutions.

A holistic approach to universal design in education was achieved by customizing the MOODLE platform to meet the specific needs of students with special educational needs. The individualization of the learning path was ensured through the implementation of ReadSpeaker courses. Collaborative interaction and mentoring were carried out using Zoom and further improved with the help of interactive tools Kahoot. Psychosocial support was provided through TalkSpace.[17]

To implement digital inclusive methodologies, the Dragon NaturallySpeaking platform was used, which supports voice control as well as NVDA screen programs. Virtual reality (VR) and augmented reality (AR) technologies were used to achieve full immersion for students with mobility disabilities.

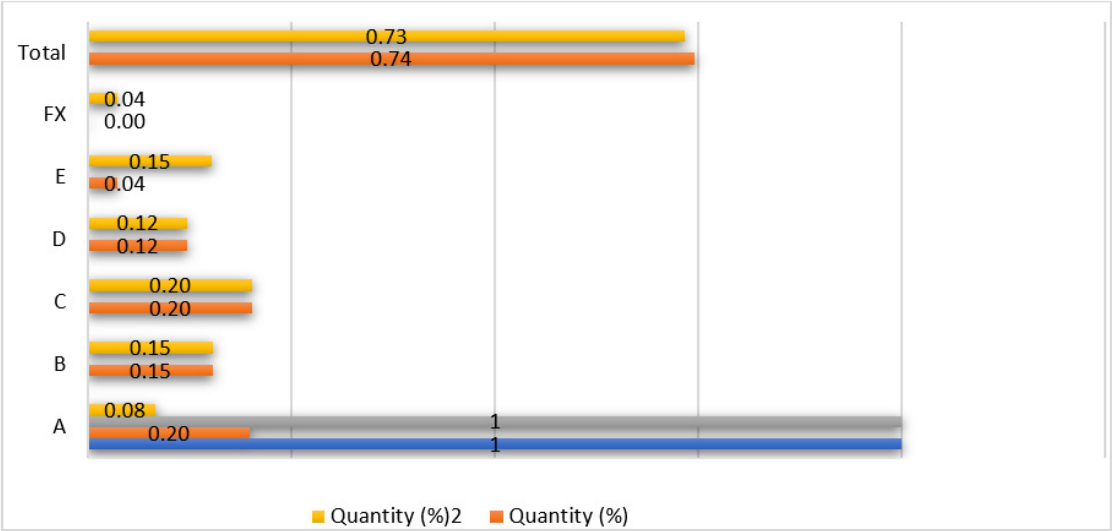
During the creation of the training material, subtitles were generated using CaptionSync, and the information was voiced using Read&Write, which performs the voiceover of the content.

Comparison of the data in figure 3 and figure 4 shows positive dynamics in the academic achievements of the experimental group. The x^2 index before the experiment was 2,03, which did not exceed the critical values. After the experiment, x^2 increased to 23,14, significantly exceeding the threshold values of 11,02 (ρ=0,05) and 15,081 (ρ=0,01). This confirms the statistically significant impact of digital inclusive tools on improving the results of students with special educational needs.



Notes: A, B, C, D, E, FX – ECTS grades

Figure 3. Assessments of students with special educational needs before the experiment



Notes: A, B, C, D, E, FX – ECTS grades

Figure 4. Grades of students with special educational needs after the experiment

DISCUSSION

In the age of information technology, inclusive education seeks to integrate students with special needs at all levels of education, which is a challenge for educators. This involves supporting inclusion through digital means, interdisciplinary professional and career activities, and the development of digital skills among educators to create inclusive environments. One of the trends of modern life, according to the goals set in the EU's Digital Action Plan for 2021 – 2027, is the use of new technologies in education.[13]

This document also outlines the directions and priorities for the digital transformation of education, as well as offers recommendations for vocational education and training policies. The Plan makes it clear that ensuring quality and inclusive education is a top priority.[14]

Hence, higher education institutions must continuously improve their digital capabilities and support the process of digital transformation to keep pace with rapid changes in the economy and growing market demand for skills.[15]

All higher education institutions should encourage the selection and implementation of the most adaptive and effective methods to create a digitally inclusive environment. Research confirms that innovative approaches in education contribute to more effective learning, digital competence, professional development, and improved collaboration, while ensuring inclusiveness.[16]

Modern technologies and teaching methods in education have provided an opportunity for effective personalized learning, creating an adaptive environment that promotes critical thinking, digital literacy, its automation, and the development of students' business competencies. Unfortunately, there are numerous challenges in implementing innovations in e-services related to the quality of teacher training, lack of active professional learning opportunities, unreliable technological infrastructure, conservatism in change, security and privacy issues, and other pedagogical problems with the latest modern digital learning tools for teachers.[17]

The STEM education system actively uses various teaching methods in academic work, including working with digital technologies in the classroom, which, in turn, is associated with a hands-on approach to learning.

Syriopoulou-Delli et al.,[18] in their study propose a partial implementation of inclusiveness in the use of robotic technologies in STEM education. This allows students with different abilities to receive equal opportunities for learning and collaboration, which in turn expands their professional prospects.

The modern educational system often does not fully take into account the individual needs of students with disabilities. In this regard, it is extremely important to create a barrier-free environment where such individuals have equal rights and opportunities, as well as the opportunity to actively participate in society through the provision of special resources, adaptive technologies, mentors and support, and psychological support.[19]

The project described by Seale et al.[20] demonstrates quite serious algorithms related to inclusiveness in employment and education. In the context of the challenges of Industry 4,0, attention is paid to combating digital and educational fragmentation, as well as unequal access to knowledge. To achieve these goals, a personalized framework based on decision trees and multimedia learning materials is being introduced in education. The high motivation and equal opportunities achieved through the use of adaptive learning have a clear positive impact on outcomes.

CONCLUSIONS

The aim of the article was to determine the effectiveness of digital transformations on the learning outcomes of students with special educational needs through the prism of inclusive technologies.

The pedagogical experiment used the following classic inclusive approaches: universal learning design, individualized curricula and learning trajectories, group work and mentoring, active education methods, and psychosocial support. Digital inclusive approaches in the study included the use of specialized software, adaptive learning platforms, virtual and augmented reality (VR) and augmented reality (AR), online learning formats, inclusive adaptation of digital materials, as well as interactive and gamified technologies.

The positive impact of the use of digital inclusive educational tools on students' educational outcomes was determined. Ensuring an integrated approach and the use of innovative digital inclusive educational tools is key to ensuring equality and accessibility of education.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Methodology: Olha Morenko.
Project management: Maryna Mykytenko.
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ANNEX 1

Self-assessment questionnaire for ensuring accessibility of education in the digital age for students with special needs

C1. Accessibility of digital learning

Please rate from 0 to 10 the accessibility of learning materials in formats compatible with screen readers

0	1	2	3	4	5	6	7	8	9	10

Please rate from 0 to 10 the availability of audio and video learning materials with subtitles or sign language interpretation.

0	1	2	3	4	5	6	7	8	9	10

C2. User-friendly interfaces of adaptive learning platforms

Please rate from 0 to 10 the compliance of the platforms you use with accessibility standards.

0	1	2	3	4	5	6	7	8	9	10

Rate the availability of adaptive interface settings from 0 to 10

0	1	2	3	4	5	6	7	8	9	10

C3. Accessibility of technical support

Rate the response time of the technical support service for students with special needs from 0 to 10.

0	1	2	3	4	5	6	7	8	9	10

A score from 0 to 10 percent of resolved requests based on support calls.

0	1	2	3	4	5	6	7	8	9	10

C4. Inclusive teacher training

Please estimate the percentage of teachers who have received training in the use of digital technologies for inclusive education, from 0 to 10 percent.

0	1	2	3	4	5	6	7	8	9	10

Rate from 0 to 10 percent of available inclusion guides and training materials in digital format

0	1	2	3	4	5	6	7	8	9	10

C5. Logistical support for inclusive education

Please estimate from 0 to 10 percent of available devices per student with special needs.

0	1	2	3	4	5	6	7	8	9	10

Estimate that 0 to 10 percent of classrooms are equipped with the necessary equipment for digital inclusion.

0	1	2	3	4	5	6	7	8	9	10

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