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The State of Accessibility in Blackboard: Survey and User Reviews Case Study

Mohamed Wiem Mkaouer
Rochester Institute of Technology

Wajdi Aljedaani
University of Texas, Denton

Stephanie Ludi
University of North Texas

Mohammed Alkahtani
University of North Texas

Marcelo M. Eler
University of São Paulo

See next page for additional authors

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Wajdi Aljedaani, Mohammed Alkahtani, Stephanie Ludi
University of North Texas

Mohamed Wiem Mkaouer
Rochester Institute of Technology

Marcelo M. Eler
University of São Paulo

Marouane Kessentini
Oakland University

Ali Ouni
ETS Montreal, University of Quebec

ABSTRACT

Context: Nowadays, mobile applications (or apps) have become vital in our daily life, particularly within education. Many institutions increasingly rely on mobile apps to provide access to all their students. However, many education mobile apps remain inaccessible to users with disabilities who need to utilize accessibility features like talkback or screen reader features. Accessibility features have to be considered in mobile apps to foster equity and inclusion in the educational environment allowing to use of such apps without limitations. Gaps in the accessibility to educational systems persist.
Objective: In this paper, we focus on the accessibility of the Blackboard mobile app, which is one of the most common Learning Management Systems (LMS) used by many universities, especially during the current COVID-19 pandemic.
Method: This study is divided into two-fold. First, we conduct a survey using questionnaires and interviews to explore the extent to which students consider the Blackboard mobile app usability. A Total of 1,308 hearing students and 65 deaf and hard-of-hearing students participated in the study. Second, we collected 15,478 user reviews from the Google Play Store and analyzed the reviews to extract accessibility issues.
Result: We observed that most deaf and hard-of-hearing students found difficulty in the Blackboard mobile app, compared to hearing students. Also, our app store analysis showed that only 31% of the reviews reported violations of accessibility principles that apps like Blackboard must comply with. This study highlights these violations and their corresponding implications to support LMS frameworks in becoming more inclusive for all users.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in accessibility**; **Ubiquitous and mobile devices**.

1 INTRODUCTION

The use of mobile devices, particularly smartphones, has significantly risen in the last few years [21, 51]. Consequently, the number of mobile apps, applications designed to run on mobile devices, has also increased. Accordingly, mobile accessibility has gained much attention in the last few years [16, 24, 37] given that there is an estimated 650 million people with disability globally, representing nearly 10-15% of the world's total population [37, 39]. Even though accessibility impacts the overall quality of a product for any user, it is focused on users with disabilities as it is "the extent to which products, systems, services, environments, and facilities can be used by people from a population with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use" [19, 37]. Accessibility for mobile computing is an important topic, especially for persons with disabilities, given that there are approximately 650 million disabled people globally, representing nearly 10-15% of the world's total population [37, 39], including students.

In addition to the massive adoption of mobile apps in education to manage day-by-day activities, most students had their educational activities conducted through Learning Management Systems (LMS) as most universities worldwide were constrained to offer online courses to keep their educational programs running due to the COVID-19 pandemic. In that sense, investigating the accessibility of LMS systems is of utmost importance once their noncompliance with accessibility guidelines can potentially hinder or prevent students from learning any content, thus excluding people with disabilities from the educational process.

In particular, Blackboard LMS is one of the most adopted platforms for online education worldwide. In previous studies, Li [32] assessed students' acceptance of the Blackboard LMS platform in the United States. They found a need for more compatible content and activities to be introduced for mobile learning. Another study by Alkhaldi and Abualkishik [10] reports on the challenges of dealing with poor mobile network signals in Saudi Arabia to make LMS platforms such as Blackboard more accessible to the general population. Furthermore, a study by Kinash et al. [31] found that

students were positive towards Blackboard mobile learning. Yet, little is known about the extent to which Blackboard successfully meets the expectations of students with disabilities because most studies focused on general usability aspects.

Therefore, this paper aims to present an investigation we conducted to learn how accessible Blackboard LMS is from the student's perspective. We thus employed two strategies. First, we surveyed students to gather their perceptions of LMS compliance with general usability and accessibility guidelines by considering Blackboard as a case study. In this investigation, in addition to surveying students without impairment, we surveyed students with hearing impairment once there are many barriers they might face, especially when online content is made available through multimedia artifacts (e.g., audio and video). Our study findings will highlight the unanswered accessibility issues that users are currently facing. Second, we leverage recent Blackboard public user reviews, the official medium for mobile users to share their feedback with the app maintainers. In this study, we identified comments regarding any type of disability or accessibility barrier. User reviews represent the *wisdom of the crowd* [11], and various successful apps have been known to interactively respond to their user's feedback by addressing their concerns in the app's newer releases [14, 38, 53]. To the best of our knowledge, none of the previous studies assessed the accessibility of the Blackboard mobile app platform using user reviews.

We framed our investigation around the following research questions:

RQ_1: To what extent do students find the Blackboard mobile application easy-to-use?

This research question discovers the extent to which students are able to use the Blackboard application. To do so, we performed a large-scale survey with 1,373 students and 65 deaf and Harding of hearing students. This 5-questions survey targets the general usability of blackboard, especially when being the main learning medium, given that most universities are currently offering online courses due to the COVID-19 pandemic. We also conducted follow-up interviews with 8 students to reflect on the findings of the survey.

RQ_2: What accessibility issues are reported by the users of Blackboard app?

Since the findings of our previous research question cannot be generalized, we also decided to explore user reviews for further analysis. To address this research question, we crawled and analyzed 15,478 user reviews publicly posted by Blackboard users on the Google Play Store. We used quantitative and qualitative procedures to filter out these reviews and extract only accessibility-related ones. Our findings will inform app developers of the most common accessibility issues so that they can be resolved in current and future applications. Also, our curated set of reviews is available, as part of our replication package, for reproducibility and extension purposes[1].

2 BACKGROUND

2.1 Mobile Accessibility Standards/Guidelines

Apps accessibility in mobiles is controlled by benchmarks and standards stipulated by the World Wide Web Consortium (W3C)[2]. The W3C, through the Web Accessibility Initiative (WAI), provides a range of guidelines and standards that are frequently updated to address any emerging issues in accessibility. The guidelines mainly include Web Content Accessibility Guidelines (WCAG), User Agent Accessibility Guidelines (UAAG), Accessible Rich Internet Applications (WAI-ARIA), and Authoring Tool Accessibility Guidelines (ATAG). Although there are many standards on accessibility, those that relate to mobile accessibility are yet to be developed, meaning that the current guidelines in use are the W3C through the WCAG 2.0 principles. Such rules apply to native apps, mobile web apps, and web content. WCAG defines accessibility in terms of four principles which include ease of operation (operable), understandable app content (understandable), robustness (robust), and coherent app content (perceivable) [43, 49].

Other than the standards provided by W3C, other independent organizations, such as the British Broadcasting Corporation (BBC), have drafted their own accessibility standards. A document called BBC Mobile Accessibility Guidelines by the BBC contains these guidelines [18]. The rules contained in the BBC guidelines are similar to those provided by the W3C [54]. These standards mainly guide principles, audio and video, designs of the apps, focus, forms, images, links, notifications, scripts, and dynamic content, structure, and text equivalence, as described in detail in Table 1.

Although BBC accessibility guidelines provide detailed instructions, there are additional standards given by WCAG 2.0 in relation to mobile accessibility. Some of the additional guidelines include rules on how to reduce content in the mobile version, eliminating form fields that are beside their labels, accessibility of interactive controls, noticeability of apps content, text minimization, provision of clear guidelines, and adjustment of the app to the different orientation of the device. The accessibility guidelines provided by BBC and WCAG are crucial. However, other organizations may also develop accessibility guidelines to complement the existing ones.

2.2 Mobile Learning and LMS

With the increasing need to offer online education by universities and institutions worldwide, the adoption of learning management systems (LMS) has also increased [50]. Indeed, mobile learning offers several benefits, including location-based services, cost-effectiveness, and education aid, among others. It has also been considered that LMS systems help improve students' problem-solving skills, performance, and knowledge and create an individualized learning system [30, 50]. Five authoring tools are considered part of a learning management system: content collaboration, content delivery, content development, content distribution, and content management [30]. During the current Coronavirus (COVID-19) pandemic, the need to reduce physical interaction in higher education institutions has increased the adoption of LMS to facilitate mobile learning [23]. Hence, LMS systems have helped many institutions

[1] https://wajdialjedaani.github.io/MobileBB/
[2] https://www.w3.org/

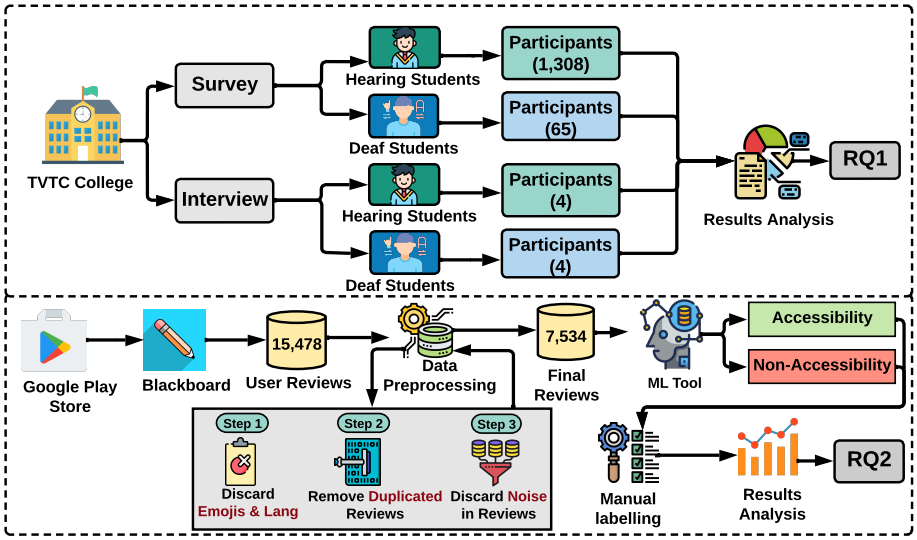

Figure 1: Approach Overview.

deliver instruction exclusively online, where content is managed, distributed, and delivered to students.

2.3 Blackboard

The Blackboard LMS provides a personalized intuition that helps learners to engage with their tutors, provides data handling capabilities, and is flexible to any teaching approach [20]. Matthew Pittinsky and Michael Chasen developed Blackboard in 1997. It is considered an excellent LMS system because it is easily available on many devices, provides quick feedback, makes tracking easier, and has better communication [2]. Learning institutions can choose between two Blackboard systems: the Networked Transaction Environment (NTE), which helps in supporting commercial transactions, and the Networked Learning Environment (NLE), which offers academic capabilities that support online learning. Blackboard is one of the most popular LMS systems today and is used by many institutions globally.

2.4 Technical and Vocational Training Corporation (TVTC)

The Technical and Vocational Training Corporation (TVTC) was established in 1980 and mandated to offer higher education in Saudi Arabia. The institution offers vocational training and development, imparting practical skills to students. Under the TVTC umbrella, there are technical colleges, vocational training centers, and secondary institutions. Students can enroll in any of the different TVTC branches distributed across Saudi Arabia. It is also important to note that the TVTC is a regulatory body for nearly 1,000 private training institutions in Saudi Arabia. Offering courses in various technical majors, the institution is important for skills development in Saudi Arabia [52]. We chose to conduct our case study at this university because it has a significant body of deaf and Harding of hearing students.

3 RELATED WORK

Accessibility in online learning involves the addition of tools and features into applications to meet the needs of all users [4–6]. It is important for users to offer reviews regarding the accessibility of education applications so that such feedback can be used to improve the apps [7, 9, 43]. In this section, we divide the section into three categories as follows: user reviews, accessibility in user reviews, and LMS in the mobile application.

3.1 User Reviews

Scholars have found that analyzing user feedback helps gather customers' opinions and feedback on a given app, which helps in improving future applications [33, 46]. Getting the perspectives of app users is a good step towards understanding what users desire in the app and fulfilling such needs [35]. In most cases, developers get user feedback through mobile devices [48], which they use in the software lifecycle of future apps [41]. There are various techniques for getting user reviews, including online surveys, opinion mining from various online review sites, and sentiment analysis [13]. For instance, Balachandran and Kirupananda used a sentiment analysis tool to get online reviews for an online evaluation system in a Sri Lankan university [15]. Most people do not understand the importance of giving app feedback, and studies have shown that only an estimated 1% of users share their reviews [15]. Commonly used apps can be improved if users provide feedback [25, 56]. For example, if learners give feedback on their LMS apps, developers can identify the services they desire and ensure that they are sufficiently accessible by [11]. Furthermore, different apps present different accessibility challenges depending on whether they are on the iOS or Android platforms, and feedback on either platform greatly facilitates app development [26]. Our study looks at user reviews within the context of learning applications.

Table 1: List of the keywords used to identify user reviews refer to accessibility. We followed the BBC standards and guidelines for mobile accessibility [18].

Guideline	Description	Relevant Keywords
Principles	These guidelines require a focus on three principles of developing usable and inclusive applications. First, developers should utilize all web standards as required. Secondly, there should be the utilization of interactive controls. Thirdly, content and functionality in the app should support native features of the app.	Accessibility, disability, screen reader, blind talkback, operable, impaired, impairment
Audio/video	Applications should provide alternative formats such as transcripts, sign language, or subtitles. Autoplay should be disabled, and the user should be provided with play/pause/stop or mute buttons to control audio. There should be no conflict between audio in application media of native assistive technology.	Subtitle, sign language, audio description, transcript, autoplay, mute, volume, can't hear
Design	The color in the app background should have appropriate contrast, and touch targets must be large enough to be touched effectively. Visible state change should be experienced in every item in the app that has been focused on. Unnecessary or frequent flickering of content must be avoided.	Contrast, background color, flicker, visual cue, touch size, overlap, font size, dark/light mode, eyestrain, seizure, can't see
Focus	There should be a logical organization of items, and users should be offered alternative input methods. Interactive and inactive elements should be focusable and non-focusable, respectively. Keyboard traps should be eliminated, and focus should not change suddenly when the app is utilized.	Focusable, control focus, keyboard trap, focus order, navigable, input/type
Forms	Every form of control must have a label. All labels must have a logical grouping, and a default input format must be given. Labels should be close to their form controls.	Unique label, missing label, visible label layout, voice-over
Images	Text images should not be included. Any background images that have content should have another accessible alternative.	Image of text, hidden text, text alternative, background image
Links	Any navigation links must indicate the function of the link. If a link to an alternative format is clicked, the user should be notified of the redirection to the alternative. Several links that redirect to the same source should be put together in one link.	Link description, unique desc., duplicate link, alternative format
Notifications	Error messages should be clear. Any notifications given must be easily seen or heard. There should be standard system notifications where necessary.	Operating inclusive, haptic, vibration, feedback, alert dialog, understandable, unfamiliar
Dyn. content	Applications should be made in a progressive manner that enables every user to benefit from them. Appropriate notifications should be given for automatic page refreshes. Flexible interaction input control must be given.	Animated content, page refresh, automatic refresh, timeout, adaptable, input sign
Structure	Every page on the application should be uniquely identified. Content should be arranged in a hierarchical and logical. manner with appropriate headings. One accessible component should be used to group interface objects, controls or elements.	Page title, screen title, heading, header unique descriptive
Text equivalent	Applications should give the objective of a specific image or its editorial aim. In addition, visual formatting must be complemented by other ways to give meaning. There should be no conflict between decorative images with assistive technology. Every element must have well-placed and effective accessibility properties.	Alternative text, non-visual, content description decorative content, no-text-content

3.2 Accessibility in User Reviews

Various scholars have investigated accessibility in user reviews in the past. For example, Eler et al. [25] evaluated user comments about the accessibility of mobile applications and found that people rarely provide accessibility-related reviews even when faced with such issues. In another study, Yan and Ramachandran investigated the accessibility of mobile apps by looking at their Graphical User Interface (GUI) features and adherence to accessibility guidelines. They found that a majority of the apps had violated accessibility guidelines and had multiple accessibility issues [56]. Another study by AlOmar et al. designed a model to help automatically identify accessibility user reviews, which was found more accurate than random classifiers or keyword-based detectors [11]. We have noted that all the previous studies did not focus on accessibility user reviews in education applications, which is the focus of our current study.

3.3 LMS in Mobile Application

Several studies have focused on learning management systems in mobile applications. For example, Papadakis et al. found that students use mobile phones as an electronic document repository when accessing content from the Moodle platform. However, the phones were limited in terms of their reliability and usability [36]. Another study by Liu et al. focused on the use of mobile apps in inquiry-based learning (IBL), which found that updated functional features promoted the use of IBL [44]. Albidinova et al. investigated the development of a mobile application for learning in a university and pointed out the need for such innovations in higher education institutions after a piloting experiment [34]. In Saudi Arabia, Arturki et al. [1] and Sahrir et al. [12] investigated the use of Blackboard and IIUM I-Taleem, respectively, and documented their usefulness in providing learning support for students. In Egypt, applying the Easy-Edu LMS platform has proven helpful in universities because of its use of agile-based systems that enable the detection and prevention of issues faster way [47].

Several scholars have investigated the accessibility of LMS educational applications. For example, a study by Batanero-Ochaita et al. [27] evaluated the accessibility of learning management systems by blind, deaf, and deaf-blind students and found that students had positive perceptions towards the use of learning management systems that were adapted to their needs because they improved content accessibility. Furthermore, conducting a study at King Saud University, Alturki et al. [1] found that Blackboard was usable and accessible. However, there was a need to customize the LMS system to cater to teachers' needs. Furthermore, at the University of Dar es Salaam in Tanzania, Mtebe et al. [17] found that the use of Mobile Moodle made it easier to use the Moodle platform and enabled them to do their learning activities more effectively.

Collecting user reviews of LMS systems has been considered one of the strategies for increasing user satisfaction and improving the experience of video education app users [40]. Some of the common problems that could affect app accessibility include user interfaces, structure, communicative features, and mobile features [55], as well as inaccessible content, slow downloading of Moodle's pages, screen size, difficulties in submitting assignments, among others [3]. In the current study, we wish to explore the accessibility of four android educational applications, which, to the best of our knowledge, have not been addressed by previous studies.

4 STUDY DESIGN

This section presents the details of our approach used in this study, as provided in Figure 1. The information covered in this section contains the survey details, interview procedures, and user reviews.

Table 2: Participants demographics information. Each participant (P#) answered the interview questions.

Participant	Age	Major	Year	Student Type
P1	22	Electronic Engineering	2	Hearing
P2	24	Mechanical Engineering	4	Hearing
P3	22	Computer Networking	3	Hearing
P4	20	Electronic Engineering	1	Hearing
P5	23	Computer Technology	3	Deaf/Hard-of-hearing
P6	22	Business	2	Deaf/Hard-of-hearing
P7	21	Business	3	Deaf/Hard-of-hearing
P8	23	Computer Technology	4	Deaf/Hard-of-hearing

Table 3: Set of interviews questions.

***First*- Background and Demographics**
Years of age, and study major Do you use the Blackboard mobile application on your phone?
***Second*- Generic Views**
How would you describe your experience while using the Blackboard mobile application? Were you able to access the class materials via the Blackboard mobile application? How often would you use the Blackboard mobile application?
***Third*- Accessibility Challenges**
How easy was the application to use? How is the navigation of the Blackboard mobile application?
***Fourth*- Students Recommendations**
Are there any features that you think you need but are missing in the mobile application? What do you think the Blackboard mobile application should improve on?

Table 4: Set of survey questions.

***Q1*- What is your Gender?**
○ Male ○ Female ○ Other
***Q1*- What is your major?**
○ Computer technology and related fields ○ Business and related fields ○ Mechanical and related fields ○ Electronic and related fields ○ Electrical and related fields ○ Telecommunication and related fields ○ Food Processing Technology and Related to It (Food Processing) ○ Chemical and related fields ○ Tourism and Hospitality and related fields ○ Civil, Architectural and related fields ○ Other
***Q3*- How satisfied are you with using the Blackboard platform on your mobile phone?**
○ Extremely satisfied ○ Satisfied ○ Neutral ○ Dissatisfied ○ Extremely dissatisfied
***Q4*- Based on your experience using the Blackboard application on your mobile phone, how easy and user-friendly is the app for you?**
○ Extremely easy ○ Easy ○ Neutral ○ Difficult ○ Extremely difficult
***Q5*- What would you like to see improved in the Blackboard mobile app?**
Open-end question

This section provides the details of our survey with 1,373 students. Then we elaborate on the follow-up interviews with 8 students. To get more insight into the users' reports about accessibility-related, we collected all the user reviews related to the Blackboard app. Next, we detail our filtration process to identify whether user reviews were accessibility-related or non-accessibility-related. Finally, we explain our manual analysis to label the user reviews based on the accessibility guidelines.

4.1 Survey

To get an overview of the issues surrounding the accessibility of the Blackboard LMS platform, we conducted the survey at Technical and Vocational Training Corporation (TVTC) college[3], which was the study's location and focus. Our participants were divided into hearing students (1,308 participants) and deaf students (65 participants). The questionnaire was in the Arabic language, which was the native language of the respondents. We asked five questions in the survey, which are given in Table 4. We sent the questionnaire using Google forms[4], which made it easier and more convenient to reach the respondents by sending them a link to the form. The analysis of the results was crucial in elaborating on students' perception of the accessibility of the Blackboard platform.

4.2 Interview

To complement the survey data, we conducted interviews so that respondents would give us their views and opinions. Given the importance of validity in interviews, we utilized investigator triangulation. We used a voluntary sample of 8 students, four deaf and four hearing students. We created an interview schedule with open-ended and closed-ended questions. The interview's semi-structured nature allows respondents to reflect, in more in-depth, on their answers. The nine questions used in the interview are given in Table 3.

We conducted the interviews using the Zoom platform[5] and used the Arabic language, which was the native language of the respondents. We offered a $25 prepaid gift card to motivate the interviewees to participate. It is important to mention that, during the interviews with deaf students, we hired a sign language interpreter as an accommodation for the students because none of us was competent in sign language. During the interviews, students were encouraged to comment on any usability or accessibility issues they experienced. Thus, deaf students also mentioned interface issues unrelated to hearing impairment. The demographic information of the interviewees is given in Table 2.

Following the interviews, we transcribed the data and translated it from Arabic to English. The translation accuracy was ensured by all the authors separately as follows: when the first author translated the work from English to Arabic, it was passed on to the second author and later to the third author, who separately compared the translated scripts to the original Arabic ones. We utilized thematic analysis to analyze the qualitative data. We perused through the interview transcripts, created codes, revised them, and deduced the themes from the pattern of answers given.

4.3 User Reviews Collection and Preprocessing

The first stage in this section was to get user reviews on the accessibility of the Blackboard platform, where we collected the reviews

[3]https://www.tvtc.gov.sa/index-en.html
[4]https://www.google.com/forms/about/
[5]https://zoom.us/

Table 5: Present an example of the eliminated reviews.

Step	Example
Emojis	👍👍
language	Algunas veces las videoconferencias no se conectan
Noise	Love it!!

from the Google Play Store [29]. We collected all the reviews relating to Blackboard, and a total of 15,478 reviews were received. The next step was data preprocessing which involved three steps:

- **Step (1)- Discard Emojis & Languages:** We removed any reviews that only contained emojis or images, such as thumbs up and others. These reviews that include only emojis are not helpful and assist us in understanding the accessibility issues in the reviews. We also removed any reviews written in languages other than English, such as Chinese or Arabic, since our study was in English. After mining the collected data, we eliminated 292 reviews containing only emojis or written in a different language than English.
- **Step (2)- Remove Duplicated Reviews:** We removed any reviews that were posted twice or severally by the same user. We eliminated such duplicate reviews because they were only repeating themselves and adding no value to the dataset. In this Step, we eliminated 1,670 reviews, and we only kept the unique reviews in the dataset.
- **Step (3)- Discard Noise in Reviews:** We discarded noise by removing all reviews that were in less than five words format, such as 'super' or 'awesome' or 'great' or 'good app' etc., which were not useful in getting user feedback. This step involved removing 5,982 reviews. Table 5 presents an example of three steps of data preprocessing.

4.3.1 ***User Reviews Filtering.*** After the data preprocessing, we remained with 7,534 reviews subjected to machine learning to know whether the user reviews were related to either accessibility or non-accessibility. To do so, we used our previous model [11] to help us automatically identify the type of user reviews. This means we put all the Blackboard user reviews as an input of the model, and the model determines the two subsets of the dataset, accessibility and non-accessibility, as an output. We used this model to reduce the human effort needed to filter the user reviews manually. After we utilized the ML model, the model's output was distinguished from 3,813 reviews (50.61%) out of the 7,534 reviews as accessibility.

4.3.2 ***User Reviews Labeling.*** Since we are using machine learning to identify accessibility user reviews, there could be user reviews that are not related to accessibility, which can be a false positive of automated detection. Therefore, to address this issue, we performed a manual analysis to filter the false positive reviews and classify the reviews based on the accessibility guideline in Table 1. More precisely, we employed three-step iterations, described in content analysis method [42, 45] involving two of the authors of this paper, who have complementary expertise in line with the goal of our analysis. The first author is a software engineer with four years of working on mining software repositories for mobile and publishing more than two papers in the accessibility field. The second researcher is a bachelor's student in computer engineering and has two years of experience in Natural Language Processing (NLP) techniques for mobile computing.

From this point forward: we introduce both of them as inspectors; they label a total of 3,813 user reviews, each using the approach outlined below:

Iteration (1): In the first stage: the inspectors analyze the 3,813 user reviews individually. The inspectors read all the user reviews during the analysis process and strive to identify any non-accessibility user reviews labeled as accessibility (false positive). After each inspector completed the labeling, the inspectors discussed the false positive user reviews. In the discussion, the two inspectors intend to stimulate a consensus. Afterward, the inspectors decided to eliminate 1,498 reviews. Thus, the inspectors ended up with 2,315 user reviews.

Iteration (2): In the second stage: the inspectors categorize the 2,315 accessibility user review proceeded from the first iteration. Both of the inspectors aimed to categorize based on the guidelines of the BBC standards and guidelines for mobile accessibility [18] and described in Table 1. During the categorizing process, the inspectors allow categorizing the user review and labeling them with one or more guidelines. After each inspector completed the labeling, the inspectors opened a discussion about the process of categorizing reviews. While discussing, the inspectors identified an issue during this iteration.

> *Review 1. "I can't review some content. That's kind of important in school."*
>
> *Review 2. "It doesn't load anything anymore on my phone ever so disappointed"*
>
> *Review 3. "The app is really easy and accessible, but it doesn't always load the pages that I need"*

The above examples demonstrate one thing in common: they do not elaborate enough to make them seem like accessibility reviews. Afterward, the inspectors decided these false positives were still non-accessible, even though they were worded in an accessible way. Hence, the inspectors eliminated 13 reviews. So, the inspectors ended up with its iteration with 2,302 accessibility user reviews.

Iteration (3): After the second iteration, where the inspectors categorized 2,302 accessibility user reviews based on the guidelines, they concentrated on dealing with the multi-guideline reviews. There were 164 accessibility user reviews belonging to two guidelines. The inspectors have to decide for each review what is the deciding factor in labeling each guideline. The inspectors opened a discussion about the multi-guideline reviews. The following is an example of one of the user reviews that was labeled as multi-guidelines.

> "This app is awful, the last one wasn't great, but it was still better than this one. It sends me notifications for the same grade like 10 times, and half of the links don't work, and it's always glitching."

The review listed above has a couple of problems, yet some do not take precedence over others, as this example was labeled notifications and links guidelines. After the discussion, the inspectors decided to label the review to the primary concern of the review,

which is link guidelines.

Additional validation: To validate the procedures executed by the inspectors, who individually examined and labeled all the accessibility user reviews related to Blackboard reviews, we followed the directions of Aljedaani et al. [8] by picking a 9% sample of the entire data set (239 out of 2,302 reviews). The selected sample satisfied the 95% confidence level, while the confidence interval was 6. Then, we randomly selected 239 reviews out of the 2,302 reviews. Afterward, the selected sample was given to two of the authors for labeling them. The selected data were not previously disclosed to the authors. The review procedure lasted for seven days to avoid fatigue. During the labeling process, the authors had the ability to look for terms/keywords online that they could not understand. The labeling of the data was followed by a comparison with the labeled reviews from the original dataset. Finally, we investigated the inter-rater agreement level between the two datasets using Cohen's Kappa Coefficient [22], which gave us an agreement level of 0.87. As noted by Fleiss et al. [28], an agreement level between (i.e., 0.81˜1.00) implies almost *perfect agreement*.

5 STUDY RESULTS

RQ$_1$: To what extent do students find the Blackboard mobile application easy-to-use?

In this question, we wanted to gauge students' experience with the Blackboard mobile app, from a usability perspective. According to the responses outlined in Figure 2, the majority (85%) of the deaf students found Blackboard extremely difficult to use. We found the high dissatisfaction rate with Blackboard among deaf students to be a significant source of concern and sought more explanation from the students. This is particularly interesting since only 12.1% of hearing students have found it extremely difficult (cf. Figure 3). One of the essential features of an LMS system is having a suitable interface for the needs of deaf students. Compared to hearing students, deaf students have e-learning challenges requiring LMS systems to have the complicity, consistency, navigation, and proper typography.

This finding has driven our interview to seek more insights about why deaf students experience difficulties when using Blackboard. As mentioned in Section 4, deaf students could freely refer to any issues that make it challenging to use Blackboard, not only barriers related to hearing impairment. For instance, participant *P6* had a problem with the Blackboard interface and explained that:

> *"Blackboard was not a friendly interface. I had an issue locating the exam component since there are a lot of headers and sub-headers in the navigation bar, and the font was tiny and hard to read." (P6)*

In our study, some students could not access the materials. *P8* who faced such a challenge said that:

> *"I usually like education apps so that it can be more convenient to learn from my phone. However, I Can't watch videos or download files in the blackboard app. Then, I stopped using the app and switched to the web version." (P8)*

P5 noted that:

> *"Because I am deaf and rely on visualization, I cannot have the video caption in the app for videos." (P5)*

Deaf students also had problems when doing exams due to a lack of pictures, and *(P7)* said:

> *"I liked the app, and it was easy to use. My issue always was in the exam where the picture is not shown in the exams, and I missed a few questions for that reason." (P7)*

Although previous studies indicated that deaf students had positive perceptions towards learning management systems [27], this study reveals another dimension of accessibility problems that negatively impact a subset of students. Therefore, we compared the survey results of deaf students with hearing students, and the results are given in Figure 2 and Figure 3.

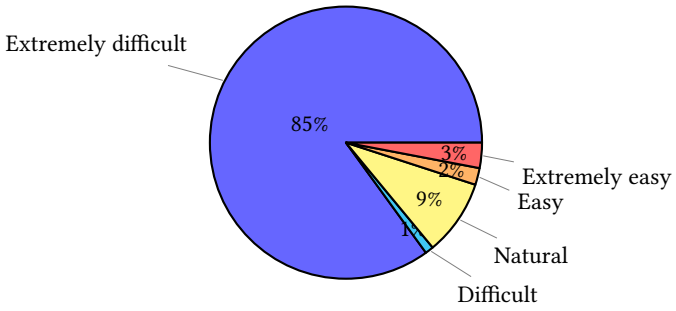

Figure 2: Percentage of the deaf students (no. 65) participated in the survey.

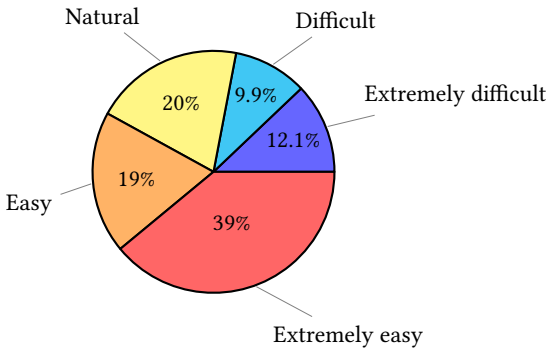

Figure 3: Percentage of the hearing students (no. 1308) participated in the survey.

Compared to deaf students, most hearing students (39%) found it extremely easy to use the Blackboard LMS application, 20% found it natural, and only 10% and 12% found the platform complex and extremely difficult respectively, as shown in Figure 3.

We wanted to identify the reviews of those students who found it difficult to use the platform. In our study, some students complained that materials were inaccessible. *P2* said that:

> *"When we were locked out in the COVID-19 pandemic, I used the application because I had no laptop to access. I tried to access the class material via the Blackboard*

app, but it is not opening documents. So, I have to ask my colleagues to share the class materials." (P2)

The user-friendliness of an education app is crucial because it indicates the ease of use of the application by students. According to the respondents, the site layout of the app, navigation labels, and overall app design should make it appealing to users, which was not the case for Blackboard. *P1* noted that:

"I used several education apps to teach my younger brothers, and they were easy and simple to use. For my studies, I used the Blackboard. I found it a highly complex app to navigate if you don't know what you're doing. It needs to be more user-friendly since it is an educational app." (P1)

P3 also highlighted that some links were not working:

"I love the app, and I used to study my class materials on it. Sometimes links in the app are not working, and the show me page was not found." (P3)

It would be plausible to suggest that the app was not user-friendly and easy to use. In a bilingual or multilingual learning environment, app users should be able to switch between languages. For instance, Arabic and English are often used in Saudi Arabia, even though some people only understand one of the languages. For the case of the students we interviewed, their native language was Arabic, and they indicated that changing the language in Blackboard was a problem. According to *(P4)*:

"When I downloaded the app, it was in the English language. I tried to change the language to Arabic, but I could not. I asked my father to change the language for me, but I realized that with the Arabic language, the application layout was weird and hard to read or navigate." (P4)

These results are consistent with previous studies [1] that have found Blackboard LMS usable and accessible, although improvements to the platform could make it easier to use.

RQ_2: What accessibility issues are reported by the users of Blackboard app?

In this second research question, we were looking at the user reviews given about Blackboard on Google Play Store. Table 8 shows the number of reviews and their percentages in relation to the various guidelines.

From Table 8, the majority of the reviews (1062 representing 46.13%) related to Principle, followed by Focus (24.15%), and Notifications (11.60%). Table 7 presents an example of accessibility reviews relating to each guideline. The principle guideline requires that apps be easy to operate, accessible to all users, robust in use, and understandable. From the reviews we analyzed, the *principle guideline* was not met, and one of the reviews indicated that:

"For a student who is Blind that uses accessibility software, JAWS, a screen reader that the Blind uses to operate on a computer, the Blackboard application does not function correctly when jaws require that some activation requires the user to do a double tap to activate some functions of radio dialogues, especially when taking an exam to open the test and when navigating to the next test question the application did not move to the next question but went and submitted the exam test.no be."

Table 6: Present the results of the accessibility reviews after labeling.

Guideline	# of Reviews	% Percentage
Principle	1062	46.13%
Focus	556	24.15%
Notifications	267	11.60%
Design	145	6.30%
Forms	93	4.04%
Audio/video	69	3.00%
Links	59	2.56%
Dyn.content	38	1.65%
Images	10	0.43%
Editorial	3	0.14%
Structure	0	0.00%
Text equivalent	0	0.00%
Total	**2,302**	

The *focus guideline* requires that the page be navigable, focusable, and the input type be compatible with the users. In relation to the Focus principle, one of the reviews suggested that:

"Not user friendly. Especially disappointed that the word "organization" is spelled incorrectly throughout the app. How can one take an app like this seriously if the designer can't spell, and nobody else corrects them???"

On the *Notifications principle*, students should be able to get notifications on updates in the courses, and upload materials, among other things, even without their laptops. If the app does not provide notifications, students may miss important communication from the university or lecturers, which means missed learning opportunities. For an application such as Blackboard, which many universities use, it was unfortunate that some users said it lacked notifications. One of the reviews said:

"Fix the goddamn notifications I missed requirements because of this!"

For the *design guideline*, a learning app should have proper interactive elements, consistent navigation options, an appropriate background color, provide light/dark models, reduce eye strain on the users, and have a good font size. However, some users did not find Blackboard to have a good design, and one of the reviews indicated that:

"It works, but what's with the zany button click animations, etc? They're really distracting, I'd like to see them toned down a good bit."

It is important to note that the issues we found affecting accessibility from the user reviews have been reported in previous studies [3, 55]. Therefore, grouping them in terms of the guidelines helped us to classify them for easier identification.

Table 7: An example of the accessibility reviews related to each guideline.

Guideline	Example
Principle	for a student who is Blind that uses accessibility software, JAWS, a screen reader that the Blind uses to operate on a computer, the Blackboard application does not function correctly when jaws require that some activation requires the user to do a double tap to activate some function actions of radio dialogues, especially when taking an exam to open the test and when navigating to the next test question, the application did not move to the next question but went and submitted the exam test.no be.
Design	Please add dark mode, plus the feature to customize, organize and categorize modules, really need it. And I need to re-login almost every day, please make the login stick.
Notifications	What's the point if it doesn't even have notifications to remind you of anything? You might as well just use the browser version and auto sign-in every time.
Focus	Hard to navigate and often causes glitches in test submission. Difficult to find what you need.
Forms	After so many updates and this app still has the same problem. It does it open all the files (PDF, PowerPoint) they do not load.
Audio/video	I downloaded this app in the hopes that the inset videos would be easier to watch on my phone. The web browser doesn't allow you to see the whole video, just a cropped amount. Unfortunately, the app does not allow for videos, and I just see code instead. But I would really like to see video capability added to this app. I do like that it has due dates listed for assignments, and for that alone, I am happy to keep the app for now. Overall though, it is somewhat unsatisfying.
Links	Absolutely awful. The app is entirely unusable. Every link opens in an embedded browser and results in an error.
Dyn.Content	Some of the worst UI designs I've ever seen in an app. There are so many unnecessary animations tied to small actions; you can't click on a link without something wobbling or showing a folder opening up and papers falling out. The worst part is, the animations clearly take up a huge amount of resources because the app will actually lag before they show, which makes the whole app feel clunky and slow. If they got rid of all of these things, the app would at least feel usable.
Images	Unable to view any images sent by the instructor (sent individually or inside a quiz).
Editorial	Activity steam updates after a very long time. Also, when opening a new announcement, it opens old announcements, not the recent one. The push notifications come on after more than 24 hours. Definitely not pleased about the app and how slow it responds to everything. Also, I can't hear my collaborative sessions, although all my microphone settings have been activated to be on and can be accessed by blackboard.

Additionally, we attempted to determine the nature of the issues that app users reported. We outlined 16 pertinent issues faced by the users in Table 8, along with the frequency of reviews that report those issues. We also provide a sample review related to each category of the listed issues. We observed that the majority of the reviews are related to the anomalies associated with *notifications*, followed by *grade visibility*. Users also encountered problems such as submitting assignments, homework, and PDF files, among others. We established that even though Blackboard is a widespread application, previous studies have shown that user feedback can benefit such applications by enabling developers to make improvements [25, 56]. Therefore, it would be important for developers to address the accessibility issues indicated for a better user experience.

6 STUDY DISCUSSION

The results of our case study give a broad understanding of the accessibility challenges currently experienced by users in perceiving, understanding, and operating the Blackboard LMS. Our results show that most hearing students find Blackboard easy to use, yet many have issues related to navigation, accessibility of materials, and changing language, among others. On the other hand, the majority of non-hearing students find Blackboard extremely difficult to use, not only due to accessibility barriers but also due to other usability problems.

In that sense, our study gives some evidence of the accessibility issues of Blackboard and their associated consequences, in addition to pinpointing areas where Blackboard mobile application needs to be improved for a better user experience. We believe our findings will show the importance of delivering accessible educational systems and benefit the developer community by showing necessary improvements not only to Blackboard but to any LMS that shares similar features. Accordingly, we present some takeaways from our investigation.

Takeaway 1: Both deaf and hearing students frequently rely on videos that have been uploaded on Blackboard to learn the contents of a course. Therefore, they should be able to easily access and download videos and material for later and further studies. This requirement may seem obvious, but it is important to show evidence that many students have problems finding and downloading study materials.

Takeaway 2: Lack of captions in videos causes problems for deaf students. Deaf students cannot hear what the teacher is saying and solely rely on captions. Unfortunately, some of the videos on Blackboard did not have captions according to students, making it challenging for deaf students to perceive and understand the content of any class. This problem happens both with live-streaming content and pre-recorded videos. One of the limitations of making available videos with proper captions is that it heavily depends on the content generator (e.g., teachers and instructors). In that sense, we believe any LMS should have a policy to enforce uploaded videos to be properly captioned. That could be done automatically or by manual inspection.

Takeaway 3: The use of a Graphical User Interface (GUI) in LMS systems is essential for deaf students because it enables them to

Table 8: Categories of issues reported by the users during their app usage.

No.	Issue Type	# of Reviews	Example
1	Quiz	19	Quizzes with images don't show the image (so I can't tell what label B is pointing at, for instance). Notifications show up repeatedly for the same things even after you've dismissed them, and there is no way to adjust settings. This is the fastest I've ever uninstalled an app.
2	Homework	40	This app crashes a lot. Sometimes the app works, sometimes it doesn't, and given the fact that students lile myself have to upload homework assignments it is very fustrating knowing that this app could crash when the assignment you must summit is due.
3	Exam	17	This app is the bane of my existence. It glitched while saving a draft of an exam I was writing, and crashed whenever I attempted to open the draft, causing me to lose time and have to email the professor my exam submission. Beyond that, it has frequent glitches and often refuses to work for no apparent reason.
4	Material	43	This doesn't not work. The previous app allowed access to my school and the material. All of the sudden my school is no longer available and the app doesn't work or recognize my University. Please bring back the old Mobil app.
5	Lecture Recording	16	The most recent update has broken echo360 lecture recordings can't watch them anymore.
6	Course Content	39	I can never see full course content and it doesn't allow me to submit my assignments.
7	Grade Visibility	220	Use to work great, until this year. Can't view my grades and some content. When I click on grades it says "something went wrong". Tried reaching out to them and put in a help ticket, still nothing 2 weeks later.
8	Assignment	179	I can never see full course content and it doesn't allow me to submit my assignments.
9	Announcement	125	I hate that you have color coded grades. This app doesnt update regularly causing me to miss announcements and content postings for classes.
10	Video	67	Worst app Couldn't load Videos,recorded lecture and lecture slides. Durning class I couldn't see the lecture Worst experience.
11	PDF	49	The app has become pretty useless as it doesn't recognise my pdf or doxc readers and won't open any files. The only thing I can check are updated grades, but often I get a notification and then the grade won't show within the app.
12	lecture	41	Can no longer stream a lecture while doing something else. Lecture stops if not in foreground. Old app was better/easier to use.
13	Image/Figure	20	Unable to view any images sent by the instructor (sent individually or inside a quiz).
14	Audio	9	It's good but i can't open the content if it's an Audio.
15	Link	83	Can not access to any links that provided by proffesors.
16	Notification	436	Crashes constantly and sends the same notification repeatedly after I look at the app and clear the notification.

visualize what they are learning. It is crucial to have high-quality images that are informative to students. Our findings further highlight the significance of user-friendly apps, which enable users of bilingual or multilingual environments to switch between languages quickly.

Takeaway 4: Students should be able to efficiently and effectively utilize the app, attend lessons, take assignments, and even download materials. It is worth mentioning that students should be able to see all files that have been uploaded and be able to download them, provide alternative access to learning materials, and use the correct format that can be opened using common programs. Again, some of the responsibility lies in the content creator. In that sense, the LMS should have a policy to enforce alternative formats to study materials made available to students.

Takeaway 5: The findings from $\mathbf{RQ}_2$ indicated that the Blackboard application lacked certain application guidelines that are required for a better user experience for students with disabilities and those without disabilities. We classified those guidelines to identify the corresponding issue more precisely in terms of principles, focus, notifications, and design. We further outline the key implications obtained from $\mathbf{RQ}_2$**:**

- *Principle Guideline:* For students with disabilities and those without, it requires that every user be able to navigate through the platform, know the information that is presented, understand it, and frequent upgrades are made to improve app accessibility.
- *Focus Guideline:* All content should be sufficiently described with unique labels, and there should be logical and intuitive navigation order of *focusable* elements.
- *Notifications Principle:* To prevent students from missing training and learning opportunities, students should be notified of any updates about coursework.
- *Design Guideline:* There should be visual cues, as well as form elements that have clearly associated labels. For students with visual impairments, accommodations should be made for them so they can access the materials.

7 THREATS TO VALIDITY

In this section, we present potential threats to the validity of our study.

Detecting accessibility user reviews. We used a previously implemented model that used supervised learning to formulate the identification of accessibility reviews as a binary classification [11]. However, there might be a false positive in the process of automatically tagging the reviews as accessibility. To migrate this issue, we manually read the 2,302 reviews while we labeled them in the guidelines, and we made sure that there was no such case where data was labeled falsely by automatic processing.

Inclusion of all possible keywords in the labeling process. There are different keywords that users use to express their concerns related to accessibility. One potential concern is whether the set of keywords belonging to each of the guidelines used in this research covers all possible keywords. For mitigating this threat, keywords defined by [25] have been employed in our study. Moreover, variants of these keywords have been adopted to ensure that the authors do not miss any relevant review during the manual validation and labeling process.

Sample size. The number of interviewed students does not be representative. Therefore, we had to mitigate this risk by performing a survey of 1,308 hearing students and 65 deaf and hard-of-hearing students. We have also mined the issues in the app store to target a wider population of users as well.

8 CONCLUSION

This study explored the student perception and user reviews of the Blackboard app from the accessibility standpoint. We believe that our research would contribute to the existing literature on the ease of use of educational applications and be the first study to utilize Blackboard user reviews from the Google Play Store to analyze the accessibility of the application. We established that most students, especially the deaf ones (85%), found it extremely difficult to use the Blackboard application. Similar results were confirmed when we

analyzed user reviews from the Google Play Store, where (31%) of the user reviews were related to accessibility. Some of the reasons that made the Blackboard application inaccessible were the lack of notifications, unavailability of captions, distracting animations, difficulty changing language, and lack of video captions. Our results provide valuable insights for educational application developers to improve the accessibility and usability of the applications.

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