Learning features and accessibility limitations of video conferencing applications: are people with visual impairment left behind

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Abstract
The COVID-19 pandemic increases the reliance on video conferencing applications for learning. Accessible video conferencing applications with good learning features can help people with visual impairment when they participate in online classes. This paper investigates the accessibility limitations and the available learning features of the top two current video conferencing applications, namely Zoom and MS Teams. A task-based expert review and a blind user evaluation are conducted using Web Content Accessibility Guidelines 2.1. In addition, the study identifies the application with the better learning features based on Universal Design for Learning guidelines. A set of recommendations are outlined for developing better inclusive video conferencing applications for people with visual impairment. The presented ideas can be applied to enhance the learning experience of people with visual impairment.

Keywords Accessibility · Web content accessibility guidelines · Learning features · Video conferencing · E-learning accessibility · Universal design for learning

1 Introduction
The most significant development in terms of computer-mediated communication and learning is the integration of virtual applications like video conferencing. Video conferencing systems have made remote communication much more accessible for a vast number of users by allowing them to communicate at the same time, effectively, through seeing and hearing one another while being in different physical locations.

Al-Samarraie [7] defines desktop video-conferencing as software that allows users to use more than one channel to learn. This channel allows the connection of one user with another user (point-to-point), one group with another group (multi-point), or one user with one group (point-to-multi). It is fully interactive and almost like face-to-face communication in the real world. In other words, video conferencing systems enable individuals separated geographically but with a reasonable Internet connection to discuss topics of common interest as if they were in the same room.

These applications are useful because they promote effective and active communication when joining a remote session with only a few button clicks. They facilitate building relationships between users and allow for smooth communication in the online environment without any obstacles or challenges. Additionally, video conferencing boosts collaboration and enables productivity with fewer associated expenses; it saves both time and cost by removing barriers such as commuting to a meeting place. This technology also provides other valuable features including
easily sharing materials or documents and recording meetings for attendees that they can refer to later. All these features can be utilized easily with minimal effort. As a result, these applications play an essential role in facilitating the learning process for both educators and students.

In online learning, the role of video conferencing is an essential dimension that provides real-time opportunities for collaboration between students and teachers. Numerous video application systems like Google Meet, Microsoft Teams, Zoom, Webex, Adobe Connect, D2L, Big Blue Button, Skype, and EduMeet have been developed to meet the varying requirements and needs of teachers and students. These purposes include supporting teamwork, student-to-student mentoring [46], practical demonstration with synchronous interaction, immediate feedback, literature circles and book discussions [36], audio conferencing [18], problem-based learning [51], real-time peer tutoring, and numerous other applications. Video conferencing systems allow teachers to interact with their students and share screens, files, audio clips, video clips, course notes, PowerPoint presentations, and case studies without any difficulty [15, 39, 40]. Students can easily access their virtual classes through various technologies like personal computers, phones, and tablets. In addition, students can access video conferencing applications to attend virtual classes from any operating system including Windows or Mac.

Video conferencing also encourages students to have one-to-one conversations or group discussions with their course teachers and classmates. This is a valuable asset of this technology whereby supporting group creation and interaction in a collaborative learning context to improve learning methods [41]. These virtual programs enable students to have enhanced communications with course instructors, to ask questions, and receive feedback in real-time. Video conferencing also allows teachers to track their students’ engagement and interactions as well as respond to their questions and comments promptly [16]. Furthermore, the technology empowers students to participate in live-streamed lectures and to join group breakout meetings during online classes. There is also a text chat service to ask a question or write a comment without interrupting the class. Other benefits are detailed in the literature [15, 16, 18, 39, 40, 46, 51].

Moreover, the COVID-19 crisis has necessitated the need for such virtual applications to support the continuity of education during periods of lockdown and quarantine. According to TrustRadius, there has been a 500% increase in the use of video conferencing tools because of the COVID-19 pandemic [49]. Most educators taught their classes through remote technologies like video conferencing systems during the outbreak of COVID-19 [13, 19, 27, 34]. Many educators migrated from traditional teaching methods to fully virtual course delivery to reduce the spread for safety reasons. Many educational institutions have increased the use of video conferencing tools after the pandemic.

In some ways, video conferencing technology has made communication and meetings more accessible for people with diverse abilities, but in other ways, it makes their application less inclusive for people with disabilities. In fact, according to the National Center for Education Statistics, 19% of undergraduate students have a disability [29]. Unfortunately, students with disabilities are more likely to not complete their courses compared to their non-disabled peers [33]. Thus, there is general research exploring the pedagogical problems that can arise when using video conferencing systems [7, 15]. Education is a fundamental right for all regardless of disability. Thus, it is important to take appropriate steps to enhance online learning tools and to develop accessible tools that guarantee equal access to learning resources for individuals with disabilities such as vision impairment. However, in the existing literature only a limited number of studies (e.g. [3, 42]) investigate accessibility issues related to the use of video conferencing applications for people with vision impairment. This is a disservice to a portion of the student population. As known, most video conferencing systems have a visual interface that requires vision. Even with the support of screen readers, there is a need to conceive the layout of the applications for the visually impaired to be able to effectively use these tools. This paper tackles and explores the accessibility challenges facing visually impaired individuals when using video conferencing systems as well as investigate inclusive learning features that can enhance their learning when using video conferencing applications to enable this population to have a more positive experience.

To combat this, some faculty members take it upon themselves to design an online version of the course for individuals with disabilities that may face challenges when attending classes on campus [1, 32]. However, accessibility in online education has “presented an immediate challenge and susceptibility for higher education institutions” (p.2). Providing accessible learning environments that are inclusive for all learners is the key to educational success [11, 14, 43]. Thus, there is a need to explore online learning accessibility for disabled students so that they may meet their academic needs within the online environment. In other words, investigating the most commonly used video conferencing applications to determine the potential obstacles and to provide clear guidelines for designing accessible online learning systems.

This paper addresses the following research questions:

- **RQ1**: What are the primary accessibility issues or challenges related to the use of video conferencing applications like Zoom and Microsoft Teams for visually impaired users?
• RQ2: Which video conferencing tool is optimal for learning based on Universal Design for Learning (UDL) guidelines to accommodate visually impaired users?
• RQ3: What recommendations and guidelines can be provided to support the development and design of video conferencing applications that are accessible to visually impaired users?
• RQ4: What recommended learning features can be emphasized to improve the video conferencing applications for people with visual impairment?

To answer these research questions, a task-based expert review and a blind user evaluation are conducted using WCAG 2.1 to assess the accessibility of video conferencing applications including Zoom and Microsoft Teams. In addition, the learning characteristics of video conferencing applications based on UDL guidelines are analyzed and the one with better learning features is defined.

The paper is structured as follows: Sect. 2 provides context and related work, Sect. 3 explains the methodology, Sect. 4 presents the study findings and recommendations, and Sect. 5 provides conclusions.

2 Background

2.1 Accessibility of remote meetings: laws and standard guidelines

Remote interactions have increased significantly in the last two years. The pandemic forced all group types to conduct their interactions and meetings remotely. Therefore, it is paramount to ensure the accessibility of remote meetings for participants with disabilities. Many countries have already established laws for digital accessibility to ensure accessible digital information resources and platforms for diverse users. The Twenty-First Century Communications and Video Accessibility Act (CVAA) [20] demands accessible communications services and products such as interconnected voice over Internet protocol (VoIP) service, electronic messaging, and interoperable video conferencing. The Americans with Disabilities Act (ADA)\footnote{https://www.ada.gov/regs2010/titleII_2010/titleII_2010_regulations.htm.} states that all educational constructs (i.e., schools, colleges, and universities) must ensure alternative ways and auxiliary aids are provided to anyone with a disability in order to access information and have equal opportunities as mainstream peers. This implicitly applies to remote meetings that nearly most educational institutes around the world transferred to as the outbreak of COVID-19 hit the world. To a large extent, many of these laws mandate that digital information constructs conform to the requirements detailed in the internationally well-established W3C Web Content Accessibility Guidelines (WCAG), or comparable standards. For example, Section 508 of the Rehabilitation Act as amended states that “electronic content shall conform to Level A and Level AA Success Criteria and Conformance Requirements in WCAG 2.0” [12]. This entails that videos must offer synchronous audio descriptions for the visually impaired, and must offer synchronous captions (i.e., subtitles) for the hearing impaired, as WCAG demands [45].

2.1.1 Web content accessibility guidelines (WCAG)

Web accessibility guidelines outline the requirements that must be met in order to facilitate accessible information resources for diverse users, including people who are blind, visually impaired, deaf, hearing impaired, motor impaired, and more [26, 35]. Among the most recognized standard accessibility guidelines is the W3C WCAG [21]. The first WCAG version (WCAG 1.0) was released in 1999. The valid versions of WCAG are WCAG 2.0 which was released in 2008, and WCAG 2.1 which was released in 2018. WCAG 2.1 is organized into 4 major principles: Perceivable, Operable, Understandable, and Robust (POUR); 13 guidelines; and 78 success criteria in three different levels: A, AA, and AAA, where Level A is the minimum (i.e., easiest to fulfill) and Level AAA is the highest (i.e., most demanding) [21]. Additionally, the W3C WAI proposed guidance to aid developers in producing accessible content; the guidance includes various resource links, advisory techniques, code examples, and common failures. Although originally oriented for Web content and applications, WCAG sets different neutral guidelines to ensure accessible content irrespective of the platform it is rendered on [8, 9].

Among the 13 WCAG 2.1 guidelines, the guideline “1.2 Time-based media” is tightly relevant to remote meetings and pertains to providing alternatives to access time-based media in the following aspects: prerecorded or live audio-only content, prerecorded or live video-only content, prerecorded or live synchronized video and audio content, and audio and/or video combined with interaction. Guideline “1.2 Time-based media” includes 9 success criteria relevant to the aforementioned aspects. Table 1 shows the success criteria of Guideline “1.2 Time-based media” as per the official reference of the W3C WCAG 2.1.

Additionally, the W3C Web Accessibility Initiative (WAI) instructs on the accessibility of video-conferencing and remote meetings [23] the following:

1. The user interface. The client video conferencing software through which the remote meeting is conducted should comply with WCAG 2.1 at Level AA;
2. Shared content through the remote meeting platform should comply with WCAG 2.1 at Level AA. Examples of content include, but are not limited to, documents, presentations, and multimedia. Some of the relevant success criteria include Success criteria 1.4.1 (Use of color), 1.4.3 (text contrast), 1.4.6 (contrast-enhanced), 2.3.1 (three flashes or below threshold), 2.3.2 (three flashes) ensure accessible user interface and presented the content of the live meeting;

3. Real-time interactions through video and audio between participants. For such interactions to be accessible, compliance with WCAG 2.1 Guideline “1.2 Time-based media” at Level AA is necessary.

### Table 1 Details of all success criteria of Guideline “1.2 Time-based media” [21]

| Success criterion                                                                 | Description (from [21])                                                                                                                                                                                                 |
|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.2.1 Audio-only and Video-only (Prerecorded) (Level A)                          | For prerecorded audio-only and prerecorded video-only media, the following are true, except when the audio or video is a media alternative for text and is clearly labeled as such: Prerecorded Audio-only
An alternative for time-based media is provided that presents equivalent information for prerecorded audio-only content. Prerecorded Video-only
Either an alternative for time-based media or an audio track is provided that presents equivalent information for prerecorded video-only content. |
| 1.2.2 Captions (Prerecorded) (Level A)                                           | Captions are provided for all prerecorded audio content in synchronized media, except when the media is a media alternative for text and is clearly labeled as such.                                                        |
| 1.2.3 Audio Description or Media Alternative (Prerecorded) (Level A)            | An alternative for time-based media or audio description of the prerecorded video content is provided for synchronized media, except when the media is a media alternative for text and is clearly labeled as such. |
| 1.2.4 Captions (Live) (Level AA)                                                | Captions are provided for all live audio content in synchronized media.                                                                                                                                               |
| 1.2.5 Audio Description (Prerecorded) (Level AA)                                | Audio description is provided for all prerecorded video content in synchronized media.                                                                                                                                   |
| 1.2.6 Sign Language (Prerecorded) (Level AAA)                                   | Sign language interpretation is provided for all prerecorded audio content in synchronized media.                                                                                                                    |
| 1.2.7 Extended Audio Description (Prerecorded) (Level AAA)                     | Where pauses in foreground audio are insufficient to allow audio descriptions to convey the sense of the video, extended audio description is provided for all prerecorded video content in synchronized media. |
| 1.2.8 Media Alternative (Prerecorded) (Level AAA)                               | An alternative for time-based media is provided for all prerecorded synchronized media and for all prerecorded video-only media.                                                                                          |
| 1.2.9 Audio-only (Live) (Level AAA)                                             | An alternative for time-based media that presents equivalent information for live audio-only content is provided.                                                                                                |

2.1.2 Authoring tools accessibility guidelines (ATAG)

The W3C Authoring Tool Accessibility Guidelines (ATAG) [22] outlines a set of guidelines in two parts: (1) guidelines to ensure the accessibility of the user interface of an authoring tool (i.e., Part A), and (2) what it needs for an authoring tool to support the generation of content that complies with WCAG accessibility requirements (i.e., Part B) [22]. Each part in ATAG includes normative conformance applicability notes applying to that part’s success criteria. The currently valid version is ATAG 2.0. ATAG ought to be considered when tackling the issue of accessibility of remote meetings because many remote meeting platforms are additionally used to create materials such as document editing, whiteboard explanations, multimedia, and presentations [23]. Moreover, remote meeting platforms can be used in conjunction with external authoring tools to facilitate the collaborative editing of content and documents. Therefore, any integration of an external authoring tool within a remote meeting should comply with ATAG in order to facilitate an inclusive experience for diverse users in two aspects: using the tool, and accessing content generated via the tool.

2.2 Video conferencing applications: learning limitations

Apart from the advantages of distance learning, there are several disadvantages as listed by researchers [5, 47, 48]. Sadeghi [48] shows that the first disadvantage of online learning is that students and teachers must have a computer, a webcam, and a stable internet connection as minimum requirements. The minimum requirements are important for teachers to deliver the lecture online where there is no physical contact between students and teachers. The limited
availability of these requirements to many students makes it impossible for them to attend classes. Even students who are able to attend online classes, s/he can easily be distracted as there is a high chance for students to lose focus in the lecture because of the absence of face-to-face interaction. Students need to be highly self-motivated and fully focused to achieve class goals.

In addition to these disadvantages, a study by Mukhtar et al. [47] collects responses from teachers and students about online learning in Pakistani institutions after they switched to distance learning because of the COVID-19 pandemic. The study shows that teachers are unable to teach students practical skills. Moreover, teachers’ responses show that it is hard to assess students’ understanding because of the lack of immediate feedback from students during over-distance learning. Furthermore, the study shows that maintaining academic integrity is difficult. Students lose their concentration during online lectures, and often do not listen to the whole lecture because they know that they can return to recordings later [6].

Serhan [50] studied the use of Zoom in the context of learning from students’ perspectives. Unfortunately, students’ attitude toward the use of Zoom is negative. They believe that their motivation for learning and their learning experience is affected negatively. The other problem that was caused by online learning is that students may feel isolated because there is no social interaction, where in traditional classrooms, students make discussions face-to-face with other classmates. A high degree of flaming and isolation can be caused due to the lack of physical interaction in the educational process between learners [28].

### 2.3 Video conferencing applications: accessibility issues

The use of video conferencing has increased significantly in the last two years because of the COVID-19 pandemic. For some disability types this transition to online learning provides a greater level of inclusion (e.g., students with mobility impairments [30] and students on the autism spectrum [4]), while some other types of disabilities experience different barriers to taking full advantage of the perceived benefits of such applications due to their special access needs [37]. The needs can be summarized by providing: an accessible interface of the remote meeting platform, closed captioning (i.e., text transcription of a speech and other sounds, sign language (i.e., translation of speech into sign language), alternative descriptive text for visual content in shared content, and audio description (i.e., auditory descriptions of visual and graphical information). Many of these needs are often neglected. For example, alternative auditory information and audio descriptions of the remote meeting presented material are rarely provided. Some platforms were found to be inaccessible in their interface options. For instance, limited support for keyboard accessibility for users who are blind or visually impaired was reported for Adobe Acrobat Connect [44]. In the present section, we briefly review the accessibility issues that people with disabilities are likely to face when engaging in remote meetings.

Some of the accessibility challenges that are often encountered by the deaf community were discussed in [10]. The same work confirmed that there is a long way to go in order to make video conferencing applications accessible and inclusive. The challenges and shortcomings in such platforms were more significant when remote meetings were conducted in the educational realm. One of the challenges is the primary view of the speaker and the sign language interpreter on the screen. Another issue is when people who are deaf communicate using sign language while muting their mics, in which case they are given a low priority position on the screen and might be unrecognized presenters in the point they are making. Some potential areas for improving the inclusivity and accessibility of video conferencing platforms were discussed in [10]. For example, utilizing gesture recognition technology to generate real-time interpretations and to give focus on the deaf contributing to the meeting at the moment. Additionally, the use of advanced natural language processing can help in providing an automatic transcription of the meeting.

Hersh et al. [37] concluded that none of the most used remote meeting platforms was fully accessible to users who are visually impaired. In particular, accessibility problems in the content shared within remote meetings were dominant. All platforms performed poorly in providing accessibility options for presentations during remote meetings. The same study contributed a number of recommendations to make remote meetings more accessible, including enabling file-sharing rather than remote presentation so that screen reader users can access shared content conveniently, and making the tool UI options compliant with standard web accessibility guidelines. Among the recommendations to facilitate accessible remote meetings are providing live captioning, identifying participants when speaking, and providing shared content in accessible formats.

Leporini et al. [42] investigated the three video conferencing tools for accessibility and usability by visually impaired people using screen readers and keyboard. The investigated tools are desktop versions of Zoom and MS Teams and the web-based version of Google Meet. The authors perform an inspection evaluation using nine tasks to identify problems encountered by screen reader users. Additionally, they surveyed 29 visually impaired users using an online questionnaire about the video conferencing tool use and the users provided comments about the issues they face and they provide suggestions for any improvements. The obtained results prove that Zoom is more accessible than MS Teams.
and Google Meet. However, none of the three tools is fully accessible using a keyboard and screen reader. The main issue found is that turning the microphone and video camera on/off is inaccessible. Also, there are no available keyboard shortcuts for all main functionalities. Additionally, the chat needs to have better organization when accessed by the screen reader.

Acosta-Vargas et al. [3] evaluated the accessibility of the six most used video conferencing tools (Google Meet, GoToMeeting, Jitsi, Teams, Webex, and Zoom). The authors used manual inspection to check the conformance of the tools with the Web Content Accessibility Guidelines (WCAG) 2.1 and 2.2. The main accessibility barriers found are the unavailability of automatic transcriptions of video or audio, providing automatic live sign language. The barriers that are least met are related to the success criterion 1.4.5 corresponding to images as sharp as possible, followed by 1.2.6 referring to sign language, 1.2.4 related to subtitling; criterion 1.2.5 related to automatic transcriptions follows. The results show that Zoom, Teams, and Google Meet are the tools with the highest conformity to WCAG 2.1 and 2.2.

Despite the previous work on the accessibility of video conferencing tools, there is still a need to investigate the accessibility of these tools in the context of learning and identify the learning features that need to be provided to have an inclusive learning environment.

### 3 Methodology

This section presents the accessibility evaluation of video conferencing applications and identifies their learning features using UDL. There are four evaluation goals which include: investigating the learning characteristics of video conferencing applications based on UDL guidelines [17]; accessibility evaluation of the selected video conferencing applications; comparing the obtained results to indicate which video conferencing application is the most accessible and which one does have better learning features; presenting recommendations for enhancing learning and accessibility of video conferencing applications.

| Table 2 | Popular video conferencing tools |
| --- | --- |
| Tools | License | URL |
| Google Meet | Free | [https://apps.google.com/meet/](https://apps.google.com/meet/) |
| Teams | Free | [https://products.office.com/](https://products.office.com/) |
| Webex | Payment | [https://www.webex.com/es/index.html](https://www.webex.com/es/index.html) |
| Zoom Meeting | Payment | [https://zoom.us/](https://zoom.us/) |

| Table 3 | The main features for Zoom and MS Teams |
| --- | --- | --- |
| Feature | Zoom | MS Teams |
| Chat with attendees | Y | Y |
| Screen Sharing | Y | Y |
| File sharing | N | Y |
| Annotate Shared Content | Y | N |
| Whiteboard | Y | Y |
| Breakout Rooms | Y | Y |
| Automatic Live Captioning | Y (manual or 3d party (e.g., Kaltura)) | Y |
| Virtually Raise Hand | Y | Y |
| Video and audio control | Y | Y |
| Recording | Y | Y |
| Waiting rooms | Y | Y |

3.1 Evaluation environment

There are four popular video conferencing tools which are presented in Table 2. For the study, the top two most frequently used video conferencing tools are selected. According to TrustRadius as of April 2020, Zoom has 50% of the users of video conferencing (200 million as of March 2020) followed by Microsoft Teams (MS Teams) with 21.3%.

Thus, these video conferencing applications are chosen for this study as they are used by more than 70% of video conferencing tools users.

Several studies (e.g., [24, 31]) show that students prefer to use a laptop for remote learning. Additionally, students with visual impairment can easily access the different options of the video conferencing tool using the keyboard which makes it more convenient to use for remote learning.

The applications are evaluated using the PC versions (i.e. the application version is downloaded and installed) of the video conferencing software. The used version is the latest update as of June 2021. The Zoom version used is 5.6.7 (1016) and Microsoft Teams Version is 1.4.00.11161. The evaluation is conducted using Windows 10 with NVDA version 2019.2.1.

The main features for each application are shown in Table 3. As shown in the table, both of them support similar features except when it comes to file-sharing as Zoom does not support that. Also, MS Teams does not support annotating shared content.

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2 https://www.trustradius.com/vendor-blog/covid-19-software-industry-data-and-statistics
3.2 Accessibility evaluation methodology

This section presents the accessibility evaluation of the two video conferencing tools. As mentioned, the PC version of the tools is evaluated. There is no automatic accessibility evaluation tool that can be used with the PC version of video conferencing tools. A task-based expert review and a user evaluation [2] are conducted to provide a deep investigation of the accessibility issues in video conferencing applications. In order to evaluate the two video conferencing applications, we selected twelve of the common tasks performed by students when they learn online using video conferencing tools. The tasks are only twelve to reduce users’ fatigue during the evaluation. The evaluation was performed by two of the authors as experts in the field of technology accessibility by using the NVDA screen reader in English. In addition, one blind user performed the same set of tasks. The following are the set of tasks used to evaluate the accessibility of the two video conferencing tools:

- Turn-off camera;
- Check if the microphone is on/off;
- The microphone is off and the user speaks (the user notified or not);
- Record the meeting (the user notified or not);
- Share screen of a specific app in the window (e.g., word document);
- User raise hand;
- Type a question in the chat (send to everyone);
- Other users type on the chat (user notified or not);
- Exploring chat window (read its content);
- Understand the content the teacher writes on the shared whiteboard;
- Understand the annotations on the shared screen (only zoom);
- Leave the meeting;

The experts and the user did a walk-through [25] to see if they can complete successfully each of the twelve tasks.

3.2.1 Expert evaluation results

The two experts completed the twelve tasks using Zoom and then using MS Teams (one is the host and one is the student). The expert with the student role uses the screen reader to complete each of the tasks. The following are the accessibility issues related to Zoom evaluation: the stop share button is not the first to be read (it is the last), which makes it not similar to what non-blind users are experiencing as it is colored with red. When MS Word is shared with the student and annotated (see Fig. 1) the screen reader does not provide any information about that. The user is not notified about the annotations or the actions (i.e., erase or write content). The same thing happened when using the whiteboard to write, as shown in Fig. 2. The screen reader notifies the user about whiteboard screen sharing, but it does not speak anything about the drawing or the text shown on the whiteboard. However, it is challenging to make a real-time video accessible [38].

In addition, the user is notified when the meeting recording starts, but this information is not keyboard accessible (i.e., during the meeting the user will not know if it is recorded by tabbing). Lastly, the reaction button raise hand is not the first to be read to the user, as its order is the 7th reaction button, but it is stretched to make it easier to sight visually for sighted users. Note that when performing each of the tasks Zoom would provide the shortcut key to accomplish the action for the user interface item on focus.

After completing the twelve tasks using Zoom, the two experts perform the same tasks using MS Teams. The following are the accessibility issues related to MS Teams...
evaluation. The task to turn the camera off is not presented naturally when doing the keyboard tab. The user must press the arrow keys when reaching to mute/unmute button to switch the camera off. Also, MS Teams requires three key combinations as a shortcut key, while Zoom requires only two keys. For example, the microphone mute/unmute in MS Teams is `ctrl+shift+o`, and in Zoom it is `alt+a`. On the other hand, MS Teams has a smaller number of reaction icons (only six) to be used during the video conferencing session when compared to Zoom (which has seven and can be expanded to become 48 as shown in Fig. 3). It is harder to read the chat messages using MS Teams. As for each message, it reads the six possible interactions (see Fig. 4) before moving to the next message in the list. This is because MS Teams allows adding interaction to each item in the chat message. As of 1 August 2021 whiteboard sharing in MS Teams can be done by only members from the same organization, while Zoom does not have this restriction.

During the evaluation, the experts identified broken WCAG A and AA success criteria (SC) as summarized in Tables 4 and 5. The issues related to WCAG Level A SC are the following: 2.1.1 Keyboard, which is a problem in MS Teams as some parts are unreadable and it did not tell the shortcut keys when the focus is on the functionality button; 1.3.1, Info and Relationships, which is a problem in Zoom as the raise hand is made available last as a text when read by the screen reader while it is stretched as a button to be easily distinguishable for non-blind students. Also, when sharing a screen using MS Teams the screen reader just mentioned (desktop and window) and it did not mention the name of the available applications to be shared, which makes it hard for the user to know the list of open applications; this is considered an issue related to 2.4.4, Link Purpose (In Context); 1.4.1, Use of Color the sharing and stop sharing buttons are distinguished visually using colors while their order is normal when using a screen reader. Also, when the user speaks and the microphone is off the message shown to the user is not read by the screen reader. This issue of setting change of the user interface component is mapped to 3.2.2 On Input.

The issues related to WCAG Level AA SC are: 1.2.4 Captions (Live) during the live lecture MS Teams currently supports English closed captioning only, while Zoom requires a third party software to enable that; 1.4.4 Resize text MS Teams allows users to increase the text size of the user interface, while Zoom has that option available only for the chat portion.

### 3.2.2 User evaluation

The same twelve tasks mentioned in the previous section are evaluated by a user who is blind. The user a is 33 year old
male with a bachelor’s degree and he is blind from birth. The
user uses the internet from the mobile device or the laptop
for 8-10 hours daily. He uses NVDA or JAWS screen read-
ers when using the computer. We did the evaluation using
NVDA, and the evaluation is done remotely while one of the
authors was with the user in a public place. The user who is
blind takes the role of the student and the expert takes the
role of the teacher.

The user started with Zoom evaluation and the following
are the main accessibility issues found: the user could not
understand the content of the shared whiteboard. He knew
only that the whiteboard is shared, but did not know what
was typed and if the teacher is erasing the content or writing
on the whiteboard. When trying to speak when the micro-
phone is turned off the user is notified, but only one time.
Finally, when sharing a screen with the user and annotating
it, the user did know that a screen is shared, but he did not
know what was annotated.

After completing the Zoom evaluation the user switched
to evaluate MS Teams as a student. The user mentioned

| Table 4 Unsatisfied Level A WCAG 2.1 for Zoom and MS Teams |
| SC No. | Level A -SC Name | Zoom | MS Teams |
|-------|-----------------|------|----------|
| 1.1.1 | Non-text Content |      |          |
| 1.2.1 | Audio-only and Video-only (Prerecorded) |      |          |
| 1.2.2 | Captions (Prerecorded) |      |          |
| 1.2.3 | Audio Description or Media Alternative (Prerecorded) |      |          |
| 1.3.1 | Info and Relationships | X | X |
| 1.3.2 | Meaningful Sequence |      |          |
| 1.3.3 | Sensory Characteristics |      |          |
| 1.4.1 | Use of Color |      |          |
| 1.4.2 | Audio Control |      |          |
| 2.1.1 | Keyboard |      | X |
| 2.1.2 | No Keyboard Trap |      |          |
| 2.1.4 | Character Key Shortcuts |      |          |
| 2.2.1 | Timing Adjustable |      |          |
| 2.2.2 | Pause, Stop, Hide |      |          |
| 2.3.1 | Three Flashes or Below Threshold |      |          |
| 2.4.1 | Bypass Blocks |      |          |
| 2.4.2 | Page Titled |      |          |
| 2.4.3 | Focus Order |      |          |
| 2.4.4 | Link Purpose (In Context) | X |          |
| 2.5.1 | Pointer Gestures |      |          |
| 2.5.2 | Pointer Cancellation |      |          |
| 2.5.3 | Label in Name |      |          |
| 2.5.4 | Motion Actuation |      |          |
| 3.1.1 | Language of Page |      |          |
| 3.2.1 | On Focus |      |          |
| 3.2.2 | On Input |      | X | X |
| 3.3.1 | Error Identification |      |          |
| 3.3.2 | Labels or Instructions |      |          |
| 4.1.1 | Parsing |      |          |
| 4.1.2 | Name, Role, Value |      |          |

| Table 5 Unsatisfied Level AA WCAG 2.1 for Zoom and MS Teams |
| SC No. | Level AA -SC Name | Zoom | MS Teams |
|-------|-----------------|------|----------|
| 1.2.4 | Captions (Live) |      | X |
| 1.2.5 | Audio Description (Prerecorded) |      |          |
| 1.3.4 | Orientation |      |          |
| 1.3.5 | Identify Input Purpose |      |          |
| 1.4.3 | Contrast (Minimum) |      |          |
| 1.4.4 | Resize text |      | X |
| 1.4.5 | Images of Text |      |          |
| 1.4.10 | Rellow |      |          |
| 1.4.11 | Non-Text Contrast |      |          |
| 1.4.12 | Text Spacing |      |          |
| 1.4.13 | Content on Hover or Focus |      |          |
| 2.4.5 | Multiple Ways |      |          |
| 2.4.6 | Headings and Labels |      |          |
| 2.4.7 | Focus Visible |      |          |
| 3.1.2 | Language of Parts |      |          |
| 3.2.3 | Consistent Navigation |      |          |
| 3.2.4 | Consistent Identification |      |          |
| 3.3.3 | Error Suggestion |      |          |
| 3.3.4 | Error Prevention (Legal, Financial, Data) |      |          |
| 4.1.3 | Status Messages |      |          |

Fig. 5 MS Teams share window with desktop and window
that there was no shortcut key announced when navigating through the options which prevent him from quickly selecting what he wants to do (e.g., turn off the camera, raise hand, or leave the meeting). When trying to speak when the microphone is turned off a message appears, but the screen reader did not read that for the user. Another problem was when sharing an application by the user (e.g., a word document) as the screen reader says only (desktop and window) and it assumes that the user needs to select window to select from the applications available there (see Fig. 5). Unfortunately, the user who is blind was not able to share the application because of this problem.

Overall, the user who is blind mentioned that MS Teams is harder to use when compared to Zoom as it has parts that are unreadable and it did not tell the shortcut keys for the navigated option which makes it harder for the user to perform the needed task quickly. These findings confirm the results obtained by two previous studies [3, 42].

### 3.3 Learning evaluation

During the COVID-19 pandemic, video conferencing applications are widely used to have synchronous classes in schools and universities. It is expected that this usage and adaptation increases because of its flexibility as many education institutions are now relying on these tools. This section investigates the learning features that must be included in video conferencing applications to have them inclusive. After that, it measures if these features are used in Zoom or MS Teams.

#### 3.3.1 Learning features using UDL guidelines

The study identifies the learning features for the video conferencing applications using UDL guidelines [17]. The selected features are for desktop applications. The authors investigate UDL guidelines to map the suitable guideline for the video-conferencing application. Each expert identifies the set of guidelines and then the experts identify the common features selected to agree on the set of features. In case of any conflict, the experts discuss their opinion to reach a mutual agreement on the selected feature.

The selected learning features along with their functionalities are presented in Table 6. As shown in the table, the second column identifies the class of the feature which can be one of the following:

1. **Interface**: features managing the presentation of the interface;
2. **Users**: features helping in administrating the users;
3. **Messages**: features helping to handle messages;
4. **Voice**: features controlling user’s voice;
5. **Video**: features controlling user video;
6. **Interactions**: features facilitate users interaction;
7. **Learning**: features to enhance learning;

#### 3.3.2 Learning evaluation results

The students can be engaged more in the learning process if the application allows teachers and students to share their feelings. Both Zoom and MS Teams allow both teachers and students to share their feelings using emojis and reactions icons (see Table 7).

Online teaching can be affected by having different features related to the spoken lecture. The students and teachers need to be able to turn the close captioning on/off as it can enhance learning. In case the student or teacher speaks, an auto message needs to be displayed to notify the user to turn on the microphone. Sometimes the teacher would prefer to have the ability to make the students just listen without participating. As shown in Table 8, Zoom does not have an automatic close captioning feature.

The student’s learning can be enhanced by including all the video features listed in Table 9. The video conferencing application needs to allow notifying users about gestures performed during lectures as this can be helpful for students who are blind. Providing students and teachers with the option to record the lecture or part of the lecture can help in getting back to it at a later time to review the learned material. Also, it is advisable to have the speaker only available to help students and teachers focus more on the person who speaks currently in the video. Zoom and MS Teams do not have gesture notifications for the presented video, but the other video features are available for both applications.

The features for controlling messages are vital for a better learning experience. Table 10 summarizes the recommended features to improve teaching and learning. The student and teacher need to be informed about the coming of new messages. In case the student left the lecture an automatic response about that needs to be received. Finally, the application needs to allow the teacher to check deleted messages at a later time if needed. The last-mentioned feature is not available in both Zoom and MS Teams.

The video conferencing application can make the learning process more efficient by including features that can help students when they participate in class or study. Students and teachers can delete the messages in the chat that are not important to reduce the amount of information. The teacher can annotate the shared screen with the important parts to enhance the student’s understanding. The teacher needs to manage the messages by releasing only the relevant students’ messages. Students and teachers can rate and pin the messages which can help them focus on the valuable content. The teacher and students need to have the ability to share
a whiteboard to explain material or share the screen. Also, they need to have the possibility of saving the shared whiteboard or screen as an image to be used as part of the lecture content. Providing students and teachers with the option of saving the chat messages can help to refer to the discussion.
later. For some students, it can be beneficial that the application reads the shared whiteboard content or notifies the student about the annotated parts of the screen. In addition, students need to have the option to participate in the shared whiteboard, and they need to be allowed to annotate the shared screen. It would be helpful for teachers to know statistical information about the student’s engagement in the class such as the number of times a student sends messages, raises hand, and speaks. In the lecture, teachers and students need to have the ability to send files to ease sharing of practices and exercises or any additional material for the class. Some students are shy and they participate more in the class discussion if they are anonymous [52]. Because of that, it is preferable to allow teachers to have the ability to show/hide the student’s name during the lecture. Sometimes teachers want to stop students from sending messages to not distract other students during the lecture. Sometimes students might send inappropriate words in their messages and it is essential to provide a mechanism to control that. The video conferencing application needs to provide a poll option to track students’ progress. Based on our analysis, Zoom and MS Teams still need to be enhanced to include these features. The total number of learning features is 20. Zoom includes only 10 of them while MS Teams includes 11, as shown in Table 11.

A username is used to identify the participant of the lecture. The students and teachers need to have the flexibility of changing their usernames. The students in the lecture need to identify the teacher from other students. This is highlighted in Zoom or MS Teams by having the word host beside the teacher username. Lastly, the teacher needs to have the ability to arrange students in different groups to enhance the learning process. As demonstrated in Table 12 Zoom has all these features while MS Teams does not allow the user to change their username.

Customizing the interface can help students and teachers have their preferred presentation of the application. As shown in Table 13 both Zoom and MS Teams do not allow adding or removing user interface components. However, Zoom allows the user to change the way of presenting the speaker in different views, namely speaker, gallery, and full screen. On the other hand, MS Teams allows the user to change the speaker view using the following presentation options: gallery, full screen, focus, together mode, and gallery at top.

### 4 Recommendations

The evaluation results of accessibility and learning features indicate a set of recommendations to be taken into consideration by researchers and developers to enhance the

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### Table 9: Learning evaluation: Video

| Feature                        | Zoom | MS Teams |
|-------------------------------|------|----------|
| Gesture notification          | N    | N        |
| Record video                  | Y    | Y        |
| Record portions               | Y    | Y        |
| Speaker only view is available| Y    | Y        |

### Table 10: Learning evaluation: Messages

| Feature                    | Zoom | MS Teams |
|----------------------------|------|----------|
| New messages notifications | Y    | Y        |
| Away auto-response         | Y    | Y        |
| Keep deleted messages      | N    | N        |

### Table 11: Learning evaluation: Learning features

| Feature                        | Zoom | MS Teams |
|-------------------------------|------|----------|
| Delete messages               | N    | Y        |
| Annotate screen               | Y    | Y        |
| Control messages              | N    | N        |
| Rate messages                 | N    | Y        |
| Pin messages                  | N    | N        |
| Explain on whiteboard         | Y    | Y        |
| Save messages                 | Y    | Y        |
| Whiteboard image              | Y    | Y        |
| Annotated screen image        | Y    | N        |
| Notifications about screen annotations | N    | N        |
| Speak whiteboard explanation  | N    | N        |
| Save lecture content          | Y    | Y        |
| Statistics                    | N    | N        |
| Send files                    | N    | Y        |
| Hide/show student name        | N    | N        |
| Read only                     | Y    | Y        |
| Bad language filter           | N    | N        |
| Use poll to monitor           | Y    | Y        |
| Two-way whiteboard            | Y    | Y        |
| Two-way shared screen         | Y    | N        |

### Table 12: Learning evaluation: Users

| Feature                        | Zoom | MS Teams |
|-------------------------------|------|----------|
| Change usernames              | Y    | N        |
| Roles                         | Y    | Y        |
| Grouping students             | Y    | Y        |

### Table 13: Learning evaluation: Interface

| Feature                        | Zoom | MS Teams |
|-------------------------------|------|----------|
| Customizing the UI            | N    | N        |
accessibility of video conferencing applications for people with visual impairment. The recommendations are split into *enhance accessibility* and *enhance learning*, which are elaborated in the next sections.

### 4.1 Enhance accessibility

It is important to have students with visual impairment use video conferencing applications without any barriers. This section describes the recommendations for enhancing the accessibility of video conferencing applications based on the conducted evaluation. Students who are blind can easily reach the needed functionality using the keyboard. The navigation burden can be reduced if the shortcut key is presented for the currently on-focus functionality. The video conferencing application must not use shapes or colors to convey information. Other clues must be used to not segregate users with visual impairment. Allowing resizing the presented text can assist students with visual impairment. It is essential to support captions for the presented live video. However, one of the accessibility limitations when using some video conferencing tools is that the online lectures do not have live transcription. This confirms the findings of [3]. Add-on tools can be used to overcome such issues (e.g., Rev Live Captions3), but the problem is that they are not free. Table 14 provides a summary of accessibility issues in the evaluated video conferencing tools.

### 4.2 Enhance learning

Based on the identified learning features for video conferencing applications using UDL guidelines mentioned in Sect. 3.3, this section will discuss the learning features that can be included to overcome the mentioned limitations. It is recommended that the user interface is customizable to help users arrange its components based on their preferences. The automatic generation of the lecture content when it is ended (i.e., video with transcript, images, and text of the explained material) is mandatory to ease sharing the class material with the students. Also, it can help review the content at a later time. Providing the explained content, on the shared screen or on the whiteboard, in different forms (i.e., text), is essential to help students with visual impairment understand the presented content. A workaround for this limitation is that teachers describe what they are annotating when sharing a screen or writing on the shared whiteboard. The spoken content can be automatically transcript.

Shared audio content may have an extra challenge for the blind if they want to navigate the screen to perform a specific task, as listening to both the screen reader and the audio simultaneously would not be feasible. In some cases, the blind student may not be aware of some of the information provided in the lecture because of not knowing the teacher or students’ gestures during the class. Automatic gesture recognition can be helpful in this matter. The video conferencing tool can keep track of the student’s participation in the class. Which can help teachers in making sure that all students, including students with disabilities, have participated in answering questions or in the class discussion. A summary of the missing learning features in the evaluated video conferencing tools is presented in Table 15.

### 5 Conclusion

During the COVID-19 pandemic, many educational institutions switched to online teaching using video conferencing tools. To ensure that students with visual impairment are learning well, it is vital to ensure that such tools are accessible and that they have inclusive learning features. This paper evaluates the accessibility of the two top video conferencing applications, namely Zoom and MS Teams, by two experts and a blind user. Furthermore, the features to have inclusive 

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3 https://www.rev.com/zoom-live-captions.
learning based on UDL are identified and used to analyze the features available for the two video conferencing applications. The evaluation results show that Zoom is more accessible than MS Teams. However, in terms of learning features, each of the two applications has its own set of inclusive learning features which make them almost similar in terms of the number of available learning features. On the other hand, both applications miss several features which could improve the students’ learning experience, i.e., show the number of times a student sends messages, raise hand, and speak. Both applications have several accessibility issues. One of the problems is that the interactive tools (i.e., share screen of an application or the whiteboard) are not described to the student. The paper presents a set of recommendations to improve the accessibility and learning features of current video conferencing applications. This can help in reducing the digital gap that faces students with visual impairment when using video conferencing applications.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Table 15 Summary of missing learning features in the evaluated video conferencing tools

| Learning feature                                      | Description                                      |
|-------------------------------------------------------|--------------------------------------------------|
| Customizing the UI (UDL 1.1)                          | Add or remove components to UI                   |
| Change usernames (UDL 1.1)                            | Change the username                              |
| Close captioning (UDL 1.2/1.3/5.1)                    | Show close captioning when user speaks           |
| Gesture notification (UDL 1.2/1.3)                    | Notify user about gesture                        |
| Delete messages (UDL 2.2/7.3)                         | Delete messages that are not important           |
| Control messages (UDL 2.2/7.3)                        | The teacher can check the message before it is presented to participants |
| Rate messages (UDL 3.2/3.3/8.1)                      | Users can vote on which messages are valuable    |
| Pin messages (UDL 3.2/3.3/8.1)                       | Fix important messages                           |
| Annotated screen image (UDL 3.4/6.3)                 | Save the annotated screen as an image            |
| Notifications about screen annotations (UDL 4.2)      | Speak what parts are annotated from the screen   |
| Speak whiteboard explanation (UDL 4.2)               | Speak what is written on the whiteboard          |
| Keep deleted messages (UDL 6.3)                      | Keep deleted messages to investigate them later  |
| Statistics (UDL 6.4)                                 | Show the number of times a participant: send messages, raise hand, and speak |
| Send files (UDL 6.3)                                 | Teachers and students can send files             |
| Hide/show student name (UDL 7.2)                     | Teacher can hide/show student name               |
| Bad language filter (UDL 7.3)                        | Allow removing offensive words (messages and speak) |
| Two-way shared screen (UDL 3.1/3.2/6.1/6.2/6.4/8.3)  | Allow students to annotate in the shared screen  |

References

1. Huss, A.J., Eastep, S.: Okay, our courses are online, but are they ada compliant? an investigation of faculty awareness of accessibility at a midwestern university. Inq. Educ. 8(2) (2016). http://digitalcommons.nl.edu/ie/vol8/iss2/2
2. Abu-Doush, I., Bany-Mohammed, A., Ali, E., Al-Betar, M.A.: Towards a more accessible e-government in jordan: an evaluation study of visually impaired users and web developers. Behav. Inf. Technol. 32(3), 273–293 (2013)
3. Acosta-Vargas, P., Guaña-Moya, J., Acosta-Vargas, G., Villegas-Ch, W., Salvador-Ullauri, L.: Method for assessing accessibility in videoconference systems. In: International Conference on Intelligent Human Systems Integration, pp. 669–675. Springer (2021)
4. Adams, D., Simpson, K., Davies, L., Campbell, C., Macdonald, L.: Online learning for university students on the autism spectrum: a systematic review and questionnaire study. Australasian J. Educ. Technol. 35(6), 111–131 (2019)
5. Al-Jarrah, A.: Development of collaborative virtual learning environments for enhancing deaf people’s learning in Jordan. In: Proceedings of the Future Technologies Conference, pp. 1017–1028. Springer (2018)
6. Al-Jarrah, A., Pontelli, E.: The collaborative virtual affinity group model: principles, design, implementation, and evaluation. Int. J. Comput. Appl. 42(5), 485–513 (2020)
7. Al-Samarraie, H.: A scoping review of videoconferencing systems in higher education: Learning paradigms, opportunities, and challenges. Int. Rev. Res. Open Distrib. Learn. 20(3) (2019). https://doi.org/10.19173/irrodl.v20i3.4037. http://www.irrodl.org/index.php/irrodl/article/view/4037
8. Alajarmeh, N.: Non–visual access to mobile devices: a survey of touchscreen accessibility for users who are visually impaired. Displays 70, 102081 (2021)

9. Alajarmeh, N.: The extent of mobile accessibility coverage in wcag 2.1: Sufficiency of success criteria and appropriateness of relevant conformance levels pertaining to accessibility problems encountered by users who are visually impaired. Univers. Access Inf. Soc. 21(2), 507–532 (2022)

10. Anderson, N.: Accessibility challenges of video conferencing technology. In: International Conference on Human-Computer Interaction, pp. 185–194. Springer (2021)

11. Betts, K., Cohen, A., Veit, D., Jr, H., Broadus, C., Allen, D.: Strategies to increase online student success for students with disabilities. Online Learning 17, 49–64 (2013). https://doi.org/10.24059/olj.v17i3.324

12. Board, U.A.: About the update of the section 508 standards and section 255 guidelines for information and communication technology (2017)

13. Boloumole, M.: Student life in the age of covid-19. Higher Educ. Res. Develop. 39(7), 1357–1361 (2020) https://doi.org/10.1080/07294360.2020.1825345

14. Burgstahler, S.: 10: Accommodating students with disabilities: professional development needs of faculty. Improve Acad. 21 (2003). https://doi.org/10.3998/ia.17063888.0021.012

15. Butler, A., Camilleri, M.A., Creed, A., Zutshi, A.: The Use of Mobile Learning Technologies for Corporate Training and Development: A Contextual Framework, pp. 115–130 (2021). https://doi.org/10.1108/978-1-80071-264-520211007

16. Camilleri, M.A.: Evaluating service quality and performance of higher education institutions: a systematic review and a post covid-19 outlook. Int. J. Qual. Service Sci. 13, 268–281 (2021). https://doi.org/10.1108/IQSS-03-2020-0034

17. CAST: National center on universal design for learning: Udl guidelines 2.2 (2021). https://udlguidelines.cast.org/

18. Cervetti, G., Damico, J., Pearson, P.: Multiple literacies, new literacies, and teacher education. Theory Practice 45, 378–386 (2006). https://doi.org/10.1207/s15430421tp4504_12

19. Cicha, K., Rizun, M., Rutecka, P., Strzelecki, A.: Covid-19 and higher education: first-year students’ expectations toward distance learning. Sustainability 13(4) (2021). https://doi.org/10.3390/ su13041889. https://www.mdpi.com/2071-1050/13/4/1889

20. Commission, F.C.: 21st century communications and video accessibility act (cvaa) consumer guide (2018). https://www.fcc.gov/consumers/guides/21st-century-communications-and-video-accessibility-act-cvaa

21. Consortium, W.W.W.: Web content accessibility guidelines (wcag) 2.1 (2018). https://www.w3.org/TR/WCAG21/

22. Consortium, W.W.W.: Authoring tool accessibility guidelines (atag) (2020). https://www.w3.org/WAI/standards-guidelines/atag/

23. Consortium, W.W.W.: Accessibility of remote meetings (2021). https://www.w3.org/WAI/PAI/task-forces/research-questions/wiki/Accessibility_of_Remote_Meetings

24. Dello Stritto, M., Linder, K.: Student device preferences for online course access and multimedia learning. Oregon State University, Ecampus Research Unit, Corvallis, OR, USA (2018)

25. Doush, I., AlMeraj, Z.: Evaluating the accessibility of kuwaiti e-government websites. Jordanian J Comput Inf Technol (JJCIT) 5(03) (2019)

26. Doush, I.A., Alhami, I.: Evaluating the accessibility of computer laboratories, libraries, and websites in Jordanian Universities and Colleges. Int J Inf Syst Soc Change (IJISSC) 9(2), 44–60 (2018)

27. Doush, I.A., Awadallah, M.A., Al-Betar, M.A.: Web accessibility of palestinian universities: Can we access higher education information during covid-19? In: CHIRA, pp. 196–201 (2020)

28. Dyrud, M.A.: The third wave: a position paper. Bus. Commun. Q. 63(3), 81–93 (2000) https://doi.org/10.1177/108056990006300

29. for Education Statistics (NCES), N.C.: The nces fast facts tool provides quick answers to many education questions (national center for education statistics). Comput. Educ. (2019). https://nces.ed.gov/fastfacts/display.asp?id=60

30. Ferri, F., Grifoni, P., Guzzo, T.: Online learning and emergency remote teaching: opportunities and challenges in emergency situations. Societies 10(4), 86 (2020)

31. Gamage, K.A., Perera, E.: Undergraduate students’ device preferences in the transition to online learning. Social Sci. 10(8), 288 (2021)

32. Getnet, M., Akalu, Y., Dagnew, B., Gela, Y., Belsti, Y., Diress, M., Fekadu, S., Seid, M.: Visual impairment and its associated factors among medical and health sciences students at the university of gondar, northwest ethiopia. PLOS ONE 16, e0255369 (2021). https://doi.org/10.1371/journal.pone.0255369

33. Gladhart, M.A.: Determining faculty needs for delivering accessible electronically delivered instruction in higher education. J. Postsecondary Educ. Disab. 22(3), 185–196 (2010)

34. González, T., De la Rubia, M., Hincz, K., Comas-Lopez, M., Subirats, L., Fort, S., Sacha, G.: Influence of covid-19 confinement on students’ performance in higher education. PloS One 15, e0239490 (2020). https://doi.org/10.1371/journal.pone.0239490

35. Hammad, M., Alnabhan, M., Doush, I.A.A., Alsalem, G.M., Al-Alem, F.A., Al-Awadi, M.M.: Evaluating usability and content accessibility for e-learning websites in the middle east. Int. J. Technol. Human Interaction (IJITH) 16(1), 54–62 (2020)

36. Hampil, R.: Rethinking task design for the digital age: a framework for language teaching and learning in a synchronous online environment. ReCALL 18 (2006). https://doi.org/10.1017/S0958344006000711

37. Hersh, M., Leporini, B., Buzzi, M.: Accessibility evaluation of video conferencing tools to support disabled people in distance teaching, meetings and other activities. In: ICCHP, p. 133 (2020)

38. Holt, M., Gillen, D., Nandlall, S.D., Setter, K., Thorman, P., Kane, S.A., Miller, C.H., Cook, C., Supalo, C.: Making physics courses accessible for blind students: strategies for course administration, class meetings, and course materials. Phys. Teacher 57(2), 94–98 (2019)

39. Hung, S.T.: Enhancing feedback provision through multimodal video technology. Comput. Educ. 98 (2016). https://doi.org/10.1016/j.compedu.2016.03.009

40. Ifenthaler, D., Schweinbenz, V.: The acceptance of tablet-pcs in classroom instruction: the teachers’ perspectives. Comput. Human Behav. 29, 525–534 (2013). https://doi.org/10.1016/j.chb.2012.11.004

41. Kurucay, M., Inan, F.: Examining the effects of learner-learner interactions on satisfaction and learning in an online undergraduate course. Comput. Educ. 115, 20–37 (2017). https://doi.org/10.1016/j.compedu.2017.06.010. Publisher Copyright: © 2017

42. Leporini, B., Buzzi, M., Hersh, M.: 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 (2021)

43. Long, G., Marchetti, C., Fasse, R.: The importance of interaction for academic success in online courses with hearing, deaf, and hard-of-hearing students the importance of interaction for academic success in online courses with hearing, deaf, and hard-of-hearing students. Int. Rev. Res. Open Distance Learn. 12 (2011). https://doi.org/10.19173/irrodl.v12i6.1015

44. Maneesaeng, N., Punyabukkana, P., Suchato, A.: Accessible video-call application on android for the blind. Lecture Notes on Softw. Eng. 4(2), 95 (2016)
45. McCarron, L.: Creating accessible videos: captions and transcripts. Commun. Assoc. Inf. Syst. 48(1), 19 (2021)
46. Mellott, R.: eaming the world into our schools: Getting into interactive video-conferencing. Multimedia and Internet@Schools 17(1) (2010). http://www.internetatschools.com/Articles/Editorial/Features/Beaming-the-World-Into-Our-Schools-Getting-Into-Interactive-Videoconferencing-5bAvailable-Full-Text2c-
47. Mukhtar, K., Javed, K., Arooj, M., Sethi, A.: Advantages, limitations and recommendations for online learning during covid-19 pandemic era. Pak. J. Med. Sci. 36(COVID19-S4), S27 (2020)
48. Sadeghi, M.: A shift from classroom to distance learning: advantages and limitations. Int. J. Res. English Educ. 4(1), 80–88 (2019)
49. Sadler, M.: Covid-19 software industry statistics. Online (2020). https://www.trustradius.com/vendor-blog/covid-19-software-industry-data-and-statistics
50. Serhan, D.: Transitioning from face-to-face to remote learning: students’ attitudes and perceptions of using zoom during covid-19 pandemic. Int. J. Technol. Educ. Sci. 4(4), 335–342 (2020)
51. Smyth, R.: Broadband videoconferencing as a tool for learner-centred distance learning in higher education. Br. J. Educ. Technol. 36, 805–820 (2005). https://doi.org/10.1111/j.1467-8535.2005.00499.x
52. Xie, B.: Multimodal computer-mediated communication and social support among older Chinese internet users. J. Comput. Med. Commun. 13(3), 728–750 (2008)

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