Organizing Web Accessibility and Security in the Open University Ecosystem*

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Abstract

Web accessibility is essential in ensuring equal access to educational resources for all users, regardless of their physical abilities, and creating barrier-free conditions during education. It promotes equity and accessibility in education, playing a crucial role in achieving the United Nations Sustainable Development Goals, particularly Goal 4, "Quality Education," and Goal 10, "Reduced Inequalities." At the same time, the open university ecosystem must meet contemporary security requirements at all levels of the educational process. Adhering to accessibility principles contributes to forming a structured, reliable, and secure university ecosystem and ensures its resilience to potential cyber threats and other risks. The paper examines key international and national standards that regulate web accessibility issues. Based on the analysis of the Web Content Accessibility Guidelines (WCAG) 2.2, the main requirements and approaches to ensure the accessibility of university web resources are highlighted. As part of the study, the first stage of implementing web accessibility standards into the ecosystem of Borys Grinchenko Kyiv Metropolitan University has been realized, namely, an analysis of the university's official portal and the websites of its structural divisions for compliance with accessibility requirements, as well as the optimization and improvement of the university portal according to the specified requirements and approaches for presenting accessible information content to eliminate identified barriers. The study results demonstrated a positive impact on the accessibility of the web resource, enhancing convenience, readability of texts, and content perception. Adherence to accessibility principles creates a foundation for building a secure digital infrastructure for the open university ecosystem.

Keywords

web accessibility, web content accessibility standards, WCAG 2.2, security, open university ecosystem

1. Introduction

In today's digital transformation landscape, establishing an open university ecosystem that ensures equal access to quality education is more pertinent than ever. This ecosystem should integrate modern digital technologies and facilitate effective interaction among all participants in the educational process while adhering to sustainable development principles. The open university concept fosters the democratization of education and the widespread sharing of knowledge, aligning with the UN Sustainable Development Goals are specifically, Quality Education (Goal 4) and Reduced Inequalities (Goal 10). It provides free access to educational resources and emphasizes transparency, flexibility, and a focus on the diverse needs of various user groups. In this context, it is essential to ensure both accessibility and security within the open university ecosystem. This entails providing equal access to educational resources for all users, irrespective of their physical capabilities, and implementing multi-layered protection for confidential data, educational content, and digital infrastructure [1]. Simultaneously, there are notable challenges in integrating innovative technologies and open resources while ensuring their quality and suitability for the needs of students and teachers. These challenges include technological inequality, limited digital infrastructure, and inadequate adaptation of educational platforms for diverse user categories, including individuals with various disabilities. Furthermore, a unified methodology is lacking for

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organizing an accessible open university ecosystem and ensuring its security. Additionally, the integration of modern technological solutions into the educational ecosystem remains low. The openness of the university ecosystem simultaneously introduces various security threats, such as the risk of unauthorized data access, breaches of integrity, content manipulation, disruptions in the distance learning process, and vulnerabilities to cyberattacks. Additionally, there are threats stemming from weaknesses within the systems themselves. Therefore, the organization of an open university ecosystem should be grounded in the principles of openness, accessibility, and rigorous security standards.

Organizing an accessible and secure open university ecosystem is an essential aspect of modern education that meets the principles of openness, accessibility, and equality of access to knowledge. In the context of globalization and the digitalization of education, ensuring web accessibility is becoming critical to meet the needs of different categories of users, including people with various types of disabilities. Compliance with accessibility standards allows the creation of web resources in the university ecosystem adapted for users with different needs, physical disabilities (visual, hearing, mobility), and cognitive developmental disabilities, including using assistive technologies. It ensures barrier-free access and equal opportunities for all participants in the educational process.

Ensuring accessibility is one of the priority areas of Ukraine's state policy. According to the National Strategy for Creating a Barrier-Free Space in Ukraine until 2030 [2], approved by the Cabinet of Ministers of Ukraine, the key areas of focus are digital and educational barrier-free access, which means creating equal opportunities and free access to education and digital services. At the same time, the Strategy identifies several common problems of educational accessibility, including low level of information accessibility of academic and information materials, insufficient material and technical support of higher education institutions with the necessary assistive technologies to provide quality and accessible services, and low level of skills in using assistive technologies. Assistive technologies help people with disabilities interact with the world around them, including digital technologies. Such devices include screen readers that allow people with visual impairments to read text on the screen, screen magnifiers to enlarge the image on the screen, speech synthesizers and voice recognition programs, special keyboards, and mice adapted for people with motor impairments. In order to meet the special educational needs of all participants in the educational process, it is essential to create barrier-free conditions during the acquisition of education, enhance the qualifications of educators, and raise awareness regarding accessibility, as well as adapting informational materials for individuals with visual and hearing impairments, among others.

The results of the annual monitoring of the web accessibility of government agency websites [3] in 2023 indicated that there has been a positive trend in website accessibility over the past three years. However, it has been noted that 97% of websites still present specific accessibility barriers and require further adaptation. Therefore, the issue of implementing accessibility principles in the ecosystem of the open university is particularly relevant.

The analysis of recent research demonstrates the growing attention of the scientific community to the issues of web accessibility of educational resources. The study [4] emphasizes that the principles of web accessibility should be integrated at the early stages of designing educational systems, taking into account compatibility with screen readers, providing a clear navigational structure, alternative text descriptions for multimedia content, adaptive design of the interface, and support for keyboard navigation.

Researchers [5] analyzed scientific studies regarding the accessibility of open educational resources for students with disabilities. They emphasized the insufficient development of this issue, particularly concerning the compliance of resources with four principles of accessibility (perceptibility, operability, understandability, and robustness), as well as the use of specialized technologies to adapt educational materials to the needs of students with disabilities. They highlighted the need to develop and implement new tools for creating accessible educational resources. Confirming this issue, U. Singh et al. [6] emphasize that educational institutions' websites are essential in providing information to students, parents, and educators but often do not

meet accessibility standards. An analysis of the main pages of 13 educational board websites administering graduation exams from developed and developing countries showed that websites from developing countries had more accessibility issues, particularly with text contrast. Singh et al. [6] underscore the importance of ensuring web accessibility of educational websites for equitable access to information for all users, regardless of their abilities, and the adherence to WCAG principles. According to the results of a systematic review of the literature on the accessibility of university websites worldwide [7], many university websites have accessibility issues. The most common violations of accessibility standards are poor website adaptability, lack of assistance when entering text, and complex and unpredictable navigation. Therefore, the issue of implementing accessibility standards on higher education institution websites that consider the needs of various users and adhere to international recommendations is particularly relevant. In this context, Hristov et al. [8] present a methodological approach to developing accessible web content. This approach, based on the standards, principles, and recommendations of the Web Accessibility Initiative, specifically the Web Content Accessibility Guidelines (WCAG), integrates accessibility aspects into all stages of the web content creation lifecycle. The authors describe the practical implementation of this method during the modernization of the university's web infrastructure, which involves creating web accessibility requirement specifications and their implementation in the development process. Researchers emphasize the need to consider various contextual factors, such as user characteristics and diversity of devices and technologies, to ensure adequate web accessibility in a university environment. The study [9] focuses on issues and opportunities of digital accessibility, identifying key accessibility barriers categorized as institutional, technological, and financial. Institutional barriers include inadequate legislative regulation and insufficient interest from institutions in implementing accessible solutions. Technological barriers relate to the lack of universal approaches to developing digital products, particularly the insufficient consideration of the needs of individuals with cognitive disabilities. Financial barriers manifest in the high costs of creating specialized technologies, often limiting their widespread implementation. The level of awareness regarding accessibility is a fundamental factor influencing the quality of implementing accessible digital solutions and creating conditions for forming an inclusive environment for various categories of users, including people with different types of disabilities.

The study by Patan L. [10] presents the experience of designing accessible mobile applications by web accessibility standards, which includes understandable navigation and well-structured content, ensuring keyboard control, the use of captions, and the transcription of audio and video content, which are necessary for deaf and hard-of-hearing users. Accessibility is viewed not merely as a regulatory requirement but as a fundamental responsibility that leads to a better digital experience for all users. Implementing accessibility principles contributes to improved SEO optimization and the site's visibility in search engines; alternative text for images, video captions, and adherence to contrast requirements enhance all users' overall perception and clarity of content.

Thus, the issue of integrating web accessibility principles into the educational process becomes particularly relevant at both the national and international levels, which is essential for ensuring equal conditions for learning and development.

The research aims to develop and substantiate approaches to ensuring the accessibility of the university's web resources based on the analysis of international web accessibility standards, specifically the Web Content Accessibility Guidelines (WCAG) 2.2, to create an accessible and secure ecosystem for the open university that facilitates equal participation of all learners in the educational process.

Research Methodology. To achieve the set goal, a comprehensive methodological approach was employed, combining theoretical and empirical methods of analysis. At the theoretical level, an analysis of regulatory acts was conducted, a monitoring report on the accessibility of government online resources was made, and studies of international experience were published in the scientific literature regarding the implementation of accessible digital technologies in educational ecosystems. Additionally, a systematic analysis of the document "Web Content Accessibility Guidelines" (WCAG 2.2) was performed to identify key approaches for ensuring web content

accessibility and forming a barrier-free ecosystem of an open university. At the empirical level, an assessment of the current level of compliance with accessibility standards of the web resources of Borys Grinchenko Kyiv Metropolitan University was carried out using automated tools for analysis and manual validation methods. Based on the results of the study, methodological materials were developed, and training was organized for the individuals responsible for populating the websites to ensure their compliance with Level AA of the WCAG 2.2 Guidelines.

2. Web accessibility and security are key aspects in the organization of an open university

In ensuring accessibility within the open university ecosystem, the WCAG, developed by the World Wide Web Consortium, play a key role. The document represents a comprehensive system of tools for creating web resources accessible to users utilizing assistive technologies, such as screen readers. It provides a fundamental basis for developing and implementing accessible educational resources that meet modern digital accessibility requirements. The Web Content Accessibility Guidelines WCAG 2.0, presented in 2008, systematically outlined the fundamental principles of web accessibility for the first time (perceptibility, operability, understandability, and robustness) which laid the methodological groundwork for understanding accessibility in the digital space. The WCAG 2.1 version (2018) expands accessibility standards for mobile devices and users with cognitive impairments and introduces requirements for sensory interaction.

International and national standards for web accessibility have been developed based on the WCAG recommendations, particularly the European standard EN 301 549, which is based on version 2.1. In Ukraine, the implementation of international standards at the national level is carried out through the national standard for web accessibility DSTU EN 301 549:2022 "Information technologies. Requirements for the accessibility of ICT products and services," which has been developed based on the European standard EN 301 549 and the WCAG 2.1 recommendations. This regulatory document establishes comprehensive digital product and service requirements, ensuring inclusivity in the information space. Legal regulation of web accessibility in Ukraine is strengthened by the CMU Resolution No. 757 dated July 21, 2023, "Certain issues of the accessibility of information and communication systems and documents in electronic form" [11], according to which all websites and mobile applications of executive authorities, as well as the electronic documents posted on them, must be accessible to persons with disabilities. This regulatory framework, together with DSTU EN 301 549:2022, forms a comprehensive system for standardizing digital accessibility in the national context [12]. Considering the evolution of web accessibility standards and the presentation of the updated version of WCAG 2.2 in 2023, this research will focus on the recommendations of WCAG 2.2, which will ensure compliance with modern requirements and cutting-edge trends in the field of digital accessibility.

The WCAG 2.2 version focuses on supporting users with cognitive and motor impairments. It includes improved compatibility with mobile devices, optimized requirements for touch screens, enhanced gesture control and navigation, updated support for assistive technologies, expanded recommendations for cognitive accessibility, and more. The WCAG 2.2 guidelines establish clear criteria and recommendations for ensuring web content accessibility, the implementation of which contributes to the creation of barrier-free web resources, enhances the overall usability of websites, and is a key factor in forming a quality, accessible, and safe ecosystem for open universities, where all users, regardless of physical abilities, can seamlessly access educational resources [13].

The WCAG 2.2 outlines the requirements that web resources must adhere to ensure accessibility for individuals with various types of limitations. These guidelines are based on four fundamental principles: Perceivability, Operability, Understandability and Robustness. Perceivability ensures accessibility for perceiving information and interface components, supporting various ways of presenting content, including using alternative text, captions, or audio descriptions. For example, video lectures should be supplemented with text summaries in educational courses. Operability creates opportunities for interaction through various technical

means, providing sufficient time for engagement, including enabling navigation via keyboard or adaptive devices, which is especially important for students with motor limitations. Understandability shapes cognitively accessible information structures, ensuring a clear content structure, excessive information's absence, and interface behavior's predictability. Robustness guarantees content compatibility with a wide range of technological platforms and accurate interpretation of content by assistive technologies, such as screen readers.

The WCAG 2.2 recommendations propose a hierarchical compliance model: Level A represents the minimum accessibility requirements; Level AA is defined as the standard, recommended level; Level AAA ensures maximum adaptability. Adhering to Level AA is essential and mandatory for government websites, educational web resources, and socially significant information resources.

When analyzing the complex impact of implementing WCAG recommendations within the university ecosystem, it is essential to note the synergistic connection between accessibility and information security of web resources. Adhering to accessibility principles lays the foundation for building a secure digital infrastructure, fosters the creation of a structured, reliable, and protected university ecosystem, and ensures barrier-free access and resilience against potential threats. Accessibility standards, particularly WCAG, require semantically correct and structured code creation. This approach facilitates website use for all categories of users, including individuals with visual or hearing impairments, and reduces the risk of technical errors. Coding errors often become entry points for hacking attacks, such as SQL injections or cross-site scripting (XSS). Thus, well-structured code inherently enhances platform security. An essential aspect of web accessibility is the development of validated data input forms, which protect against automated attacks. Inclusive authentication mechanisms, including audio CAPTCHA and text elements, support accessibility, and system security.

It is also essential to consider the website's compatibility with assistive technologies used by individuals with disabilities (such as screen readers or alternative input devices). If the site is not adapted to such technologies, it may create risks of confidential information leakage or system malfunctions. Ensuring web accessibility minimizes these threats and guarantees safe operation for all users. Thus, web accessibility and security complement each other. Providing accessibility makes the site barrier-free for all categories of users and helps identify and eliminate technical deficiencies that could be exploited for attacks.

At the same time, adherence to web accessibility standards positively impacts the website's search engine optimization (SEO), as many principles outlined in the WCAG 2.2 recommendations correlate with search engine ranking factors. Using semantic HTML code, proper heading structure, and descriptive text increases the accuracy of content interpretation by search engine algorithms, improving its visibility in search results. Additionally, alternative descriptions for images enhance image indexing in Google Images, which is an additional factor in attracting organic traffic. Accessible websites provide a better user experience through straightforward navigation, logical content structure, and fast page loading, which is reflected in engagement metrics (CTR, time on site, bounce rate) considered by ranking algorithms. Google's crawlers primarily analyze the mobile version of the site, assessing its user-friendliness, content display accuracy, and accessibility of control elements; thus, well-adapted mobile sites by WCAG 2.2 achieve higher rankings in search results.

At the same time, adherence to accessibility principles directly contributes to the achievement of the Sustainable Development Goals, particularly Goal 10, "Reduced Inequalities," by ensuring equal access to the university's educational and informational web resources, providing learning materials in convenient and alternative formats, which helps eliminate barriers to accessing information used in the educational process. Goal 4, "Quality Education," is addressed through creating high-quality online courses for each academic discipline, adapting learning content and other educational resources for users with diverse needs, and improving the e-learning system in accordance with web accessibility principles. Ensuring quality distance education contributes to the achievement of Sustainable Development Goals (SDGs 4, 10, 13) by providing accessibility,

reducing inequality, and lowering the carbon footprint, thus learning materials need to be adapted for different categories of learners [14-15].

The organization of an accessible and safe ecosystem for the open university requires systematic integration of technological, management, and pedagogical solutions that provide reliable protection while maintaining the principles of openness and accessibility in the educational space [16]. At the same time, it is essential to pay special attention to the development of effective information security policies, the implementation of accessibility standards, the formation of a cybersecurity culture, and the conduct of systematic security audits [17]. It is also important to regularly analyze and improve the implemented solutions, considering the emergence of new cybersecurity threats, especially during a state of military emergency, the development of accessibility technologies, changes in educational requirements and needs, as well as feedback from real user experiences.

The accessibility and security of the open university ecosystem are formed based on a comprehensive approach that includes the following stages (Fig. 1):

- Analysis and evaluation of existing content, web resources, digital educational materials, and platforms for compliance with accessibility and cybersecurity standards.
- Preparation of staff, including conducting training sessions for educators, developers, and technical specialists to raise awareness of the principles of web accessibility, data protection, and safe use of digital resources.
- Optimization and adaptation of web resources according to modern standards, including the implementation of adaptive design, enhancement of interactivity, and ensuring ease of interaction with content for all categories of users.
- Monitoring and improvement involve regular audits of accessibility and security, analysis of user feedback, and prompt identification and resolution of potential issues.

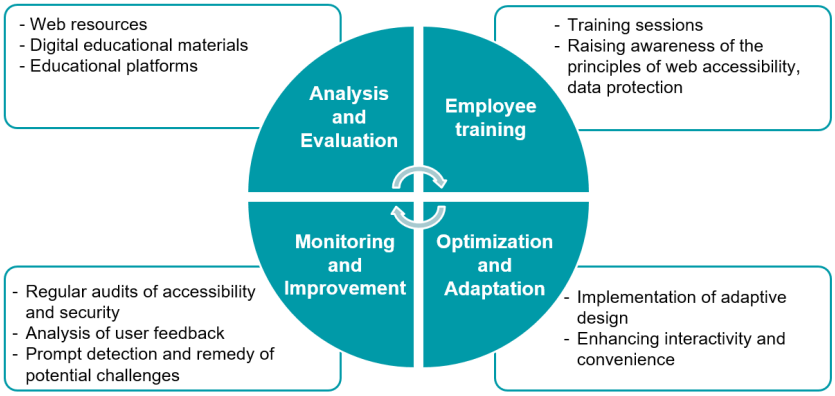

Figure 1: Stages of organizing an accessible and safe ecosystem for an open university

The principal methodologies for assessing the accessibility of open educational resources [5] are identified as automated assessment using software tools (AChecker, WAVE, W3 Validation Service, SortSite, Tanaguru), assessments using simulators that replicate the experience of users with disabilities (aDesigner, Spectrum, NoCoffee), and manual assessments, which include conducting surveys with users with disabilities, analyzing feedback on the usability of educational resources, and identifying problems and barriers for different user groups. However, automated tools are not capable of detecting all accessibility issues, so to ensure high quality, it is important to conduct a comprehensive evaluation that includes both software tool assessments and user checks, particularly by people with disabilities, to ensure a real interaction experience with the resources [10, 18]. We share the researchers' views on the importance of a comprehensive assessment of web resource accessibility, as this approach allows for not only the automatic identification of errors and non-compliance with accessibility standards but also the consideration of actual user experience. Combining automated analysis with human-involved testing provides a more complete picture of the usability and accessibility of web resources, uncovers hidden barriers, and develops ways to address them.

3. Implementation of web accessibility standards in the ecosystem of Borys Grinchenko Kyiv Metropolitan University

Given the importance of organizing web accessibility within the open university ecosystem, an assessment was conducted on the accessibility level of the web resources of Borys Grinchenko Kyiv Metropolitan University for users utilizing assistive technologies. Considering the significant number of web resources, a step-by-step process for adapting them to accessibility standards was developed, which includes the following stages: the primary task is to bring the official university portal and the websites of its structural units into compliance with international accessibility standards (WCAG 2.2); the next stage involves adapting the e-learning system, educational materials, and other educational resources used in the educational process with consideration of accessibility principles; in the third stage, the enhancement of websites for international projects and other web resources takes place. This systematic approach ensures the consistent and effective implementation of accessibility principles across the web resources of the open university ecosystem, promoting the creation of equal opportunities for all users.

At the first stage of implementing web accessibility standards in the open university ecosystem, an analysis was conducted of some of the key components of the ecosystem are the official university portal and the websites of its structural units. The web accessibility of official websites of higher education institutions is a crucial aspect of ensuring equal access to educational resources and services for all users, as they play an essential role in disseminating information and interacting with students, faculty, researchers, and administrative staff [19-20].

The analysis of web resources was conducted using the WAVE Evaluation Tool, which assesses compliance with web accessibility standards, identifies potential barriers for users with disabilities, and provides recommendations for their removal (Fig. 2). Additionally, other automated and manual verification methods were used to ensure a comprehensive approach to evaluating the accessibility of web content.

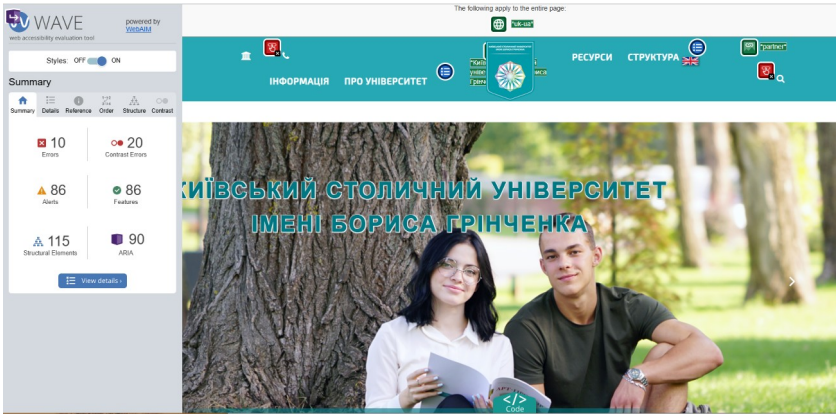

Figure 2: The use of the WAVE Evaluation Tool software for analyzing the official portal of Grinchenko University for compliance with web accessibility standards

The WAVE Evaluation Tool for web accessibility uses a multi-component evaluation methodology based on six key metrics [21]:

- Errors are indicators of critical violations are visualized with red markers and require mandatory remediation to ensure the essential accessibility of the resource.
- Contrast Errors are errors indicating insufficient color contrast between text and background. Adequate contrast is critical for users with visual impairments.
- Alerts are potential accessibility issues marked with a yellow symbol that require expert review to confirm or refute their impact on accessibility.
- Features are elements that potentially enhance website accessibility are marked with a green symbol and include components such as alternative text for images, headings, form labels, etc.

- Structural Elements are indicators of the semantic structure of the page, which include headings, lists, navigation elements, and other structural HTML components that ensure logical content organization
- ARIA are special attributes to improve the accessibility of dynamic content. The tool checks for the presence and correct usage of ARIA markup.

The tool offers advanced functionality for analyzing web content through specialized modules. It provides a detailed analysis of elements with precise localization of problems on the page (Details), explanations of the nature of the issues, and recommendations for addressing shortcomings with references to the relevant WCAG criteria (Reference). The accessibility standards compliance analysis includes automatic detection of errors, explanations of their impact on users, step-by-step remediation recommendations, and references to WCAG criteria (Reference). The keyboard navigation analysis evaluates the logical order of movement between elements (Tabbing), the availability of all interactive components, and the navigation sequence's correspondence to the page's visual structure (Order). The semantic structure check of the webpage encompasses an analysis of the heading hierarchy, correct use of structural areas (header, nav, main, aside, footer), proper application of lists and other semantic elements, and the logical relationships between page components (Structure). The contrast analysis includes an assessment of the compliance of contrast levels with the minimum WCAG requirements, using a simulated achromatic vision mode (Desaturate page) and identifying potential contrast issues directly on the page (Contrast). There is also the option to check the contrast of any color combinations to assess content readability for users with visual impairments [21].

The complex structure of the WAVE Evaluation Tool provides a practical toolkit for assessing the accessibility of web resources, allowing for the prompt identification of critical violations and in-depth analysis of specific aspects of accessibility.

The analysis results confirmed the full compliance of the university's web resources with Level A of the WCAG 2.2 guidelines and partial compliance with Level AA, indicating the need to improve web resource accessibility further, as full compliance with Level AA is mandatory for higher education institutions. Among the key accessibility errors identified were a lack of alternative descriptions for multimedia content, inadequate size of navigation elements, and insufficient color contrast. To fully comply with Level AA, it is necessary to remove barriers related to enhanced contrast requirements, navigation, alternative representations of content, and interactive elements.

Convenient tools for automated accessibility assessment include using artificial intelligence-based services such as AccessiBe, UserWay, and EqualWeb. These services utilize machine learning algorithms to analyze and improve the accessibility of web content, significantly facilitating the process of adapting digital resources for people with disabilities. In particular, AccessiBe provides automatic detection and correction of accessibility errors, integrating a control panel for users to personalize the interface. UserWay offers adaptive tools to optimize content according to WCAG recommendations, while EqualWeb combines automated and manual accessibility correction methods, including support for multimodal adaptations.

To ensure compliance with Level AA, an analysis of international and national web accessibility standards has been conducted, specifically the WCAG 2.2. The requirements and approaches for presenting information content have been structured around key areas: text content, hyperlinks, images, audio and video, tables, PDF documents, and diagrams to ensure maximum accessibility within the open university ecosystem, which aims to provide equal opportunities for all users regardless of their characteristics (Fig. 3).

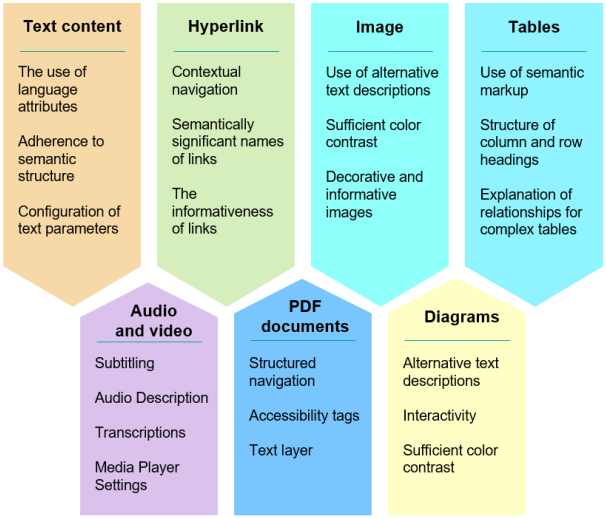

Figure 3: Presentation of informational content taking into account the principles of web accessibility

In content creation, properly using language attributes is critically important to ensure the correct pronunciation of content by screen readers. The primary language of the page (Ukrainian) is set using the tag <html lang="uk">. Suppose the text contains fragments in another language. In that case, using the “lang” attribute on the relevant elements is recommended to ensure the correct rendering of the text by reading software.

* He said bonjour during the meeting. *

Semantic text markup using headings of various levels, lists, and other structural elements creates a clear information hierarchy and ensures correct information perception by screen readers and other assistive technologies. The information needs to be presented in a logical sequence, which helps users easily navigate the page and ensures proper interpretation of the document's structure by assistive technologies. This is achieved using semantic HTML tags for headings (<h1>, <h2> і т.д.), which can be applied through the CMS’s built-in text editor. It is crucial to follow the correct order of headings without skipping levels, for example, not using Heading 3 without a preceding Heading 2 (Fig. 4). An effective tool for structuring information on a website is lists, which help organize information, simplify understanding, and enhance perception.

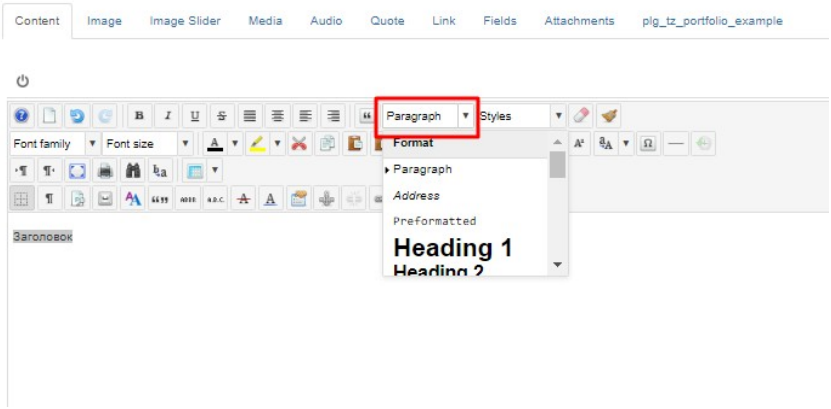

Figure 4: Structuring informational content using semantic HTML header tags

Customizing font size, line spacing, and contrast ensures comfortable reading of text information for various categories of users. The color contrast ratio can be checked using special software tools, including the WebAIM Contrast Checker or built-in browser developer tools.

Particular attention is required to organize the navigation structure through hyperlinks. Contextual navigation must be intuitive, and the link text should be informative without needing surrounding context. Each link should be informative and understandable out of context, allowing users with different perception characteristics to navigate effectively in the information space. Avoiding formulations like "click here" and semantically meaningful link titles significantly enhances the user experience for individuals using screen readers.

Modern artificial intelligence models, including ChatGPT 3.5, Copilot, and Gemini, allow for the quick generation of code that meets web accessibility requirements, making them extremely useful in organizing an accessible ecosystem for an open university that complies with all accessibility standards and enables every participant in the educational process to interact with the content without barriers [22].

Multimedia content requires a comprehensive approach to ensuring accessibility. Providing alternative text descriptions that convey meaningful content is mandatory for images (Fig. 5).

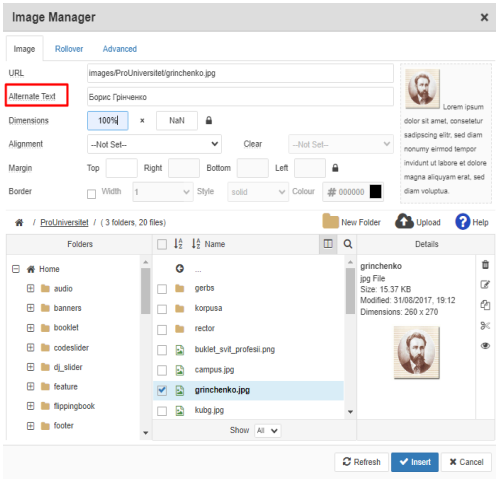

Figure 5: Adding an alternative text description for an image

An effective tool for the automated generation of text descriptions of images is AltTexter, which creates meaningful and accurate descriptions based on artificial intelligence. By using advanced image processing methods and context analysis, this tool enhances the accessibility of digital content for users with visual impairments.

It is essential to distinguish between decorative and informative images by applying relevant accessibility attributes. Audio and video materials should be accompanied by subtitles, transcripts, and, when necessary, audio descriptions. AI-based services such as Sonix.ai and YouTube Automatic Captions offer automated subtitle generation using speech recognition technologies to create synchronized text transcripts. At the same time, Whisper by OpenAI provides multilingual support and subtitle adaptation for individuals with hearing impairments. At the same time, media players should support keyboard navigation and have clear control elements.

Accessibility of tabular data is ensured through proper semantic markup that defines column and row headers, creating a structured representation of information (Fig. 6). For complex tables, it is essential to provide text alternatives and explanations of the relationships between the data. Artificial intelligence tools, such as Table Transformer (Microsoft AI), are convenient for adapting complex tables into accessible formats. This service automatically converts tables into structured data with enhanced navigation for users who utilize screen readers.

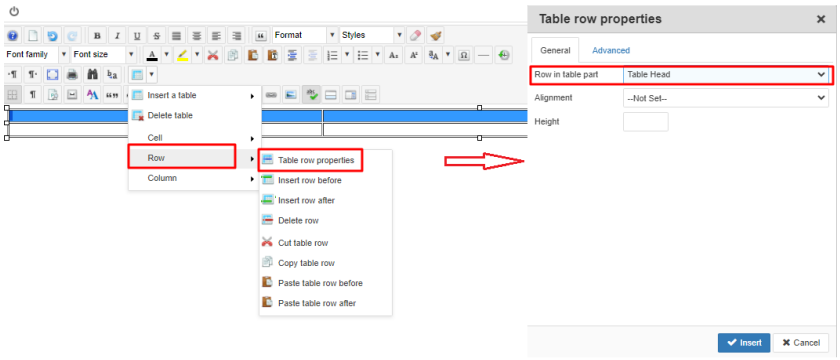

Figure 6: Setting row and column headers of the table

The importance of ensuring the accessibility of PDF documents, which are widely used for presenting educational and informational materials on university ecosystem web resources, cannot be overstated. Such documents must be created with accessibility requirements, including proper heading structure, alternative image descriptions, and keyboard navigability. This entails having structured navigation, correct element tagging, and a text layer for screen reader compatibility.

Data visualization through charts requires particular attention to providing alternative means of presenting information. A detailed text description should accompany each chart, ensuring sufficient contrast and the ability to perceive information without relying on color.

Taking into account the changes made in accordance with the specified requirements and approaches to presenting accessible information content, the university portal was further analyzed using the Silktide service, which allowed for an assessment of its accessibility based on criteria such as color contrast, alternative text, focus order, headings, compatibility with screen readers, as well as page perception by users with visual impairments, color blindness, and dyslexia (Figs. 7–9).

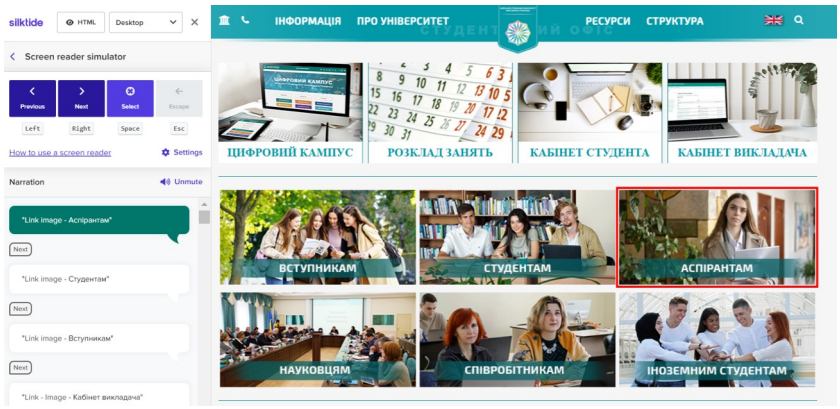

Figure 7: Analysis of content compatibility with screen readers

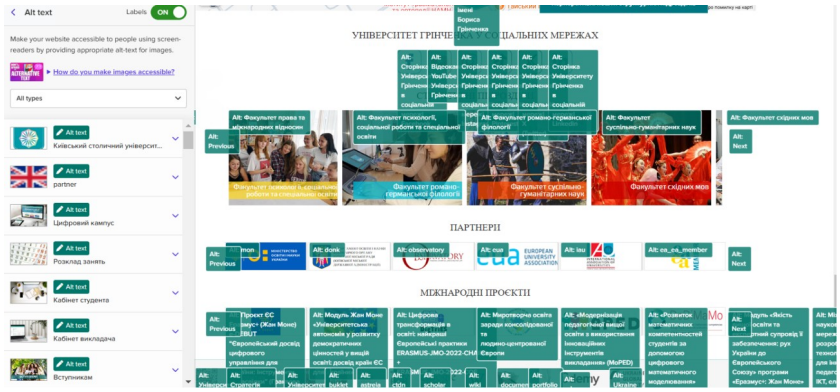

Figure 8: Checking for the availability of alternative text for images

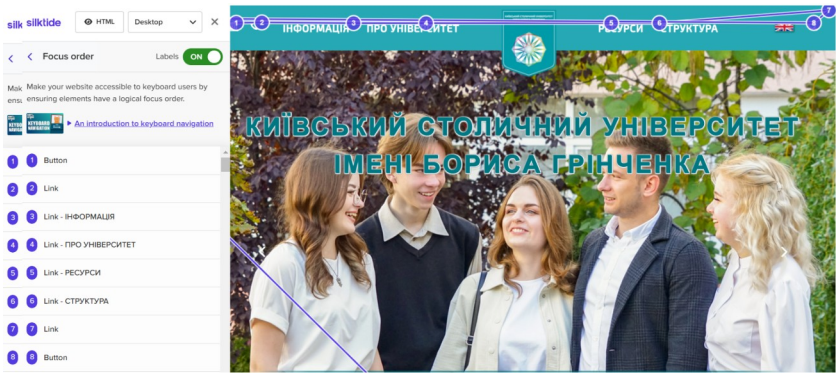

Figure 9: Analysis of the focus order for ease of keyboard navigation

As part of the improvements, alternative text was added to images, headings were structured, and the focus order was optimized for keyboard navigation convenience. The color contrast assessment revealed the need for further refinement. Additionally, the perception of the site by users with disabilities was analyzed, which helped to identify problematic aspects and determine directions for additional optimization.

The user survey results on the portal indicated an increase in convenience, readability of texts, and easier comprehension of content, confirming the improved accessibility and inclusivity of the university's web resources.

According to the research findings, a series of methodological materials were developed to ensure the accessibility of the web resources of Borys Grinchenko Kyiv Metropolitan University, and training sessions were organized for the staff responsible for updating the websites of the structural units. During the training, special attention was given to the WCAG version 2.2, the principles of creating accessible digital content, and the requirements for developing accessible educational materials.

After the responsible parties make changes, a detailed analysis will be conducted on the websites of the structural divisions using tools for automated web accessibility analysis, assessing the impact on the SEO performance of the University's web resources, and evaluating the actual user experience of interaction, particularly with the use of assistive technologies. We plan to reflect on the results in a subsequent study.

Accessible content is more structured, understandable, and user-friendly for all categories of users, which enhances the effectiveness of using the University's web resources, improves user experience, breaks down barriers to accessing information, and creates equal opportunities for all categories of users, including individuals with disabilities.

In organizing the ecosystem of an open university, integrating accessibility and safety principles at all levels of the educational process is of particular importance. This applies to technical aspects and methodological approaches to organizing teaching, assessment, and IT infrastructure [23]. The next step involves analyzing and optimizing the e-learning system and the educational content used by learners in the educational process, taking into account the principles of accessibility to ensure the flexibility of academic programs and the ability to adapt them to the individual needs of learners.

The organization of an accessible and secure ecosystem for an open university requires a comprehensive approach to structuring and presenting content, which necessitates developing and implementing a Web Accessibility Policy and updating the current Cybersecurity Strategy in light of the demands of martial law. Ensuring web accessibility and security within the open university ecosystem requires a multifaceted approach, including ongoing compliance monitoring with standards, employee training, and effective technical solutions. An essential aspect of successfully implementing accessibility principles is enhancing the qualifications of faculty and technical staff. This involves regular training on creating accessible content, using specialized tools, and developing educational materials that consider accessibility principles in the educational process. Incorporating these principles into the open university ecosystem contributes to forming a barrier-

free educational environment that meets modern accessibility standards and allows for equal access and opportunities for quality education for all categories of users, including individuals with various types of disabilities.

Conclusions

Implementing web accessibility and security principles in the open university ecosystem is a complex task that requires a systemic approach and constant monitoring of content compliance with established standards, including regular audits of web resources, staff training, and the implementation of appropriate technical solutions. It is essential not only to ensure equal access to quality education for all learners but also to create a secure ecosystem with high protection for web resources. Key aspects of this process include the introduction of innovative technologies, employee training on accessibility and cybersecurity standards, the development of a Web Accessibility Policy, and regular monitoring and updating of web resources according to current requirements. This approach will contribute to forming barrier-free, reliable, and resilient web resources in the university ecosystem.

The organization of an accessible and safe ecosystem for the open university will positively impact the overall quality of the educational process. Specifically, adapted content is beneficial not only for individuals with disabilities but also for students studying in challenging conditions. such as in noisy environments or with low internet connection speeds. At the same time, ensuring accessibility and safety in the ecosystem of the open university is not just a technical standard; it is a fundamental component of modern education that defines its openness, quality, and overall accessibility. Integrating these principles into the activities of the open university not only contributes to improving the educational process and creates conditions for equitable access to knowledge but is also an essential step toward forming a just educational space that directly supports the achievement of the United Nations Sustainable Development Goals, particularly ensuring Quality Education (Goal 4) and Reduced Inequalities (Goal 10).

We see the prospects for further research as the development and implementation of a Web Accessibility Policy, the updating of the existing Cybersecurity Strategy by the requirements of martial law, and the analysis and adaptation of the e-learning system and educational content while adhering to accessibility principles. Higher education institutions may use the research results to develop web resources that consider principles of accessibility and security, which are adapted for proper interpretation by assistive technologies.

Declaration on Generative AI

While preparing this work, the authors used the AI programs Grammarly Pro to correct text grammar and Strike Plagiarism to search for possible plagiarism. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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