What's the Weather: Making Weather Data Accessible for Visually Impaired Students

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Abstract

We determined during a collaboration project in Kenya that students with visual impairments were interested in learning about weather data as part of their Science, Technology, Engineering, and Mathematics (STEM) education. Unfortunately much of this data is not accessible to the students due to lack of integration with assistive technologies, as well as limited access to landline internet. Therefore we created the Accessible Weather App to run on Android and integrate with the TalkBack accessibility feature that is already available on the operating system. This paper discusses the process for determining what features the users' would require, and our methodology for evaluating the beta version of the app. User feedback was positive and suggestions have helped advance the interface design. The overall goal of our project is to develop, evaluate, and integrate the Accessible Weather App into weather and meteorology learning activities for students with visual impairments.

Author Keywords

Accessibility; Weather; Android; App; Visually Impaired; TalkBack; Kenya; Assistive Technology.

ACM Classification Keywords
H.5.1. Information interfaces and presentation: Multimedia Information Systems; H.5.2. Information interfaces and presentation: User Interfaces.

1.0 Introduction

For many of us, checking the weather forecast is a regular part of our morning routine. A quick look at our favorite weather app lets us know if we need a jacket, an umbrella, or sunglasses for the day. But climate data is not only useful for planning your outfit or commute; it is a vital resource for farmers, transportation workers, retailers, and various other professions. Access to current weather information is a convenience that most of us are used to having readily available on our favorite apps and widgets. Climate data is continuously collected and studied by scientists, but it can also be easily studied in the classroom. Teachers can use weather data in science and math courses as a set of easily understandable and relatable information that students can help collect and analyze. Using weather data can make math easier to understand through grounding the concepts of mean, median, and mode into familiar information (e.g., "let's look at the average weather this week"). Access to weather forecasts can directly support weather and climate education in the science classroom, as these are important notions to more complex ideas of the global ecosystems and climate change.

During a recent trip to Kenya for a research collaboration we found that students at the Thika School for the Blind were very interested in learning about weather and climate in their science classes, but did not have access to many of the resources we take for granted. Most weather apps and websites display current weather conditions with various visual icons, complex graphs, and data tables that are not accessible to users with visual impairments. Recognizing this issue as a barrier to education that students and teachers directly identified, we determined that building an application specifically designed to work with existing accessibility features as a low cost option to overcoming this problem.

Even though internet infrastructure in Kenya is growing and becoming more accessible to a larger portion of the population, mobile devices have become the primary way that majority of users connect to the internet. Electricity and internet are not always reliable at the classroom locations, but the telecommunications infrastructure is easier to build and maintain, and it remains the most successful technology available at a large scale [1]. Over the past decade there has been a staggering growth of mobile phone users in Kenya. The United Nations, through the Communication Commission of Kenya estimated around 330,000 users of cell phones in 2001 and about 30 million in 2013. This is opposed to 200,000 internet users in 2000 and 19.6 million by the end of 2013 [7]. In 2011, the U.S. Embassy in Nairobi forecast that Information and Communication Technologies (ICTs) were one of five major areas of growth for Kenya in the coming years, highlighting that there were an estimated 13 million mobile internet users, much higher than those who used more traditional cybercafés for internet access [12]. Last year, Pew Research estimated 82% of adults in Kenya had access to mobile phones, with at least 15% being smart phones (iPhones, Android, Blackberry, etc.), and of the remaining 18% who did not own a phone, 10.5% reported sharing access to a phone with a phone owner. In a huge contrast to that,

97% of those surveyed reported not having a working landline telephone. While the majority of these users send texts from their mobile devices, many use them to access other information like social networks, health, and political data [11]. Previous research has also found that utilizing already existing infrastructure makes ICT adoption more successful than trying to implement a completely new technology [5].

As of early 2014, Android phones dominate the majority of the mobile OS market in Africa, and this trend follows for Kenya as well [8]. Even with the growing prevalence of smartphones [15], more widespread access to information on their phones, and their overall affordability compared to other forms of ICT access, much of the information available is not accessible to those with vision impairment. And as of 2014, the Kenyan Society for the Blind estimated a total of 300,000 people with some level of vision impairment [4].

On Android devices, the majority of phone apps are not designed to work well (or at all) with TalkBack, Google's Text-to-Speech (TTS) service. The same is also true for many iOS applications. Since most of the apps are designed with visual displays as the focus, getting basic information, such as current weather conditions, is not typically fast or easy. An evaluation of the top five free weather apps for Android and iOS ranged from 2 to 17 swipes (or taps on the screen) before the current temperature is read by the TTS. Table 1 contains more detailed information about the individual weather apps and their navigation counts. While some of these apps provided the current weather in just a few swipes, it is important to know that they also tend to chunk additional information together so that the listener is still required to listen to an extended list of information before the current weather was displayed.

Weather App	TalkBack (Android)	VoiceOver (iOS)
1. Weather Channel	8	10
2. MyRadar Weather	2	2
3. AccuWeather	5	4
4. WeatherBug	10	14
5. Weather Underground	17	2

Table 1: The number of swipes or taps required for a user to navigate to the current weather using TalkBack (on Android) or VoiceOver (on iOS) on the top 5 free weather apps for both operating systems.

These apps (and the information they contain) should be accessible to all users, especially since mobile phones are the main ICT Kenyans use for obtaining information. An important cultural consideration for this is that failure to complete a task, for Kenyans, is frequently thought to be a personal issue rather than an issue with the technology [10]. This means that a lack of ability to access the weather information may be seen as a personal failure, and not necessarily a failure of the information providers. For this reason, users may not request accessible access. One factor that will help support navigability and accessibility of this weather information (and information more generally for apps) is design and testing with a consideration for optimal presentation order when navigated using TalkBack or VoiceOver. Determining that a larger portion of Kenyans use Android over iOS, we decided to start with a focus on developing an accessible weather application to work with TalkBack.

Figure 1: Image of our research team meeting with teachers in a classroom at one of the Schools for the Blind in Nairobi, Kenya.

Figure 2: Image of researchers Brianna Tomlinson, Dr. Carrie Bruce, and inABLE staff member Peter Okeyo with the Rainwise digital weather station before it was installed on the roof of the Thika School for the Blind.

2.0 Groundwork

One driving force behind this work was based on feedback gathered from both students and teachers at a school for the blind in Kenya. In partnership with a non-profit group, inABLE [3], whose goal is to empower blind and visually impaired students through access to technology and education, we visited a school for the blind near Nairobi, Kenya in early 2014. During this visit we interviewed teachers to learn more about the content they teach (Figure 1), and facilitated focus groups with students at all ages in the primary and secondary schools. Interviews with instructors during previous trips had highlighted student interest in weather, but at that time the only local weather station was at the Nairobi Airport (and provided minimal information). Weather is an engaging topic because everyone has physical experiences with it. The teachers talked about how students' related their experiences to the weather phenomena (e.g. they can hear the rain on the metal roofs), and it is a more interesting data set to use when discussing simple math concepts. Weather and climate are gateways into other STEM (Science, Technology, Engineering, and Mathematics) areas, as they are more easily relatable and understandable than other topics, because someone can experience weather in daily life (hearing rain or thunder, and feeling rain, wind, and sunshine) [6].

In addition to facilitating interviews and focus groups, another goal of our trip was to set up a RainWise MK-III-LR weather station donated by Weather Underground [14]. This weather station can be seen in Figures 2 and 3. Placing the weather station on the outside of one of the school buildings helped provide hyperlocal information about the weather conditions at their school. The instructors, inABLE staff, and the researchers hoped to provide a more engaging experience for weather and climate education for the students through the local weather station data.

Once a weather station is setup, real-time data is available online. However, even though the weather station on top of the students' school was collecting local climate data there was still an issue regarding the students being able to access it. The school's computer labs had both access to the internet and each computer had free screen-reader software installed [9]. Although a great deal of content online was made accessible through the screen-readers, many sites that display weather data use Flash and other JavaScript that is inaccessible because screen-readers cannot parse it. With the reported unreliability of consistent internet access available to the school by the inABLE staff, and the prevalence of cell phones and stable telecommunication infrastructure, it was decided that a more reliable means of making the information accessible would be on a mobile app.

3.0 Evaluating Users' Needs For the Accessible Weather App

The decision was made to begin creation of an accessible weather app for Android devices as they are more common in Kenya than other mobile operating systems, and TalkBack, the built-in screen-reader, has not yet been widely utilized in a majority of apps available through the Google Play Store. The structure for this project included researching the current status of weather apps, designing and building a version for beta testing, then iteratively testing and developing the app. We completed a thorough survey of what information is included in weather apps and completed a breakdown of what information was on the home

Figure 3: Image of the RainWise MK-III-LR digital weather station after it was installed on the roof of the Thika School for the Blind.

screen, the details screen, and common five day and ten day forecast layouts. We were also interested in determining how weather notifications and current weather apps work with TalkBack. Feedback from initial phases informed the design process, the information architecture, the specifics of the TTS read out by TalkBack, and other details, such as incorporation of auditory icons and earcons.

Auditory Icons are brief sounds, generally based on something naturally occurring. For instance the sound of thunder can be used to represent stormy weather. Auditory earcons work in a similar way, but are created based on more abstract or musical tones. The benefit of earcons is that they offer more flexibility and the associated meanings can be easily learned [13]. In our use case, auditory icons and earcons were implemented to take the place of the common visual icons that are often used to provide glanceable details about current weather conditions that are almost ubiquitous to weather reports. An example of some of the standardized visual icons recommended by Weather Underground can be seen in Figure 4.

While the goal of this project is to provide an accessible technology to students with visual impairments in Kenya, we made the decision to beta test with a broader user group. This decision was made for two primary reasons: first, it allowed us to beta test with users who were already familiar with TalkBack, and second, because we did not want to deploy the weather app to students at the schools for the blind until initial usability testing (plus re-designs and bug fixes) had been completed. Deployment of an incomplete app could lead to confusion and frustration on the part of the teachers and students at the schools for the blind in Kenya. Therefore, for the initial beta testing, we decided to recruit users from two websites: the Eyes-free Google Group and the American Foundation for the Blind message board on technology.

3.1 Surveys

The study began with an initial pre-survey, posted on June 5th, 2015, which 30 individuals completed before downloading the Accessible Weather App from the Google Play Store. This was succeeded by one-week and one-month follow-up surveys, which had fewer responses (eight and one, respectively). In addition to the survey, many users posted comments on the Eyes-free Google Group, or emailed comments and suggestions to the researchers, whose contact information was present on the initial post. Through the Google Play Store Developer Dashboard, the statistics show that over 60 people installed the app on their Android devices and kept it. Over the lifetime of the app being available, there have been 118 unique user downloads. The top ten countries with downloads of the Accessible Weather App included the USA, Germany, Japan, Italy, Russia, France, the U.K., Spain, the Netherlands, and South Korea.

In each of the three surveys, we tried to identify a variety of things. One goal of the first survey was to hear from users what weather information they found most relevant (e.g., daily conditions, level of details, and weather alerts), what their experiences and level of satisfaction were with their current weather app's use of TalkBack, and what other types of media they prefer for learning about weather forecasts. While we had previously investigated what information is commonly included in weather apps, we were unsure if the users would have additional needs. Some of the reported

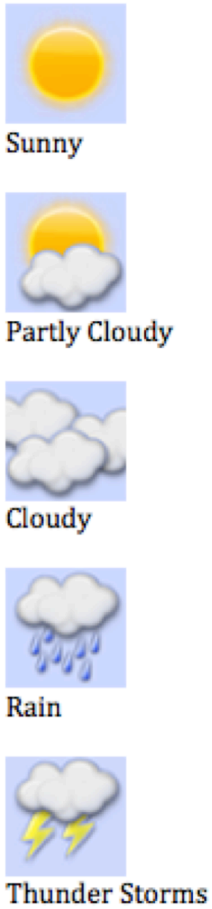

Figure 4: Depiction of common visual weather icons used for apps, widgets, and webpages to provide glanceable details about weather conditions.

issues with current weather apps included that they cannot change data provider or set alerts, some buttons and other UI components were unlabeled and thus not identifiable by TalkBack, and that there was an inability to access the hourly and extended forecasts. Additionally, users reported that their current weather apps lacked auditory feedback including level of details and information for alerts or other notifications.

3.2 Feedback

The one-week survey attempted to learn about users' opinions of the Accessible Weather App, collect information about usage, and discover what the users' thought about the incorporated auditory icons. On a scale of 1-5 (not at all helpful to completely helpful), six of the seven respondents reported the sounds as being somewhat helpful to completely helpful (one user skipped the question). Six users thought they gave a pleasurable user experience and thought that the sounds intuitively represented the weather conditions. When asked "How helpful were the sounds at presenting info about the current weather status," five out of seven said they did not notice the weather sounds. It is not clear if this is because they turned the sounds off or if they fit in the context of the app so well that they were not disturbed or distracted by them. Another possibility might have been the month testing took place; if users had consistent sunny weather over the summer, they may not have observed any differences in the sounds (as they would only change when the weather conditions did). For the TTS descriptions through TalkBack, one user was completely satisfied, five were mostly satisfied, and one was not at all satisfied; looking at the free response portion afterward showed that users were either unhappy with the setting change notifications (and receiving feedback through TalkBack) or the ease of navigating to the settings menu when TalkBack was active. Only a few users completed the follow-up surveys, and without in-person observation and cognitive walkthroughs, it was hard to identify user's actual opinions on the auditory icons. A follow-up study will take place to get a more comprehensive understanding of the role that auditory weather icons can play in providing a quick overview of current conditions.

We received a large amount of feedback from the users, even though it was not always through the follow-up surveys; much of the more detailed feedback came by email or through replies to the Eyes-free Group posting. Many users liked that the pop-up notifications included the chance of rain or storms, since that is a feature that does not typically work on their other weather apps, or it is not accessible with TalkBack. Overall, the users were pleased with the weather information the app provided, but would like more control and customization abilities so they can add and remove details as they prefer.

During user evaluation and testing, we identified bugs, new features, and updates to current features. While this resulted in many additions and changes to the original design of the Accessible Weather App, we consider the initial round of evaluation and beta testing to be a success. Many of the comments we received were about features and components that the users were very happy to have. As of late September there were almost 60 users still utilizing the app. We received positive feedback about the detailed hour-by-hour weather provided without visual icons that "get stuck" with TalkBack, the option to remove graphics (allowing a high-contrast mode with better visibility to low-vision

users), and the fact that every component in the app was labeled and thus read by TalkBack. These design details significantly impacted each user's experience with the Accessible Weather App and allowed them to bypass barriers that existed within their previous weather apps.

4.0 Future Work

The initial release and beta testing of the accessible weather app provided a huge amount of feedback and comments for making apps accessible in general, besides the main goal of creating an accessible app specifically for weather information. Thorough compatibility testing with TalkBack made the user experience more fluid compared to typical app experiences. There are features and bug fixes that still need to be completed, including incorporating severe weather alerts and adding a training page in the 'Settings and Help' menu to allow users to hear the auditory weather icons in a descriptive context. This may help users learn weather icons they may not typically experience (i.e., during the summer they may not have snowy weather). Other updates include providing even more options to customize the detailed weather page: UV information, dew point, atmospheric pressure, control over precipitation types (rain, snow, etc.), and providing the forecasted high and low for the day. We want to incorporate an easier way to specify location, as the location search feature crashed in some versions of the app (perhaps due to Android version differences or differences in user's location settings for GPS and Wi-Fi).

Adding hyperlocal forecasting capabilities, especially for precipitation, is an important feature for the next version of the weather app. Forecast.io [2] has provided free access to their hyperlocal forecasting API for the duration of development and testing so we can research how to incorporate very specific information about weather conditions and precipitation. This level of detail is very important to visually impaired users as they need to plan ahead for numerous reasons, including modifying their travel plans, changing their white cane navigation methods, and bringing umbrellas, raincoats, and supplies for themselves (or for their guide animal) to accommodate the inclement weather. Finishing updates with the bug fixes and additional features are the next steps with the Android version of the Accessible Weather App, and incorporating these concepts into an iOS version is also underway. There are many iPhone users with visual impairments that we want to reach as well. Integration with VoiceOver is more comprehensive and developed than TalkBack, so many iOS users should be quick to adopt an app designed to take advantage of this. Adapting the research and design from the layout of the Android version to mesh with iOS navigation methods and VoiceOver conventions will help to inform the design of both versions.

A final step of this work is to take the app back to the schools for the blind in Kenya. As mobile technology is more widely available to these schools, teachers will be able to incorporate this app into their math and science classes. These students are already learning to use computers and technology, making the transfer between desktops (and the netbooks they utilize in multiple classes) to mobile devices such as phones and tablets not be as intimidating as it might have initially seemed. With more stable telecommunication infrastructure, adoption of these mobile devices is happening at an incredibly fast pace, and providing

universal access to information, such as real-time weather data, is both empowering and educational. As inABLE broadens their training and support to other schools for the blind, the opportunity to distribute information and access to weather related learning activities will continue to grow.

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6.0 References

1. Jenny C. Aker & Isaac M. Mbiti. 2010. Mobile phones and economic development in Africa. *Center for Global Development Working Paper*, 211.
2. DarkSky LLC: 2013. https://developer.forecast.io/ URL. Accessed: 2015- 10- 9.
3. inABLE: 2015. http://www.inable.org/ URL. Accessed: 2015- 10- 9.
4. Kenya Society for the Blind. 2014. KSB Annual Report.
5. Rajendra Kumar & Michael L. Best 2006. Impact and sustainability of e-government services in developing countries: Lessons learned from Tamil Nadu, India. *The Information Society*, *22*(1), 1-12.
6. Hee-Sun Lee & Nancy Butler Songer. 2003. Making authentic science accessible to students. *International Journal of Science Education*, 25, 8: 923-948.
7. Joel Macharia. April 2014. Internet Access is No Longer a Luxury. In the United Nations: From Africa Renewal.
8. Muyiwa Matuluko. July 23, 2014. Africa Mobile OS Market Share - Android Is Winning. http://techcabal.com/2014/07/23/africa-os-marketshare-android-winning/ URL. Accessed: 2015- 10- 9.
9. NonVisual Desktop Access: 2015. http://www.nvaccess.org/ URL. Accessed: 2015- 10- 9.
10. Cecilia Oyugi, Lynne Dunckley, & Andy Smith. 2008. Evaluation methods and cultural differences: studies across three continents. In *Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges*, 318-325.
11. Pew Research. April 2015. Cell Phones in Africa: Communication Lifeline.
12. U.S. Embassy. 2011. Doing Business in Kenya.
13. Bruce N. Walker, and Greg Kramer. 2004. Ecological psychoacoustics and auditory displays: Hearing, grouping, and meaning making. In Ecological Psychoacoustics, J. Neuhoff (Ed.), New York: Academic Press, 150-175.
14. Weather Underground: 2015. http://www.wunderground.com/about/background.asp URL. Accessed: 2015- 10- 9.
15. Enock Yonazi, Tim Kelly, Naomi Halewood, & Colin Blackman. 2012. *The Transformational Use of Information and Communication Technologies in Africa*. The World Bank, Washington, DC.