Remote Education Trajectories for Learners with Special Needs During the Covid-19 Outbreak

An Accessibility Analysis of the Learning Platforms

https://doi.org/10.3991/ijet.v17i21.32401

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Abstract—The sudden transfer of in-class education to remote teaching and learning due to the COVID-19 pandemic was stressful for all, particularly for the differently abled students. It seems that most of them were literally abandoned and missed out on their education. The learning results of those who were enabled to remotely learn significantly decreased, undermining their already low self-esteem. Even hybrid education challenged the inclusiveness in primary and secondary schools, disabling children with special needs to learn and actively participate in education. On the other hand, remote education enabled modernization of traditional education that will soon become part of the new normal. The main prerequisite to incorporating remote learning and teaching as a complementary part of education is to adapt it to all students, regardless of their abilities. Our major motivation presented in this paper was to resolve the dilemma of whether the essential groundwork for the inclusiveness of remote education exists. The research behind it examined the accessibility of learning management systems, audio and video teleconferencing applications, and massive open online courses, which are crucial to the move from onsite to online education. Four impairments: motor, vision, hearing and cognitive were carefully explored in line with WCAG 2.1 recommendations. The current state of the synergy between the components was assessed carefully and thoroughly. For each of the four impairments, the compliance with WCAG 2.1 is presented in detail and discussed. Based on the research findings, recommendations for making remote learning more accessible to students with special needs are proposed, with the goal of enabling everyone to receive a broad education without discrimination based on disability.

Keywords—accessibility, remote learning applications, inclusive education, WCAG

1 Introduction

In 2021, UNICEF reported that since March 2020, around 170 million out of 1.6 billion pupils worldwide were completely absent from school [1, 2]. Furthermore, 45 million children have missed three-quarters of the previous and current academic year [2]. A joint survey by UNESCO, UNICEF and the World Bank revealed that over 90% of the countries switched to remote learning, involving radio, TV, and the Internet [3]. In all these reports, special-needs students were almost completely neglected. They are only mentioned in the joint survey [3], which is related to the development of dedicated applications intended to enable communication between students and pedagogical professionals. Additional efforts associated with the creation of an alternative approach that increases information access and equal opportunity to education seem to be ignored. This motivated us to examine whether remote education restricts equal educational opportunities to students with disabilities.

To avoid the threat of disabling education for their students, most schools, particularly upper secondary and higher education, immediately moved from traditional in-class education to online teaching and learning by the end of March 2020 [2]. This was not a victimless activity. The replacement of face-to-face education by remote activities has considerably affected the schools, the teachers, and the students.

Schools had to immediately adapt their existing infrastructure to support online education. For many higher education schools, this was not a challenging task because they had already strongly supported online education relying on learning management systems [4]. However, many schools had no experience in providing remote education [5] and were obliged to decide which learning management system (LMS) would most effectively support access to existing learning resources, assignments, tests, and practical exercises without delay. The second crucial decision was the selection of a corresponding audio and video teleconferencing (AVT) tool, which is compatible with the selected LMS and enables smooth, scalable, and technically undemanding communication. To support the assessment, schools were supposed to determine how to organize the exams and to provide the best protection against students' scams, including secure browsers and monitoring via video chat or via video streaming applications. After finishing the selection process, schools had to train teachers to use these services within a very short period of time [6].

Teachers, who play a critical role in the educational process, were forced to reinvent themselves and adapt their teaching methods to the new environment [7]. They were supposed to learn how to use the technology to successfully create an active online learning environment. Their responsibility was to develop many techniques that stimulate interactivity during lectures, to transform the teaching and learning habits, facilitating the creation of a pleasant environment that motivates students to persist, and to find attractive ways to initiate collaboration [8]. Moreover, they had to engage parents, whose main role was to support the remote attendance of lectures and learning of their children, and to monitor their involvement in alternative education [9]. Many parents were not ready to take on these new responsibilities, either because they didn't know how to use technology or because the pandemic forced them to have more responsibilities.

The major goal of education is to prepare students for a life of learning and gaining new knowledge and skills [10]. To cope with the pandemic, learners had to accept new technological activities even when their home infrastructure was insufficient to enable access to remote learning resources [11]. An additional effort was to find a good motivation to persist with the imposed school rules [12]. Students' duty to focus on-screen for hours, to learn and prepare their assignments without the support of teachers and schoolmates, affected their learning achievements [13]. The greatest challenge of the online environment was to suppress the impression of being left alone [14, 15].

The impact of the school closure due to COVID-19 was stressful for everyone, but especially for students with special needs. For decades, pre-school and school children have been supported by teaching assistants, whose role was to contribute to the inclusion of children with different disabilities in mainstream schools [16]. In many inclusive schools that were not closed due to the COVID-19 pandemic, teaching and learning continued through the implementation of a hybrid mode, which combines online learning with a face-to-face model [17]. Younger students attended the lectures at school and then continued at home, relying on online education. Their socio-emotional and academic learning outcomes depended on the devotion of their teachers and particularly on the active engagement of their parents, who had to balance their own responsibilities and struggle with the new role imposed by remote learning [18]. The teachers' and parents' sacrifice was crucial and valuable because the consequences of disregarding the educational needs and emotional balance of disabled children are irreversible.

According to a UNICEF report [2], students with disabilities who were forced to shift to online education were literally abandoned [2]. This resulted in the exclusion of many impaired students from education [19]. In parallel, the results of those who were enabled to remotely learn significantly decreased [20], which additionally undermined their already low self-esteem [21]. All these proofs were the motivation to check whether the essential groundwork for remote education exists. It depends on the accessibility of the applications enabling online teaching, learning and assessment, as presented in Figure 1.

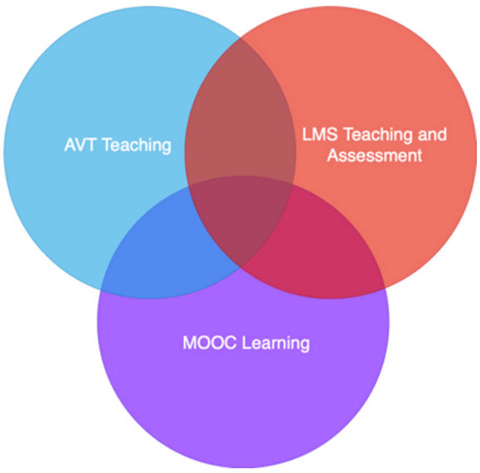

Fig. 1. Synergy of applications enabling efficient online teaching, learning, and assessment

The development of accessible online environments is usually evaluated with these two guidelines and standards: Web Content Accessibility Guidelines 2.1 [22], and Section 508 of the Vocational Rehabilitation Act of 1973, upgraded in 2017 [23]. As stated by [24], the main goal of the Web Content Accessibility Guidelines (WCAG) is "to ensure that Web content is accessible to as many people as possible". It was approved by the ISO/IEC/TC Information Technology Technical Committee in 2012 [25].

In university settings, prior to COVID-19, we experienced several challenges related to students with various disabilities. Students with motor disabilities, such as cerebral palsy or polio, had many problems during time-limited examinations. To enable them to have equal conditions, all the time limits were either relaxed or completely removed. On the second midterm exam in the *Introduction to Computer Science course*, they were supposed to show mastery of image editing and desktop publishing. The lack of alternative input methods apart from the mouse was the major reason for dropping out of the faculty after the first semester, even if they were successful in the theoretical courses. We had several students with impaired hearing and vision. They were supported by their teachers, assistants, and mates, but no accessibility options were activated in the labs. Deaf and blind students have never even tried to enroll in engineering studies, primarily because the faculty does not offer teaching in sign language and books written in Braille script. Several students with dyslexia have successfully studied, with great support from the teaching staff.

During COVID-19, it was crucial to promptly switch to remote teaching and learning. All the students with impaired hearing and vision were in their final year of studies. They were offered an alternative way to access their lectures and study materials. The exams were organized outside of the regular exams on a person-to-person remote communication basis. It was time-consuming for their teachers, but in the absence of any accessible solution, this was the only way to enable them to successfully finish the enrolled courses and graduate. Since there were no other students with these disabilities, the corresponding accessible solutions were not added to the faculty learning management system Moodle and the audio and video conferencing tool BigBlueButton.

Based on the facts elaborated in the beginning of this section and the experience with differently abled students, we were motivated to find the answers to the following research questions:

- RQ1: Are students with various disabilities restricted from continuing their education during the emergent remote education circumstances triggered by COVID-19?
- RQ2: Is there an essential groundwork for inclusive online education?
- RQ3: Are the existing applications intended for remote education compliant with the web accessibility guidelines?

The rest of the paper is structured as follows: The second section highlights the related work and background knowledge. It emphasizes the transition to remote education, its challenges, and barriers. In addition, it also introduces the most widely used accessibility options. Due to its international recognition and wider applicability to wider categories of disabilities, the assessment of accessibility options of the three mutually interconnected applications is conducted using Web Content Accessibility Guidelines 2.1 [22]. This approach is explained in the third section. The results of the assessment are presented in the fourth section, where we carefully explore teaching and learning components aiming to evaluate how much they accommodate the educational needs of students with motor, vision, hearing, and cognitive impairments. Within the fifth section, research questions are answered. Based on the findings of the research, the paper concludes with recommendations on how to make online learning more accessible to students with special needs, allowing for a broad education for all without discrimination.

2 Related work and background

The ongoing pandemics triggered a rapid shift to online and remote education, exposing some of the shortcomings of traditional learning platforms and infrastructures as well as new opportunities for developing sustainable and accessible solutions. The body of knowledge has evidenced a significant growth in terms of the quantum of published papers related to COVID-19 and online learning implications. A thematic recommendation for future sustainable programs and the teachers' perspective in terms of distress, loneliness, and happiness during the COVID19 outbreak were addressed in [26, 27, 28, 29]. Another investigation of teachers' opinions was conducted by [30], whereas the digital activism of students in the COVID19 era was explored in [31].

However, the research is very scarce towards examining the challenges of disabled learners during the pandemics, including an accessibility investigation of the learning platforms. As indicated by [32], accessibility issues for learners with hearing impairments were hampering continued learning and impacted learners' well-being and confidence. In [33], the authors highlighted the need for a teacher support system to strengthen the online class competency of special education teachers and recommended a continuum of learning opportunities to foster effective communication.

Accessibility challenges and barriers to the successful design and exploitation of digital resources in the emerging remote education context are explored by [34]. Among different findings and considerations, the creation and the utilization of open educational resources were identified as a necessary step to bridge the accessibility-related obstacles of digital teaching in inclusive education settings. Interactive teaching strategies advocating for compassion and accessibility and using open educational resources to promote equity in education were suggested by [35]. The application of accessibility review methodologies with transversal actions in the creation and management of learning resources and MOOCs (Massive Open Online Courses) is suggested in [36]. The authors claim that this approach could ensure inclusive and equitable quality education for all. An analysis to explore design criteria for learning applications that favor the learning process and meet the needs of people with disabilities, equal opportunities, and universal accessibility was conducted by [37]. In another work [38], the e-learning experiences of deaf learners during the pandemics are investigated. The findings from this study identified several relevant issues, where the inaccessibility of content from the learning systems was one of them.

A universal design-based framework for addressing accessibility issues in learning platforms and for making online learning more equitable and inclusive is proposed by [39]. The author believes that such an approach can contribute to achieving a new normal post-pandemic and involves designing inclusive learning opportunities for all learners. An exhaustive survey of relevant papers was performed by Russ and Hamidi [40], aiming to shed light on the accessibility of learning platforms at the time of the COVID-19 crisis. Among the numerous findings, the authors also emphasize how accessible content can prevent increasing opportunity gaps.

When it comes to the accessibility of video conferencing tools, an evaluation study to test the accessibility of Zoom, Google Meet, and MS Teams with visually impaired users was conducted by [41]. The findings showed that, although Zoom was preferred, none of the tools were found to be fully accessible via keyboard and screen reader. Furthermore, an investigation of the accessibility properties of Zoom to improve equity in the classroom was performed by Dolamore [42]. This study recommends that the spotlight feature and backchannel button can further enhance the accessibility of the learning experience for all learners, claiming that incorporating these features is critical for creating a more inclusive learning environment.

3 Overview of WCAG 2.1 and its impact on accessible education

Online learning can impose unique challenges on students with disabilities, many of which rely on physical and occupational therapy, after-school programs, and other support services that are difficult to replicate online. This was the major reason for the World Wide Web Consortium (W3C) to create an exhaustive list of guidelines for web developers who build accessible web pages for people with disabilities [22]. The referenceable technical standards in the form of guidelines and resources are united within WCAG: Web Content Accessibility Guidelines [22], which is expected to ensure a single standard for web and mobile accessibility.

WCAG 2.1 is a wide collection of recommendations intended to assess and enable better accessibility of web content that was approved by the ISO standard *ISO/IEC 40500:2012*. It is hierarchically organized, starting with the four layers of guidance that encompass: principles, guidelines, success criteria, and techniques. Web accessibility, which is crucial for online higher education of special-needs students, is further divided into four principles: perceivable, operable, understandable, and robust (See Figure 2). Each principle has guidelines that suggest the success criteria corresponding to the four principles.

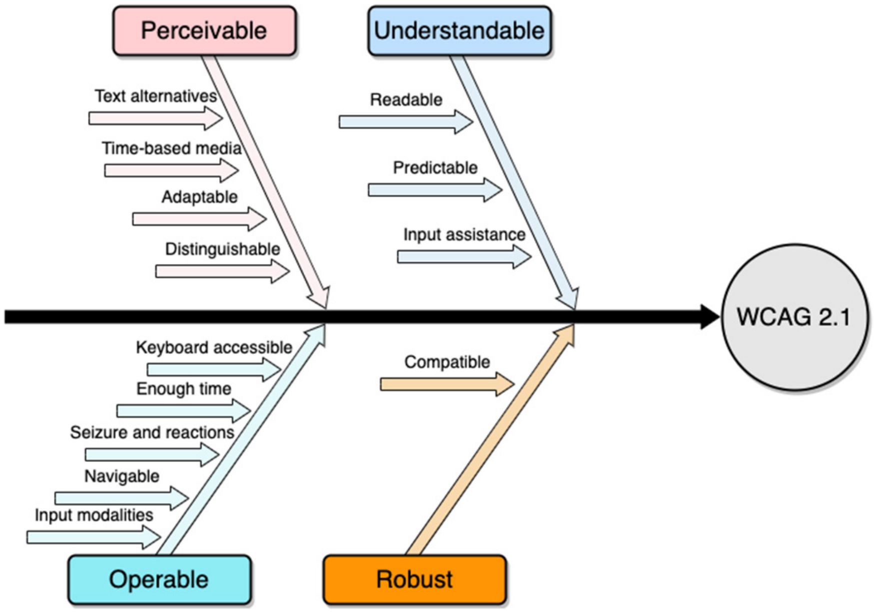

Fig. 2. The four principles of WCAG 2.1

The guidelines are divided based on their success criteria. Due to their volume, they are not presented in the hierarchical tree. They are testable, so they will be examined in detail in the following section. Success criteria progress from the lowest level of conformance (A) to the highest level of conformance (AAA).

WCAG 2.1 presents a range of techniques, divided into sufficient, advisory, and failures. Sufficient techniques cover the essential ways to meet the success criteria, whereas advisory techniques are recommendations to improve accessibility, while failures present the major accessibility barriers. The upgraded version of WCAG 2.2 was drafted in May 2021, and it is still under review [43].

As mentioned in the introduction, this paper is concerned with the following four impairments: motor, vision, hearing, and cognitive. The explanation of WCAG 2.1 levels of guidance and the corresponding success criteria for each of the selected impairments will be presented in more detail in the following subsections.

3.1 Motor impairment

Remote learning is challenging for students with motor skills disorders, who are frequently incapable of making purposeful movements with precision due to tremors or muscle slowness. For example, dyspraxia, which affects 5–6% of people, limits their fine and gross motor skills [44]. Although most schools have developed robust e-learning programs, especially due to the COVID-19 pandemic, many students still struggle with executive functioning and technology skills needed to succeed during online instruction. Among others, they may require a lot of supervision to stay on task. This is also due to technical difficulties that might appear during Zoom classes (e.g., video is blocky and keeps freezing, application crashes, audio problems, etc.), and since in many families, parents cannot be around all the time with their school children, this can be quite overwhelming [45].

Applications suitable for students with motor impairment must meet the following operable guidelines:

1. Keyboard accessibility (guideline 2.1)

Students with tremors or muscle slowness usually have difficulty using the mouse for navigating through the web. Therefore, it is preferred to provide them with the use of a keyboard. All the four success criteria of this guideline: keyboard (success criterion 2.1.1), no keyboard trap (2.1.2), keyboard (exception) (2.1.3), and character key shortcuts (2.1.4) are important for motor-impaired students.

2. Enough time (guideline 2.2)

Students with motor impairments need more time to read, react, and complete activities than average students. Although all the success criteria are important for them, our experience of examining two students with mild cerebral palsy indicates that they needed fewer time constraints. The success criteria that we used within our examination site was timing adjustable (2.2.1). For more severe problems, no timing (2.2.3) is a better solution.

3. Input modalities (guideline 2.5)

Some webpages use complex and timed motions, demanding a precise and instantaneous reaction. Similarly, to the need for more time, an alternative method of input should be provided to enable students with motor impairments to interact with the content via single untimed pointer gestures. Three of the success criteria within this guideline are important for motor-impaired students: pointer cancelation (2.5.2), motion actuation (2.5.4), and target size (2.5.5).

All user interfaces should be understandable per se for all the students. For the motor impaired, predictable content is a complement to guideline 2.2, so the final desired feature of the learning application is:

4. Predictable (guideline 3.2)

This parameter provides an easy way to determine how to complete the tasks using the fewest keystrokes. In other words, predictability will reduce the risk of accidental change in the context. The two critical criteria are focus (3.2.1) and input (3.2.2). A recent study four-times

3.2 Vision impairment

A recent report by the American Foundation of the Blind [46] estimated that more than half a million US students have some vision difficulties, one tenth of them being blind. The World Health Organization [47] calculates that approximately 1 billion people have moderate or severe vision problems, with a four-times [48] higher prevalence in countries with low or middle income. According to [49], the two main difficulties vision-impaired students experience are related to accessing and using the online tools. Inaccessibility is considered to be the main problem for acute vision impaired users because WCAG 2.1 guidelines do not consider the accessibility of learning materials that are uploaded in the learning repositories. Consequently, it is crucial to understand the needs of visually impaired users in order to design an effective and accessible e-learning environment [49]. A survey of vision impaired students revealed that the ratio of accessing teaching materials via laptop computers and via smartphones was 2:1 [50]. The preference for larger displays is mainly because the essential concepts like tables, graphics, disabled, and visualization elements are stored and presented as raster graphics, better known as bitmaps [51]. Raster graphics disable students with low vision to scale illustrations, including diagrams, restricting their perception, and understanding of what is being taught. Armstrong listed three obstacles related to this division: visual presentation of the learning materials, inappropriate design of web-based content and lack of play and experimentation in a computer environment [52]. These obstacles confirm the doubt that online learning can cause digital marginalization and dichotomy of students with vision disabilities, who, as a result, lose their self-confidence due to emotional blocks that hinder their participation in online education [53]. The universal solution for vision-impaired students is text alternatives [54]. They unite non-text content in the form of pre-recorded or synthetized speech to present the content and speech recognition applications intended to interpret written commands, notices, and automatic assessments into spoken content [55].

The following text is focused on the most convenient WCAG 2.1 guidelines and success criteria that an online environment should provide. A perceivable principle is crucial for both vision and hearing-impaired students. Namely, most content is available either in a visual or an audio format. To avoid the barrier of disabling access to educational content for students with severe perception disabilities, online content must be alternatively presented to enable recognition and understanding. Within this principle, four guidelines are important for students with vision deficiency:

1. Text alternatives (guideline 1.1)

Text alternatives provide an alternative way of presenting the visual content using large print, speech, Braille display, symbols, and a simpler language. Non-text content includes time-based media. Their minimum requirement is descriptive identification. This guideline consists of only one criterion: non-text content (1.1.1).

2. Time-based media (guideline 1.2)

Pre-recorded audio content is an appropriate alternative for the vision impaired with no hearing or cognitive problems. They encompass several success criteria that are important for the vision impaired: audio only (1.2.1), captions (1.2.2), limited audio description (1.2.3), live captions (1.2.4), complete audio description (1.2.5), extended pre-recorded (1.2.7), and live audio only (1.2.9).

3. Adaptability (guideline 1.3)

Adaptability embraces various ways to present the content, including simpler screen layout, content presentation in different screen sizes without losing context, as well as content interpretation with speech. This approach is the most effective way of presenting visual content for students who have sight problems. The recommended success criteria should be "programmatically determined" (W3C, 2018). The success criteria related to seeing disability are: info and relationships (1.3.1), meaningful sequence (1.3.2), sensory characteristics (1.3.3), and orientation (1.3.4).

4. Distinguishable (guideline 1.4)

Students with visual impairment need to distinguish the main or core content from the web page background. To fulfill the guidelines, web-accessible content should conform to most of the proposed success criteria: color (1.4.1), contrast (minimum) (1.4.3), text resize (1.4.4), text images (1.4.5), contrast (enhanced) (1.4.6), text images (no exception) (1.4.9), reflow (1.4.10), non-text contrast (1.4.11), text spacing (1.4.12), and content on hover or focus (1.4.13)

Operability is almost as important to students with vision deficiency as it is to students who have motor impairment. Here are the main guidelines suitable for these students:

5. Keyboard accessibility (guideline 2.1)

The content becomes functionally available by allowing students with vision impairments to access all parts of the onscreen content and use the keyboard to activate it. The corresponding success criteria for them are: keyboard (2.1.1), no keyboard trap (2.1.2), and keyboard (exception) (2.1.3).

6. Enough time (guideline 2.2)

Students with vision impairments need more time to read or use the content. Imposed time limits should be avoided as much as possible. To fulfill this goal, time adjustable (2.2.1), no timing (2.2.3), interruptions (2.2.4), and timeouts (2.2.6) are the necessary success criteria.

7. Navigable (guideline 2.3)

Navigable features help students with vision (2.4.7) to easily understand where they are on the webpage and to easily go through the content. They include page titles (2.4.2), focus content (2.4.3), link purpose (in context) (2.4.4), multiple ways (2.4.5), headings and labels (2.4.6), focus visible (2.4.7), and section headings (2.4.10).

8. Input modalities (guideline 2.5)

Input modalities are important to provide vision impaired students with alternative input devices, including mice, touch screens, and particularly assistive technologies, such as speech-to-text, that enable students to verbally express their choices. For vision-impaired students, the following success criteria are required: pointer gestures (2.5.1), pointer cancellation (2.5.2), and label in name (2.5.3).

Understandable features are divided into three groups of guidelines: readable, predictable, and input assistance.

9. Readable (guideline 3.1)

Text content readability and the ability to understand the educational content are related to add-ons that are used to interpret the presented text and content as speech. Therefore, all the suggested success criteria: language of page (3.1.1), language of parts (3.1.2), unusual words (3.1.3), abbreviations (3.1.4), and particularly reading level (3.1.5) and pronunciation (3.1.6) should be taken into consideration when creating the educational content intended for vision-impaired students.

10. Predictable (guideline 3.2)

Completion of tasks using the fewest keystrokes can also be beneficial to students with minor or severe vision deficits. All the five success criteria: on focus (3.2.1), on input (3.2.2), consistent navigation (3.2.3), consistent identification (3.2.4), and change on request (3.2.5) will prevent the accidental change of the content.

11. Input assistance (guideline 3.3)

Input assistance is a complementary quality of readability and predictability that provides visual clues to people using specific national conventions, like national telecommunication standards. Therefore, they are not additionally examined in this paper. Robust content is explained as content that "can be interpreted by a wide variety of user agents, including assistive technologies" [56]. Robustness consists of one guideline only: compatibility, referring to the possibility to access digital content on different infrastructures, including devices, browsers, operating systems, and assistive technology.

12. Compatible (guideline 4.1)

Compatibility as a crucial software quality criterion is the main parameter that supports the unification of assistive technologies with the visible onscreen content. Parsing (4.1.1) and status messages (4.1.3) are the main compatible success criteria intended for the vision impaired.

3.3 Hearing impairment

Hearing impairment affects 430 million people worldwide, including 34 million children, the majority of whom are from low-or middle-income countries [57]. The hearing impaired mostly rely on the use of technology such as hearing aids or cochlear implants [58]. In the online environment, their challenges arise. Due to their inability to clearly understand others, these students hardly concentrate, frequently become tired or stressed, and avoid participating in the discussions. Moreover, the distortion of the sound and the noise from unmuted microphones additionally affect their participation in online meetings, making them feel more marginalized. To overcome the drawbacks imposed by this impairment, online learning materials should provide real-time text captioning for all audio, video, and multimedia presentations that are placed on learning platforms or websites [58]. Many innovative technologies have been invented to support the learning of hearing-impaired students, like speech-to-text recognition [59], virtual reality [60], 3D audio [61], and AAC [62].

According to WCAG 2.1, accessibility of web content for students with hearing impairments should embrace the following five guidelines:

1. Time-based media (guideline 1.2)

For students who are hearing impaired, pre-recorded video content (1.2.1), pre-recorded captions in synchronized media (1.2.2), and sign language (1.2.6) can significantly facilitate the acquisition of new knowledge and the visual interpretation of verbally presented content.

2. Adaptable (guideline 1.3)

Although online content is predominantly visual, and audio content is supported with subtitles, a simpler layout can additionally facilitate awareness. To achieve this goal, it is sufficient to support information and relationships (1.3.1).

3. Distinguishable (guideline 1.4)

Distinguishable content is valuable for students with hearing problems because they need to use and read the content from a webpage with appropriate foreground sound. If they are not completely deaf, audio control (1.4.2) and low or no background audio (1.4.7) will help them listen to the audio content more clearly without additional sound distractions.

4. Enough time (guideline 2.2).

Students with hearing impairments who communicate using sign language need more time to read information printed in text. Control over time limits is also important if a sign interpreter clarifies audio content for them. The most important success criteria of this guideline for hearing impaired students are: timing adjustable (2.2.1) and re-authenticating (2.2.5).

5. Predictable (guideline 3.2)

Similarly, for the vision impaired, completion of tasks using the fewest keystrokes can be beneficial to students with minor or severe hearing problems. Again, all the five success criteria: on focus (3.2.1), on input (3.2.2), consistent navigation (3.2.3), consistent identification (3.2.4), and change on request (3.2.5) are important to prevent the accidental change of the context, particularly when the explanation of the intended modification is orally presented.

3.4 Cognitive impairment

"Cognitive impairment" refers to problems people have with cognitive functions such as thinking, reasoning, memory, or attention [63]. Even though they don't need special tools when they navigate and browse web pages, they typically need more time to interpret the content. Therefore, it is important to develop a regular school and classroom community that fits, nurtures, and supports the educational and social needs of every student [64]. Students with cognitive impairments have some characteristics that affect their classroom performance. Based on the study Instructional Strategies for

Students with Cognitive Impairments Study Guide [65], the challenges they face are short attention span, little endurance, low motivation, getting tired easily, poor memory skills, and trouble forming thoughts into words to communicate their needs and wants. Accessibility of webpages for students with cognitive impairments is a greater challenge compared to other types of disabilities. Since this impairment is considered to be the least understood, most of the data found or published is from a clinical point of view that is not related to website accessibility. Due to this lack of data, WCAG 2.1 has managed to help users with cognitive impairments through success criteria that will make a web page accessible for them. The following paragraphs present them in more detail.

6. Adaptable (guideline 1.3)

Our personal experience with students with mild cognitive impairment is that they communicate better with images. They prefer to add icons to input fields so they can understand the purpose of the fields visually. The most important success criteria for this type of impairment are to identify input purpose (1.3.5) and input purpose (1.3.6).

7. Enough time (guideline 2.2)

Students with various cognitive impairments, such as dyslexia, need more time to read and comprehend the content of a webpage. They tend to read the information by pausing the content of a webpage. All the six success criteria: time adjustable (2.2.1), no timing (2.2.2), pause, stop, hide (2.2.3), interruptions (2.2.4), re-authentication (2.2.5), and timeouts (2.2.6) are important for them.

8. Navigable (guideline 2.4)

Students with cognitive impairment prefer organized content to easily navigate through the web and to have an intuitive overview of the site rather than reading and traversing through several web pages. To achieve this objective, these seven success criteria must be considered: bypass blocks (2.4.1), page titles (2.4.2), link purpose (in context) (2.4.4), multiple ways (2.4.5), headings and labels (2.4.6), location (2.4.8), and link purpose (link only) (2.4.9).

9. Readable (guideline 3.1)

Cognitively impaired students need additional content to help them understand difficult and complex text that appears on screen. Similarly, for the vision impaired, the content should obey all the success criteria: language of page (3.1.1), language of parts (3.1.2), unusual words (3.1.3), abbreviations (3.1.4), and particularly reading level (3.1.5) and pronunciation (3.1.6).

10. Predictable (guideline 3.2)

The intuitive structural order of repeated components makes students more comfortable, and they can easily find the things on each page. Out of the five success criteria belonging to this guideline, these three: focus (3.2.1), consistent navigation (3.2.3), and change on request (3.2.5) are important for students with cognitive impairment.

11. Input assistance (guideline 3.3)

Students with cognitive impairment need the notices for the errors occurring on a webpage due to their activities, so they will be able to understand what they should do to correct that error. In other words, students should be provided with clear, unambiguous labels and instructions so they can enter information correctly. All the six success criteria: error identification (3.3.1), labels of instruction (3.3.2), error suggestion (3.3.3), error prevention (legal, financial, data) (3.3.4), help (3.3.5), and error prevention (all) (3.3.6) completely or in parts, will assist all the impaired students, but particularly the students with cognitive deficiencies.

4 Assessing the conformance of learning platforms to WCAG 2.1

After making a thorough review of several technical journals [66], marketplaces [67], and knowledge sharing platforms [68], we decided to evaluate the following learning management systems: Blackboard Learn (blackboard.com/), D2L Brightspace (d2l.com/), Instructure Canvas (instructure.com/canvas), and Moodle (moodle.org/). Blackboard and D2L are proprietary, while Canvas and Moodle are open source.

This section will explore how much the functionalities of most popular learning management systems, the most frequently used audio and video telecommunication tools, and the most popular massive open online courses conform to WCAG 2.1 guidelines. The bigger the conformance, the more successful is the replacement of traditional education with completely online teaching, learning, and assessment.

For this analysis, we followed the method of functional analysis, proposed by Löwgren and Stolterman [69]. The main purpose of this method is to summarize and structure the available functional information and to decide where more information is needed in a particular context, which in our case is accessibility. Hence, the idea behind function analysis is to express what the future product should do in terms of functions in order to meet certain requirements or criteria. Moreover, Landqvist [70] defines function analysis as a process for summarizing and structuring given information and determining where further information is required.

4.1 Accessibility of learning management systems

This section is centered on the analysis of the degree of accessibility of learning management systems from the point of view of WCAG 2.1 guidelines across the four types of impairments.

Students with motor impairment. The conformance of selected guidelines and success criteria for motor-impaired students is presented in Table 1. Blackboard has a specialized product, Ally, created for students with various disabilities. According to Ally's checklist [71], the conformance to WCAG 2.1 level AA is complete. On the other hand, with a more thorough examination, it shows that only 18.18% of the success criteria selected in the previous section conform to WCAG 2.1. D2L Brightspace explicitly declares full conformance with WCAG 2.1 level AAA. The Brightspace core list shows that 63.64% of the success criteria, important to motor impaired students, are fully supported by this LMS.

Table 1. Comparison of the conformance of selected LMS to WCAG 2.1 for motor impaired students

Motor Impairment					
Guideline	**Success Criterion**	**Blackboard Learn**	**D2L Brightspace**	**Instructure Canvas**	**Moodle**
Keyboard accessible (2.1)	Keyboard (2.1.1)	Supports	Partially supports	Partially supports	Partially supports
	No keyboard trap (2.1.2)	Not considered	Supports	Supports	Supports
	Keyboard (exception) (2.1.3)	Not considered	Not considered	Not considered	Not considered
	Character key shortcuts (2.1.4)	Not considered	Supports	Not considered	Supports
Enough time (2.2)	Timing adjustable (2.2.1)	Supports	Supports	Supports	Supports
	No timing (2.2.3)	Not considered	Not considered	Not considered	Not considered
Input modalities (2.5)	Pointer cancelation (2.5.2)	Not considered	Supports	Supports	Supports
	Motion actuation (2.5.4)	Not considered	Supports	Supports	Not applicable
	Target size (2.5.5)	Not considered	Not considered	Not considered	Not considered
Predictable (3.2)	On focus (3.2.1)	Not considered	Supports	Supports	Supports
	On input (3.2.2)	Not considered	Supports	Supports	Supports

Henceforth, this was the major reason it was awarded the best solution for students with special needs [72]. Instructure Canvas has recently published a report presenting the conformance to WCAG 2.1 levels A and AA [73].

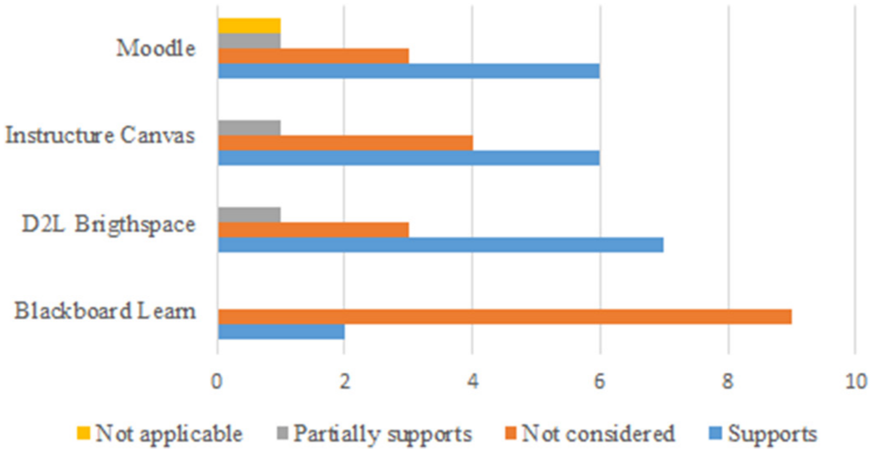

Fig. 3. Success criteria for people with motor impairment and their presence in the selected learning management systems

Statistical distribution of the compliance with the selected success criteria related to motor impairment is presented with the chart on Figure 3. It uses the keywords: "not applicable", "partially supports" and "supports," according to WCAG 2.1 recommendations. Whenever none of the following three compliance categories was indicated for the selected success criteria, we decided to mark it as "not considered". It shows that D2L Brightspace is the most suitable LMS for the motor impaired, while Blackboard Learn supports only 2 out of 11 selected success criteria, neglecting all the remaining ones.

The only success criterion for the motor impaired that is inferior to Brightspace is the lack of character key shortcuts, making Canvas a very accessible LMS for these students. Moodle is the only LMS on our list with a WCAG 2.1 Level AA accreditation badge for 2021 and 2022. According to their accessibility conformance report [74], the fulfillment of accessibility success criteria is equal to Canvas, with an alteration between character key shortcuts and motion actuation.

All the assessed LMSs have not taken these three success criteria into consideration: keyboard (exception) (2.1.3), no timing (2.2.3) and target size (2.5.5). They all belong to the highest-level AAA, which is not recommended as a general policy for entire sites according to WCAG 2.1. If they are excluded from the list of compulsory criteria for motor-impaired students, then the examined LMSs have a very high level of accessibility intended for students with motor impairment. It ranges between 25% for Blackboard Learn and a remarkable 93.75% for D2L Brightspace.

Vision impaired students. Because most of the content is presented in textual and graphical formats, vision-impaired students are the most affected by complete online learning. Therefore, the list of WCAG 2.1 guidelines and the corresponding success criteria that are presented in Table 2 is huge. Therefore, for better presentation of the findings, we have divided them into 3 parts.

Table 2a. Comparison of the conformance of selected LMS to WCAG 2.1 guidelines (1.1, 1.2, 1.3, 1.4) for vision impaired students

Vision impairment					
Guideline	**Success Criterion**	**Blackboard Learn**	**D2L Brightspace**	**Instructure Canvas**	**Moodle**
Text alternatives (1.1)	Non-text content (1.1.1)	Supports	Partially supports	Partially supports	Supports
Time-based media (1.2)	Audio only (1.2.1)	Not considered	Not applicable	Not applicable	Supports
	Captions (1.2.2)	Supports	Not applicable	Not applicable	Supports
	Limited audio description (1.2.3)	Supports	Not applicable	Not applicable	Not applicable
	Live captions (1.2.4)	Not considered	Not applicable	Not applicable	Not considered
	Complete audio description (1.2.5)	Supports	Not applicable	Not applicable	Not considered
	Extended pre-recorded (1.2.7)	Not considered	Not considered	Not applicable	Not considered
	Live audio only (1.2.9)	Not considered	Not considered	Not applicable	Not considered
Adaptable (1.3)	Info and relationships (1.3.1)	Supports	Supports	Partially supports	Supports
	Meaningful sequence (1.3.2)	Not considered	Supports	Supports	Supports
	Sensory characteristics (1.3.3)	Not considered	Supports	Supports	Partially supports
	Orientation (1.3.4)	Not considered	Supports	Supports	Not considered
Distinguishable (1.4)	Use of color (1.4.1)	Not considered	Partially supports	Supports	Supports
	Contrast (minimum) (1.4.3)	Supports	Supports	Supports	Not considered
	Resize text (1.4.4)	Not considered	Partially supports	Supports	Not considered
	Images of text (1.4.5)	Not considered	Supports	Supports	Not considered
	Contrast (enhanced) (1.4.6)	Supports	Not considered	Not considered	Not considered
	Images of text (no exception) (1.4.9)	Not considered	Not considered	Not considered	Not considered
	Reflow (1.4.10)	Not considered	Partially supports	Supports	Not considered
	Non-text contrast (1.4.11)	Not considered	Partially supports	Supports	Not considered
	Text spacing (1.4.12)	Not considered	Partially supports	Not applicable	Not considered
	Content on hover or focus (1.4.13)	Not considered	Supports	Supports	Not considered

Also, to avoid repetition, all the common success criteria from the previous table were omitted. The repeated 7 features were included in the estimation of WCAG 2.1 conformance for vision impaired students.

Table 2b. Comparison of the conformance of selected LMS to WCAG 2.1 guidelines (2.2, 2.4, and 2.5) for vision impaired students.

Vision Impairment					
Guideline	**Success Criterion**	**Blackboard Learn**	**D2L Brightspace**	**Instructure Canvas**	**Moodle**
Enough time (2.2)	Interruptions (2.2.4)	Supports	Not considered	Not considered	Not considered
	Timeouts (2.2.6)	Not considered	Not considered	Not considered	Not considered
Navigable (2.4)	Page titles (2.4.2)	Supports	Partially supports	Not applicable	Supports
	Focus content (2.4.3)	Not considered	Partially supports	Supports	Supports
	Link purpose (in context) (2.4.4)	Not considered	Supports	Supports	Supports
	Multiple ways (2.4.5)	Not considered	Not considered	Supports	Not considered
	Headings and labels (2.4.6)	Supports	Not considered	Partially supports	Not considered
	Focus visible (2.4.7)	Not considered	Not considered	Supports	Not considered
	Section headings (2.4.10)	Not considered	Not considered	Not considered	Not considered
Input modalities (2.5)	Pointer gestures (2.5.1)	Not considered	Supports	Supports	Supports
	Pointer cancelation (2.5.2)	Not considered	Supports	Supports	Supports
	Label in name (2.5.3)	Not considered	Supports	Partially supports	Supports

Table 2c. Comparison of the conformance of selected LMS to WCAG 2.1 guidelines (1.4, 2.2, 2.4) for vision impaired students

Vision Impairment					
Guideline	**Success Criterion**	**Blackboard Learn**	**D2L Brightspace**	**Instructure Canvas**	**Moodle**
	Pointer cancelation (2.5.2)	Not considered	Supports	Supports	Supports
	Label in name (2.5.3)	Not considered	Supports	Partially supports	Supports
Readable (3.1)	Language of page (3.1.1)	Supports	Supports	Supports	Supports
	Language of parts (3.1.2)	Supports	Not considered	Not applicable	Not considered
	Unusual words (3.1.3)	Not considered	Not considered	Not considered	Not considered
	Abbreviations (3.1.4)	Not considered	Not considered	Not considered	Not considered
	Reading level (3.1.5)	Not considered	Not considered	Not considered	Not considered
	Pronunciation (3.1.6)	Not considered	Not considered	Not considered	Not considered
Predictable (3.2)	Consistent navigation (3.2.3)	Not considered	Supports	Supports	Not considered
	Consistent identification (3.2.4)	Not considered	Supports	Supports	Not considered
	Change on request (3.2.5)	Supports	Not considered	Not considered	Not considered
Compatible (4.1)	Parsing (4.1.1)	Supports	Not considered	Supports	Supports
	Status messages (4.1.3)	Not considered	Not considered	Supports	Not considered

Similar to motor impairment, statistical analysis was made related to compliance of the selected success criteria that are important for vision impaired students. It is presented in Figure 4.

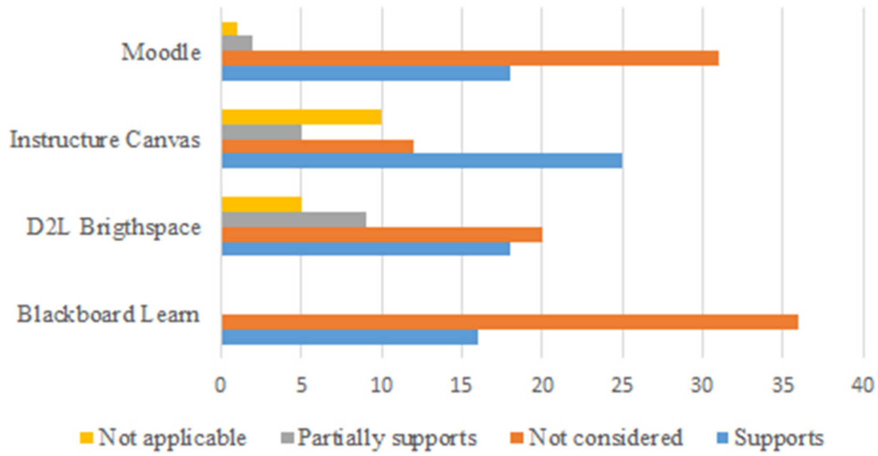

Fig. 4. Success criteria for people with vision impairment and their presence in the selected learning management systems

The percentage of fully supported success criteria ranges from 30.77% for Blackboard, 34.62% for D2L and Moodle, to 48.08% for Canvas. Partial support of an additional 3.85% was found for Moodle, 9.62% for Canvas and 17.31% for D2L. In total, D2L, with 51.82%, and Canvas, with 57.69% coverage, are the most suitable LMSs for vision impaired students. Still, the average of 47.60% of completely ignoring success criteria is disturbing. Among the assessed LMSs, Blackboard (69.23%) and Moodle (59/62%) overlook more than half of the suggested success criteria.

Combined with the average of 7.69% of not applicable criteria, the impression of the authors of this paper is that vision impaired students have serious obstacles to attending online education without additional extracurricular assistance outside the learning management systems.

Hearing impaired students. The list of selected success criteria for hearing impaired students consists of 13 WCAG 2.1 standards. The majority of them are applicable to students with motor and vision difficulties. Therefore, Table 3 presents only the hearing impairment specific success criteria.

Table 3. Comparison of the conformance of selected LMS to WCAG 2.1 for hearing impaired students

Guideline	Success Criterion	Blackboard Learn	D2L Brightspace	Instructure Canvas	Moodle
Time-based media (1.2)	Video only (1.2.1)	Not considered	Not applicable	Not applicable	Supports
	Sign language (1.2.6)	Not considered	Not considered	Not considered	Not applicable
Distinguishable (1.4)	Audio control (1.4.2)	Not considered	Not applicable	Supports	Supports
	Background audio (1.4.7)	Not considered	Not considered	Not considered	Not applicable
Enough time (1.2)	Re-authenticating (2.2.5)	Not considered	Not considered	Not considered	Partly supports

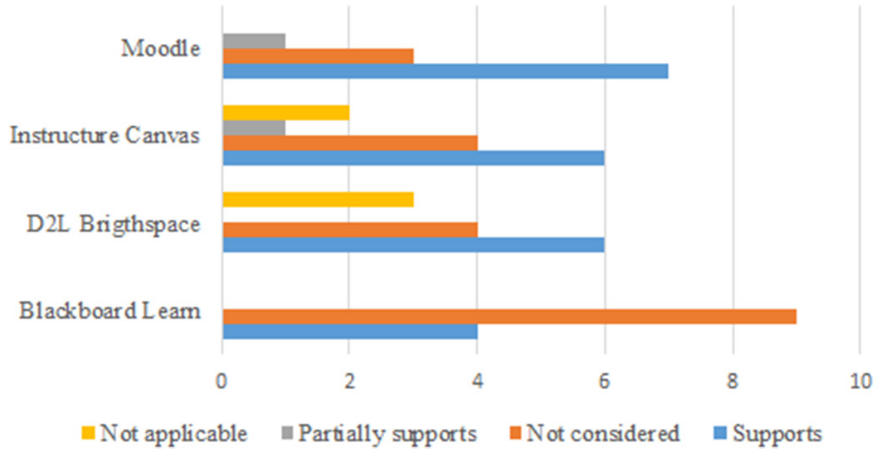

Fig. 5. Success criteria for people with hearing impairments and their presence in the selected learning management systems

Statistical analysis is presented in Figure 5. Hard of hearing and deaf students seem to be ignored by most LMSs that either do not consider WCAG 2.1 recommendations or declare that they are not applicable. Concerning hearing deficiency, Moodle is undeniably the best LMS, fully supporting 53.85% and partially supplementary 1.92% of all the chosen success criteria. D2L and Canvas support 46.15% of these criteria, while Blackboard has a low conformance level of 30.77%. The authors' impression is that LMSs rely on the hypothesis that the learning content is presented in a written format, and therefore LMS creators do not pay additional attention to accommodating hearing-impaired students. This fact is supported by the results of the experiment conducted by Lachner et al. [75], who suggest that written explanations are more effective than oral explanations.

Cognitively impaired students. Students with cognitive impairment do not necessarily have intellectual problems. For example, we have witnessed several students with bipolar disorder whose results were exceptional. One of them was always frustrated whenever the screen was packed with too much information. This is a unique case, which motivated us to extend the list of impairments to include the cognitive one. To accommodate such students, LMSs should conform to a total of 30 success criteria belonging to 6 guidelines. Table 4 presents only those that were not previously examined.

As presented in Figure 6, the average percentage of not considered success criteria of all LMSs is 60.00%, much higher than for any of the previously evaluated impairments. Respectively, the level of support is low, ranging from 30.00% for Moodle, 33.33% for Blackboard and D2L, to a modest 40.00% for Canvas.

Table 4. Comparison of the conformance of selected LMS to WCAG 2.1 for cognitively impaired students.

Cognitive Impairment					
Guideline	**Success criterion**	**Blackboard Learn**	**D2L Brightspace**	**Instructure Canvas**	**Moodle**
Adaptable (1.3)	Identify input purpose (1.3.5)	Not considered	Supports	Supports	Not considered
	Input purpose (1.3.6)	Not considered	Not considered	Not considered	Not considered
Enough time (2.2)	Time adjustable (2.2.1)	Supports	Supports	Supports	Supports
	No timing (2.2.2)	Supports	Supports	Supports	Not evaluated
	Pause, stop, hide (2.2.3)	Not considered	Not considered	Not considered	Not considered
Navigable (2.4)	Bypass blocks (2.4.1)	Supports	Supports	Supports	Supports
	Location (2.4.8.)	Not considered	Not considered	Not considered	Not considered
	Link purpose (2.4.9)	Not considered	Not considered	Not considered	Not considered
Input assistance (3.3)	Error identification (3.3.1)	Not considered	Supports	Supports	Supports
	Labels of instruction (3.3.2)	Supports	Supports	Partially supports	Supports
	Error suggestion (3.3.3)	Not considered	Not considered	Supports	Not considered
	Error prevention (3.3.4)	Not considered	Not considered	Supports	Not considered
	Help (3.3.5)	Not considered	Not considered	Not considered	Not considered
	Error prevention (all) (3.3.6)	Not considered	Not considered	Not considered	Not considered

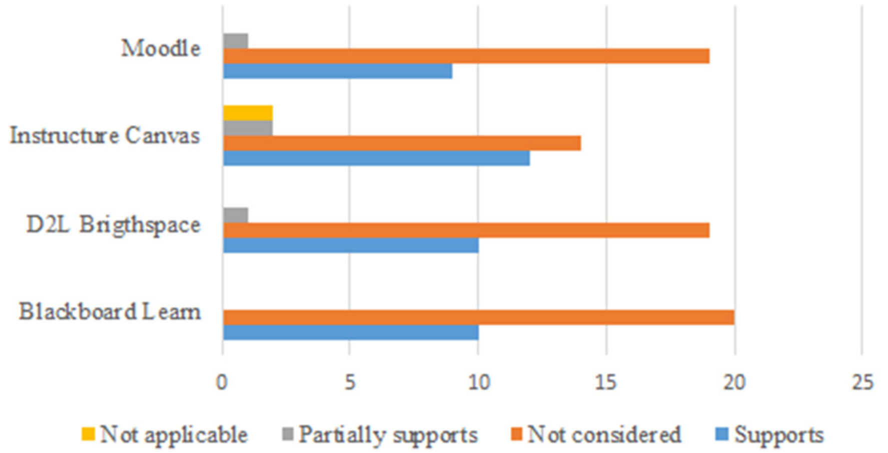

Fig. 6. Success criteria for people with cognitive impairment and their presence in the selected learning management systems

By merging the selected success criteria for the four impairments: motor, vision, hearing, and cognition, the supremacy of D2L Brightspace, reported by SIIA CODiE, is not confirmed. It is noticeable from the chart in Figure 7. Namely, this LMS has full support of 34.67%, compared to 45.33% of Instructure Canvas. One of the possible reasons for the inconsistency of the results is that in the assessment presented in this paper, all the success criteria were considered equally important. This premise is not completely valid, because some interface components, particularly the perceivable ones, are inevitable for some impairments. For example, without Braille or speech as a text alternative (guideline 1.1), blind students will never be able to participate in online education.

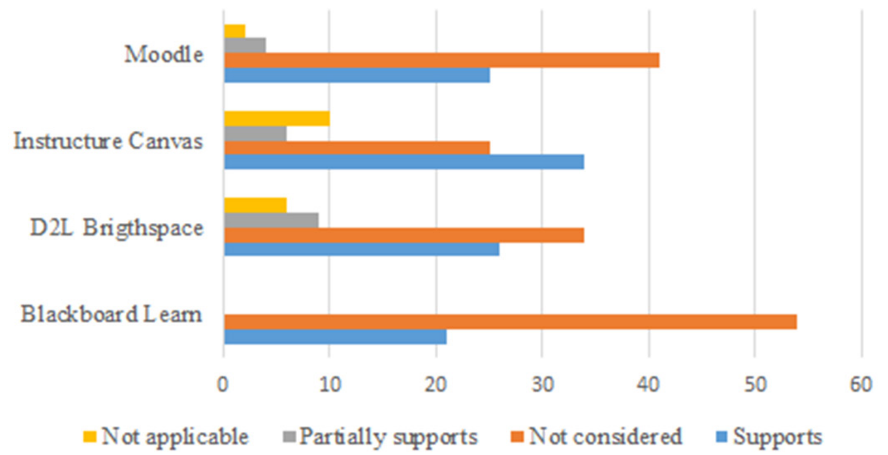

Fig. 7. Merged success criteria for all impairments and their presence in the selected learning management systems

4.2 Accessibility of audio and video teleconferencing tools

The major focus of this research was the following AVTs: BigBlueButton or BBB (bigbluebutton.org/), Blackboard Collaborate (blackboard.com), Google Meet (apps.google.com/meet/), Microsoft Teams (teams.microsoft.com) and Zoom (zoom.us), due to their acceptance for events the authors of this paper participated in since March 2020. Their accessibility is part of the complementary W3C convention called RTC Accessibility User Requirements [76]. It was created in 2017 but became important due to the shift to remote communication. Unlike WCAG 2.1, RTC does not offer any guidelines that are explicitly testable.

The accessibility of BigBlueButton (BBB) is certified according to WCAG 2.0 AA [77]. Unfortunately, the tutorials for using BBB are not accessible, restricting their use as a complementary tool for lecturing and examinations. Blackboard Collaborate has several features that support students with motor, vision, and hearing impairments [78]. The greatest benefit of using this AVT is its support for the JAWS screen reader [79]. The main problem is that it can be accessed by Windows operating system users only. Google Meet offers support for vision and hearing-impaired students' keyboard shortcuts [80]. Microsoft Teams provides a large list of supported accessibility features, including screen reader support [81], whereas Zoom has the same accessibility options as Google Meet, and it is conformant to WCAG 2.1 AA [82].

BigBlueButton has a large list of so-called LMS integrators [83]. They are either integrated with the LMS platforms or available as plugins. Blackboard Collaborate is merged with Blackboard Learn and its accessible version, Ally, providing all the incorporated accessible features of both [84]. Blackboard Collaborate is compatible with the four examined LMSs [85]. Due to its popularity, many LMSs have their own plugins for Google Meet, including Blackboard, D2L, Canvas, and Moodle. These plugins allow teachers to create a Google Meet room without leaving the LMS. The only prerequisite is that all participants, including the teachers and the students, must have an active Google account. Apart from the four selected LMSs in our study, Microsoft Teams [86] is compatible with Schoology (schoology.com). Zoom can be easily integrated with a variety of LMSs via CirQlive MEETS [86].

4.3 Accessibility of massive open online courses

The third component of the online education synergy is massive open online courses (MOOCs). Like AVTs, the selection was made according to their influence on the courses created at the universities the authors are affiliated with. Coursera (coursera.org), edX (edx.org), MIT OpenCourseWare (ocw.mit.edu/), and OpenLearning (openlearning.com) are all supported.

Coursera [87] offers various accommodations for students with hearing impairments in the form of multilingual subtitles. Most courses are supported by four different screen readers, intended for Windows, Mac OS, and mobile operating systems, Android, and iOS. Coursera enables several additional accommodations for learning disabilities. A great advantage of the edX accessibility [88] options is the transmission of page text towards the Braille display device. edX can accommodate motor-disabled students who provide eye-gaze-activated technology instead of traditional input devices. MIT

OpenCourseWare, a MOOC offered by MIT, the leading engineering university in the world, offers many remote teaching tools for disabled students [89]. A great advantage of this MOOC is the complementary video lectures, which facilitate access to teaching materials for vision-impaired students. Their activities are harmonized with the online conferencing tool Zoom, enhanced with closed captioning and automatic transcription of the meetings. OpenLearning has a large list of accessibility options [90] offered to students with vision and hearing problems. This MOOC instructs course creators on how to make accessible documents, spreadsheets, presentations, and other accessible content with Google and Adobe Acrobat.

5 Research findings

In order to answer the research questions defined in the introduction of the paper, a thorough assessment of the accessibility of e-learning components in line with WCAG 2.1 recommendations was performed. The findings of the detailed analyses are presented in the following subsections.

5.1 Are students with various disabilities restricted from continuing their education during the emergent remote education circumstances triggered by COVID-19?

The reports presented in the introduction of this paper, as well as the estimates of the number of impaired students presented throughout the second section, show that the majority of students from low and middle-income countries were left out, unable to study. Their fundamental human right to education was violated [2]. Students from English-speaking and high-income countries, particularly those who are enrolled in socially responsible universities in rich countries, have already experienced the advantages of online education. Their education has not been significantly affected by the pandemic [91].

There are still no reports about the number of impaired students who failed or decided to withdraw from the classes they enrolled in prior to the corona pandemic. Many students with various disabilities have given up studying due to the obstacles caused by online teaching, learning, and assessment. For them, teachers' presence and interventions are the decisive factors to persist. Even the most person-centered accessibility technologies cannot replace an empathetic teacher who is ready to spend hours upon hours demystifying the lecture and encouraging students to dive into knowledge.

5.2 Is there an essential foundation for inclusive online education?

The assessment presented in this paper covered the guidelines and the corresponding success criteria that should be respected to bypass the problems that obstruct students with motor disabilities from accessing learning resources; the accessibility prerequisites of services intended for the vision and hearing impaired, including deaf-blind students; and finally, the embedded add-ons for cognitive impairment. The synergy of the three e-learning components was carefully and thoroughly examined with the specific

WCAG 2.1 success criteria, whose presence determines the degree of conformance with the broader topic.

The essential groundwork for inclusive online education already exists. The observed LMSs, including the open-source Canvas and Moodle and non-commercial versions of AVTs, support this inclusiveness. For the essential students' demands, they are quite useful. Language drawbacks can be solved by nationally supported localization of the crucial accessible tools, at least the text-to-speech and speech-to-text applications [92]. Teachers should slightly sacrifice part of their spare time and encourage their disabled students to persist, knowing that any sacrifice leading to student satisfaction and better academic success is valuable.

5.3 Are the existing applications intended for remote education compliant with the web accessibility guidelines?

The learning management systems that were evaluated met the fundamental success criteria for students with motor impairment. To enable full participation of vision-impaired students in remote curricular and extracurricular activities, LMSs must be additionally upgraded with many success criteria that are currently ignored or omitted. Moreover, they do not sufficiently accommodate hearing impaired students, supporting additional written explanations. Finally, they still miss many add-ons intended for students with cognitive impairment.

People with various impairments can use audio and video teleconferencing tools that are WCAG 2.1 compliant, enabling full access to all their functionalities. They are created to enable mutual online communication for all purposes, despite their abilities [93]. Moreover, they are fully compatible with LMS platforms. Their integration has superior accessibility compared to its constituents (AVTs and LMSs), because some missing features of one component can be compensated for by the second one. Another interesting fact arising from this evaluation is that Blackboard Collaborate and Microsoft Teams are compatible exclusively with the LMSs selected in our study, confirming the validity of our selection.

MOOCs pay a lot of attention to various disabilities. Despite this initial impression, only OpenLearning addresses all the four disabilities examined in this paper. These MOOCs have specific accessibility opportunities for students with motion sensitivity and cognition disabilities, in addition to tools for low-vision and hard-of-hearing students. Although the importance of accessibility to online educational resources has been widely explored [94], there is still a limited discussion and investigation into the accessible design of MOOC courses. MOOCs do not collect accessibility information from their learners, which leads to a missed opportunity to obtain comprehensive user feedback and to deliver a personalized learner experience. We believe that would help them to better support and improve accessibility over time. According to Ferguson, Sharple, and Beale [95], MOOC development should follow a path of meeting social needs while leveraging technological advances, and future research and development agendas must include cutting-edge accessibility profiling standards.

6 Conclusions and recommendations

The design of sustainable and accessible online learning environments is of paramount importance for making information easily available to students with disabilities so that they can effectively utilize the underlying services and resources. The results of this review concerning the LMSs indicate that they enable sufficient techniques intended for students with motor, vision, hearing, and cognitive disabilities. On the other hand, AVTs additionally reinforce inclusive education because all the popular tools embed their own inclusive tools. Moreover, all the examined MOOCs are powered by many inclusive add-ons, enabling additional help for impaired students. This is very optimistic news that supports the prospective remote teaching and learning intended for students with special needs. Unfortunately, numerous weaknesses can severely obstruct that intention.

The first weakness of the accessible applications embedded in the learning management systems is that they are primarily intended for Windows OS users whose native language is English. For example, the widely used screen reader JAWS is Windows-compatible only, and it enables text-to-speech interpretation in English, Dutch, German, Spanish, and French [79]. Similarly, NVDA access is available for Windows users only [96]. Its main advantage is the multilingual support, with 50 languages. Conversely, VoiceOver with Braille is intended for Apple users and for English only [97]. Localized multilingual cross-platform applications should be of the highest priority for software developers who create or intend to create accessible applications.

The second barrier restricting inclusive online education is pricing. Although many add-ons are free, the most powerful tools, such as the adaptable recorded speech communication device Logan® ProxTalker® Mid-Tech AAC [98], cost more than 3000 USD. The economic consequences of the coronavirus pandemic are disastrous, so the majority of disabled students cannot afford this luxurious gadget. Even the mind-mapping tools for cognition-impaired students, like the visual thinking tool Inspiration 10 [99], with an annual price of 67 EUR, are not affordable to many disabled students. Open source and cloud applications might contribute to overcoming this problem. Since quality education is a national priority, its development should be supervised and supported by the national ministries of education.

The last, and probably the most embarrassing problem, is teachers' lack of experience in supporting students to learn at a distance [100]. Teachers in developing countries had to figure out how to help disabled students on their own [100]. Empathy prevailed, and all the demands of motor and cognitively disabled students were immediately resolved by modifying the LMS and AVT. Hearing impaired students had supplementary tutorials that helped them understand the recorded lectures. Additionally, it was recommended to empower the presentations with notes that explain the content. So far, we have never had a student with a severe vision disability. The responsive design of the used LMS and AVT was sufficient to assist students with a decreased ability to see. The responsibility of national ministries of education is to continuously support the lifelong learning of all teaching staff. Preparation for remote education should be regarded as more important than other retraining activities.

Given the current trend toward online education, which was additionally emphasized during the COVID19 outbreak, an optimal interaction of technological and pedagogical standards is needed to ensure that the synergy of learning management systems, teleconferencing tools, and MOOCs can become both a productive and joyful experience for people with motor and sensory impairments. National ministries of education should be aware that online applications are and will remain an inseparable part of modern education, both in normal and emergency remote education settings. Therefore, all the efforts should be directed towards empowering the schools with the necessary accessible tools available in the countries' official languages. Otherwise, differently abled students will fall behind their peers, and the gap between rich and poor economic growth will become deeper.

7 References

[1] UNICEF (2021). "Time to roll out education's recovery package" [Online]. Available: https://en.unesco.org/news/time-roll-out-educations-recovery-package

[2] UNESCO (2021). "COVID-19 and school closures: One year of education disruption" [Online]. Available: https://data.unicef.org/resources/one-year-of-covid-19-and-school-closures/

[3] OKR (2020). "What have we learnt?: Overview of findings from a survey of ministries of education on national responses to COVID-19" [Online]. Available: https://openknowledge.worldbank.org/handle/10986/34700

[4] Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. Journal of Educational Technology Systems, 49(1), 5–22. https://doi.org/10.1177/0047239520934018

[5] Hobbs, T. D., & Hawkins, L. (2020). The results are in for remote learning: It didn't work. Wall Street Journal, 5.

[6] Carrillo, C., & Flores, M. A. (2020). COVID-19 and teacher education: A literature review of online teaching and learning practices. European Journal of Teacher Education, 43(4), 466–487. https://doi.org/10.1080/02619768.2020.1821184

[7] König, J., Jäger-Biela, D. J., & Glutsch, N. (2020). Adapting to online teaching during COVID-19 school closure: Teacher education and teacher competence effects among early career teachers in Germany. European Journal of Teacher Education, 43(4), 608–622. https://doi.org/10.1080/02619768.2020.1809650

[8] Bowen, J. A. (2012). Teaching naked: How moving technology out of your college classroom will improve student learning. John Wiley & Sons.

[9] Alea, L. A., Fabrea, M. F., Roldan, R. D. A., & Farooqi, A. Z. (2020). Teachers' Covid-19 awareness, distance learning education experiences and perceptions towards institutional readiness and challenges. International Journal of Learning, Teaching and Educational Research, 19(6), 127–144. https://doi.org/10.26803/ijlter.19.6.8

[10] Glaser, R. (1984). Education and thinking: The role of knowledge. American psychologist, 39(2), 93. https://doi.org/10.1037/0003-066X.39.2.93

[11] Estriegana, R., Medina-Merodio, J. A., & Barchino, R. (2019). Student acceptance of virtual laboratory and practical work: An extension of the technology acceptance model. Computers & Education, 135, 1–14. https://doi.org/10.1016/j.compedu.2019.02.010

[12] Mishra, L., Gupta, T., & Shree, A. (2020). Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. International Journal of Educational Research Open, 1, 100012. https://doi.org/10.1016/j.ijedro.2020.100012

[13] Dorn, E., Hancock, B., Sarakatsannis, J., & Viruleg, E. (2020). COVID-19 and student learning in the United States: The hurt could last a lifetime. McKinsey & Company.
[14] Ali, W. (2020). Online and remote learning in higher education institutes: A necessity in light of COVID-19 pandemic. Higher Education Studies, 10(3), 16–25. https://doi.org/10.5539/hes.v10n3p16
[15] Dalipi, F., Jokela, P., Kastrati, Z., Kurti, A., & Elm, P. (2022). Going digital as a result of COVID-19: Insights from students' and teachers' impressions in a Swedish university. International Journal of Educational Research Open, 3, 100136. https://doi.org/10.1016/j.ijedro.2022.100136
[16] Bowles, D., Radford, J., & Bakopoulou, I. (2018). Scaffolding as a key role for teaching assistants: Perceptions of their pedagogical strategies. British Journal of Educational Psychology, 88(3), 499–512. https://doi.org/10.1111/bjep.12197
[17] Palacios-Pacheco, X., Roman-Cañizares, M., & Luján-Mora, S. (2021). Analysis of educational data in the current state of university learning for the transition to a hybrid education model. Applied Sciences, 11(5), 2068. https://doi.org/10.3390/app11052068
[18] Garbe, A., Ogurlu, U., Logan, N., & Cook, P. (2020). Parents' experiences with remote education during COVID-19 school closures. American Journal of Qualitative Research, 4(3), 45–65. https://doi.org/10.29333/ajqr/8471
[19] OECD (2020). "The impact of COVID-19 on student equity and inclusion: Supporting vulnerable students during school closures and school re-openings" [Online]. Available: http://www.oecd.org/coronavirus/policy-responses/the-impact-of-covid-19-on-student-equity-and-inclusion-supporting-vulnerable-students-during-school-closures-and-school-re-openings-d593b5c8/
[20] Sutton, H. (2020). Survey reviews COVID-19-based disruptions for students with disabilities. Disability Compliance for Higher Education, 26(3), 9–9. https://doi.org/10.1002/dhe.30921
[21] Saracoglu, B., Minden, H., & Wilchesky, M. (1989). The adjustment of students with learning disabilities to university and its relationship to self-esteem and self-efficacy. Journal of Learning Disabilities, 22(9), 590–592. https://doi.org/10.1177/002221948902200913
[22] W3C (2018). "Web Content Accessibility Guidelines (WCAG) 2.1" [Online]. Available: https://www.w3.org/TR/WCAG21/
[23] Guilbaud, T. C., Martin, F., & Newton, X. (2021). Faculty perceptions on accessibility in online learning: Knowledge, practice and professional development. Online Learning, 25(2), 6–35. https://doi.org/10.24059/olj.v25i2.2233
[24] Pittman, C. N., & Heiselt, A. K. (2014). Increasing accessibility: Using universal design principles to address disability impairments in the online learning environment. Online Journal of Distance Learning Administration, 17(3), 1–11.
[25] ISO (2012). ISO/IEC 40500:2012 Information technology — W3C Web Content Accessibility Guidelines (WCAG) 2.0 [Online]. Available: https://www.iso.org/standard/58625.html
[26] Karakose, T., Yirci, R., Papadakis, S., Ozdemir, T. Y., Demirkol, M., & Polat, H. (2021). Science mapping of the global knowledge base on management, leadership, and administration related to COVID-19 for promoting the sustainability of scientific research. Sustainability, 13, 9631. https://doi.org/10.3390/su13179631
[27] Karakose, T., Polat, H., & Papadakis, S. (2021). Examining teachers' perspectives on school principals' digital leadership roles and technology capabilities during the COVID-19 pandemic. Sustainability, 13, 13448. https://doi.org/10.3390/su132313448
[28] Karakose, T., Ozdemir, T. Y., Papadakis, S., Yirci, R., Ozkayran, S. E., & Polat, H. (2022). Investigating the relationships between COVID-19 quality of life, loneliness, happiness, and internet addiction among K-12 teachers and school administrators—A structural equation modeling approach. Int. J. Environ. Res. Public Health, 19, 1052. https://doi.org/10.3390/ijerph19031052

[29] Karakose, T., Yirci, R., & Papadakis, S. (2022). Examining the associations between COVID-19-related psychological distress, social media addiction, COVID-19-related burnout, and depression among school principals and teachers through structural equation modeling. Int. J. Environ. Res. Public Health. 19, 1951. https://doi.org/10.3390/ijerph19041951
[30] Can, Y., & Bardakci, S. (2022). Teachers' opinions on (urgent) distance education activities during the pandemic period. Advances in Mobile Learning Educational Research, 2(2), 351–374. https://doi.org/10.25082/AMLER.2022.02.005
[31] Aguayo, J. M., Valdes, J., Cordoba, V. H., Nájera, M., Vázquez, F. R., Muñoz, E., & García Lirios, C. (2022). Digital activism in students of a university in central Mexico in the COVID-19 era. Advances in Mobile Learning Educational Research, 2(1), 297–307. https://doi.org/10.25082/AMLER.2022.01.014
[32] Long, E., Vijaykumar, S., Gyi, S., & Hamidi, F. (2021). Rapid transitions: Experiences with accessibility and special education during the COVID-19 crisis. Frontiers in Computer Science, 59. https://doi.org/10.3389/fcomp.2020.617006
[33] Byrd, D. R., & Alexander, M. (2020). Investigating special education teachers' knowledge and skills: Preparing general teacher preparation for professional development. Journal of Pedagogical Research, 4(2), 72–82. https://doi.org/10.33902/JPR.2020059790
[34] Marcus-Quinn, A., & Hourigan, T. (2022). Digital inclusion and accessibility considerations in digital teaching and learning materials for the second-level classroom. Irish Educational Studies, 41(1), 161–169. https://doi.org/10.1080/03323315.2021.2022519
[35] Bartholomay, D. J. (2021). A time to adapt, not "return to normal": Lessons in compassion and accessibility from teaching during COVID-19. Teaching Sociology, 0092055X211053376. https://doi.org/10.1177/0092055X211053376
[36] Ingavélez-Guerra, P., Robles-Bykbaev, V., Teixeira, A., Otón-Tortosa, S., & Hilera, J. R. (2022). Accessibility challenges in OER and MOOC: MLR analysis considering the pandemic years. Sustainability, 14(6), 3340. https://doi.org/10.3390/su14063340
[37] Moreno-Rodriguez, R., Diaz-Vega, M., Lopez-Bastias, J. L., & Espada-Chavarria, R. (2021). Online training in accessibility and design for all: A tool to train Post-COVID inclusive graduates. International Journal of Environmental Research and Public Health, 18(23), 12582. https://doi.org/10.3390/ijerph182312582
[38] Aljedaani, W., Aljedaani, M., AlOmar, E. A., Mkaouer, M. W., Ludi, S., & Khalaf, Y. B. (2021). I cannot see you—The perspectives of deaf students to online learning during COVID-19 pandemic: Saudi Arabia case study. Education Sciences, 11(11), 712. https://doi.org/10.3390/educsci11110712
[39] Burgstahler, S. (2021). What higher education learned about the accessibility of online opportunities during a pandemic. Journal of Higher Education Theory and Practice, 21(7), 160–170. https://doi.org/10.33423/jhetp.v21i7.4493
[40] Russ, S., & Hamidi, F. (2021, April). Online learning accessibility during the COVID-19 pandemic. In Proceedings of the 18th International Web for All Conference (pp. 1–7). https://doi.org/10.1145/3430263.3452445
[41] Leporini, B., Buzzi, M., & Hersh, M. (2021). Distance meetings during the COVID-19 pandemic: Are video conferencing tools accessible for blind people?. In Proceedings of the 18th International Web for All Conference (pp. 1–10). https://doi.org/10.1145/3430263.3452433
[42] Dolamore, S. (2021). Accessibility features in ZOOM to improve equity in the MPA classroom. Journal of Public Affairs Education, 27(3), 376–379. https://doi.org/10.1080/15236803.2021.1929020
[43] WCAG (2022). "Web Content Accessibility Guidelines (WCAG) 2.2" [Online]. Available: https://www.w3.org/TR/WCAG22/

[44] Miller, L. T., Missiuna, C. A., Macnab, J. J., Malloy–Miller, T., & Polatajko, H. J. (2001). Clinical description of children with developmental coordination disorder. Canadian Journal of Occupational Therapy, 68(1), 5–15. https://doi.org/10.1177/000841740106800101
[45] Herscowitz, E. (2020). "For students with disabilities, e-learning fails to replicate in-person attention and support" [Online]. Available: https://dailynorthwestern.com/2020/04/21/city/for-students-with-disabilities-e-learning-fails-to-replicate-in-person-attention-and-support/
[46] AFB (2020). "Statistics about children and youth with vision loss" [Online]. Available: https://www.afb.org/research-and-initiatives/statistics/statistics-blind-children
[47] WHO (2021a). "Blindness and visual impairment" [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment
[48] Bocconi, S., Dini, S., Ferlino, L., Martinoli, C., & Ott, M. (2007). ICT educational tools and visually impaired students: Different answers to different accessibility needs. In International Conference on Universal Access in Human-Computer Interaction (pp. 491–500). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-73283-9_55
[49] Permvattana, R., Armstrong, H., & Murray, I. (2013). E-learning for the vision impaired: A holistic perspective. International Journal of Cyber Society and Education, 6(1), 15–30. https://doi.org/10.7903/ijcse.1029
[50] Kent, M. (2016). Access and barriers to online education for people with disabilities, Curtin University of Technology, Department of Internet Studies.
[51] Choi, J., Jung, S., Park, D. G., Choo, J., & Elmqvist, N. (2019). Visualizing for the non-visual: Enabling the visually impaired to use visualization. In Computer Graphics Forum, 38(3), pp. 249–260. https://doi.org/10.1111/cgf.13686
[52] Armstrong, H. L. (2009). Advanced IT education for the vision impaired via e-learning. Journal of Information Technology Education: Research, 8(1), 243–256. https://doi.org/10.28945/691
[53] Kharade, K., & Peese, H. (2012). Learning by e-learning for visually impaired students: Opportunities or again marginalisation?. E-learning and Digital Media, 9(4), 439–448. https://doi.org/10.2304/elea.2012.9.4.439
[54] WCAG (2018). "Web Content Accessibility Guidelines (WCAG) Overview" [Online]. Available: https://www.w3.org/WAI/standards-guidelines/wcag/
[55] Sierkowski, B. (2002). Achieving web accessibility. In Proceedings of the 30th Annual ACM SIGUCCS Conference on User Services (pp. 288–291). https://doi.org/10.1145/588646.588725
[56] Clark, L (2021). Understanding WCAG 2.1, retrieved from https://onlineada.com/articles/understanding-wcag-2-1/
[57] WHO (2021b). "Deafness and hearing loss" [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss
[58] Crowe, A. R. (2004). Teaching by example: Integrating technology into social studies education courses. Journal of Computing in Teacher Education, 20(4), 159–165.
[59] Shadiev, R., Wu, T. T., Sun, A., & Huang, Y. M. (2018). Applications of speech-to-text recognition and computer-aided translation for facilitating cross-cultural learning through a learning activity: Issues and their solutions. Educational Technology Research and Development, 66(1), 191–214. https://doi.org/10.1007/s11423-017-9556-8
[60] Hohmann, V., Paluch, R., Krueger, M., Meis, M., & Grimm, G. (2020). The virtual reality lab: Realization and application of virtual sound environments. Ear and Hearing, 41(Suppl 1), 31S. https://doi.org/10.1097/AUD.0000000000000945
[61] Cuevas-Rodriguez, M., Gonzalez-Toledo, D., Rubia-Cuestas, E., Garre, C., Molina-Tanco, L., & Reyes-Lecuona et al. (2017). An open-source audio renderer for 3d audio with hearing loss and hearing aid simulations. In AES Convention 142.

[62] Meinzen-Derr, J., Sheldon, R. M., & Henry, S., et al. (2019). Enhancing language in children who are deaf/hard-of-hearing using augmentative and alternative communication technology strategies. International Journal of Pediatric Otorhinolaryngology, 125, 23–31. https://doi.org/10.1016/j.ijporl.2019.06.015
[63] Roy E. (2013). Cognitive impairment. In: Gellman M.D., & Turner J.R. (eds) Encyclopedia of Behavioral Medicine. Springer, New York, NY. https://doi.org/10.1007/978-1-4419-1005-9_1118
[64] EU (2019), "European accessibility right" [Online]. Available: https://ec.europa.eu/social/main.jsp?catId=1202
[65] Study (2017). "Instructional strategies for students with cognitive impairments" [Online]. Available: https://study.com/academy/lesson/instructional-strategies-for-students-with-cognitive-impairments.html
[66] Fenton, W. (2018). "The best LMS (Learning Management Systems)" [Online]. Available: https://www.pcmag.com/picks/the-best-lms-learning-management-systems
[67] G2 (2020). "Best learning management systems" [Online]. Available: https://www.g2.com/categories/learning-management-system-lms
[68] Sood, L. (2018). "An overview of 4 popular learning management systems for higher education" [Online]. Available: https://elearningindustry.com/learning-management-systems-for-higher-education-overview-popular
[69] Löwgren, J., & Stolterman, E. (2004). Thoughtful interaction design: A design perspective on information technology. MIT Press.
[70] Landquist, J. (1994). Wild ideas and deep analysis: On the basics of design methodology. Carlsson, Stockholm.
[71] Blackboard (2021). "Ally accessibility checklist" [Online]. Available: https://help.blackboard.com/Ally/Ally_for_Websites/Administrator/Accessibility_Report/Checklist?_ga=2.109383109.194668506.1631001573-221202264.1624965069
[72] SIIA CODiE (2021). "Best solution for students with special needs" [Online]. Available: https://history.siia.net/codie/2021-Finalists/details/cID/80
[73] Instracture (2021). "Canvas Student App and Canvas Teacher App Voluntary Product Accessibility Template (VPAT)" [Online]. Available: https://www.instructure.com/canvas-student-app-and-canvas-teacher-app-voluntary-product-accessibility-template-vpat
[74] Moodle (2021). "VPAT accessibility conformance report" [Online]. Available: https://docs.moodle.org/311/en/VPAT#Moodle%20accessibility%20conformance%20report
[75] Lachner, A., Ly, K. T., & Nückles, M. (2018). Providing written or oral explanations? Differential effects of the modality of explaining on students' conceptual learning and transfer. The Journal of Experimental Education, 86(3), 344–361. https://doi.org/10.1080/00220973.2017.1363691
[76] W3C (2021). "RTC accessibility user requirements" [Online]. Available: https://www.w3.org/TR/2021/NOTE-raur-20210525/#what-is-real-time-communication-rtc
[77] BigBlueButton (2019). "Compliance analysis and opinion" [Online]. Available: https://bigbluebutton.org/accessibility/
[78] Collaborate (2021). "Accessibility in blackboard collaborate" [Online]. Available: https://help.blackboard.com/Learn/Instructor/Ultra/Interact/Blackboard_Collaborate/Accessibility_in_Blackboard_Collaborate
[79] JAWS (2021). "Freedom scientific, JAWS headquarters" [Online]. Available: https://support.freedomscientific.com/JAWSHQ/JAWSHeadquarters01
[80] Google (2021). "Google meet accessibility" [Online]. Available: https://support.google.com/meet/answer/7313544?hl=en
[81] Microsoft (2021a). "Accessibility overview of Microsoft teams" [Online]. Available from: https://support.microsoft.com/en-us/office/accessibility-overview-of-microsoft-teams-2d4009e7-1300-4766-87e8-7a217496c3d5

[82] Zoom (2021). "Accessibility statement" [Online]. Available: https://support.zoom.us/hc/en-us/articles/204119749-Accessibility-Statement
[83] BigBlueButton (2021). "LMS integrators" [Online]. Available: https://bigbluebutton.org/schools/integrations/
[84] Blackboard (2020). "The essential guide to LMS evaluation" [Online]. Available: https://www.blackboard.com/en-eu/teaching-learning/accessibility-universal-design/blackboard-ally-lms
[85] Microsoft (2021b). "Your LMS and teams: Better together for distance learning" [Online]. Available: https://support.microsoft.com/en-us/topic/your-lms-and-teams-better-together-for-distance-learning-35e3c70f-11b7-447d-a4d4-3964b27911ae
[86] CirQlive (2019). "Zoom LMS integration" [Online]. Available: https://www.cirqlive.com/zoom-lms-integration-for-edu
[87] Coursera (2021). "Accommodations for learners with disabilities" [Online]. Available: https://www.coursera.support/s/article/208280056-Accommodations-for-learners-with-disabilities?language=en_US
[88] edX (2020). "Supporting stdents with diverse needs" [Online]. Available: https://edx.readthedocs.io/projects/edx-partner-course-staff/en/latest/accessibility/supporting_learners_diverse_needs.html
[89] MIT (2021). "Accessibility of remote teaching tools" [Online]. Available: https://accessibility.mit.edu/digital-accessibility/accessibility-remote-teaching-tools
[90] OpenLearning (2021). "Creating accessible content for course creators" [Online]. Available: https://help.openlearning.com/t/m2svwm/creating-accessible-content-for-course-creators
[91] Krasniqi, V., Zdravkova, K., & Dalipi, F. (2022). Impact of assistive technologies to inclusive education and independent life of down syndrome persons: A systematic literature review and research agenda. Sustainability, 14(8), 4630. https://doi.org/10.3390/su14084630
[92] Ladner, R. E., & May, M. (2017, March). Teaching accessibility. In Proceedings of the ACM SIGCSE Technical Symposium on Computer Science Education (pp. 691–692). https://doi.org/10.1145/3017680.3017804
[93] Lazar, J. (2020, October). Accessibility research in the pandemic: Making a difference in the quality of life for people with disabilities. In the 22nd International ACM SIGACCESS Conference on Computers and Accessibility (pp. 1–1). https://doi.org/10.1145/3373625.3430947
[94] Acosta, T., & Luján-Mora, S. (2016, July). Comparison from the levels of accessibility on LMS platforms that supports the online learning system. In 8th International Conference on Education and New Learning Technologies (pp. 2704–2711). https://doi.org/10.21125/edulearn.2016.1579
[95] Ferguson, R., Sharples, M., & Beale, R. (2015). MOOCs 2030: A future for massive online learning. In MOOCs and open education around the world (pp. 315–326). Routledge. https://doi.org/10.4324/9781315751108-36
[96] Apple (2021). "Accessibility: Vision, for every point of view" [Online]. Available: https://www.apple.com/accessibility/vision/
[97] NVDA (2021). "We believe that every Blind + Vision impaired person deserves the right to freely & easily access a computer!" [Online]. Available: https://www.nvaccess.org/
[98] Logantech (2021). "Logan® ProxTalker® Mid-Tech AAC Device" [Online]. Available: https://logantech.com/products/proxtalker
[99] Inspiration (2020). "Inspiration 10 for Windows" [Online]. Available: https://www.inspiration-at.com/inspiration-10/
[100] Whalen, J. (2020). Should teachers be trained in emergency remote teaching? Lessons learned from the COVID-19 pandemic. Journal of Technology and Teacher Education, 28(2), 189–199.

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Article submitted 2022-05-12. Resubmitted 2022-08-20. Final acceptance 2022-08-20. Final version published as submitted by the authors.