Assessment of usability and sustainability of digital braille assistive devices for learners with visual impairment in Kenya

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ABSTRACT

This research focuses on examining usability and sustainability of digital braille assistive devices towards improving inclusivity of learners with visual impairment (VI) in formal education. This study was guided by the universal design for learning and assistive technology theories. Firstly, the study examined the usability of digital braille assistive devices in improving inclusivity of learners with VI in secondary school and at university level. Secondly, sustainability of access to digital assistive technologies for use among the learners with VI was examined. The study employed a mixed methodology approach within which a descriptive survey design was adopted. The study utilized interviews and questionnaires in data collection. The study was delimited to 2 institutions in Kenya: a mainstream private University & Special School for the Blind. The study participants included 34 learners with visual impairment who were purposefully sampled from the 2 selected institutions. Four teachers and 2 technical support staff were also purposefully sampled as study participants. Quantitative and qualitative data analysis techniques were adopted. The findings show that the usability of digital braille assistive devices for visually impaired learners is vital in increasing inclusivity of learners, promoting learner's independence and enhancing learning opportunities. The study underscores the importance of increasing device usability to improve device performance and foster user independence. The study recommendations highlight the need for schools to establish robust support systems for the users of assistive technologies in order to enhance sustainability, including dedicated technicians for adequate training for both students and educators, and regular device maintenance.

Keywords: Digital Assistive Technologies, Device Usability, Inclusive Education, Sustainable Access, Visual Impairment

1. INTRODUCTION

Use of assistive digital devices can support learners with visual impairment (VI) improve access to quality education thus enable them to become independent and live normal lives as adults (Arslantas & Gul, 2022). The term learner with visual impairment (VI) as used in this study refers to both those who are blind and those with low vision, who mainly rely on assistive devices (manual or digital) for their studies and information access (Le Fanu et al., 2022). While there are various studies focusing on usability of digital assistive devices for the visually impaired exists, there are limited studies that have holistically explored usability of fast evolving digital braille assistive technologies especially regarding how usability relates to realizing the targeted benefits including inclusivity of learners with VI in formal education settings. The current study therefore seeks to assess the usability of digital assistive devices for learners with visual impairment (VI).

Globally, the numbers of people with visual impairment (VI) have continued to increase mainly due to increase in population and conditions of hygiene, poverty and ignorance (World Health Organization [WHO], 2021). In Kenya, the prevalence of VI among children is estimated to be 2.4% (Fricke et al., 2018; Muma & Obonyo 2020). The Kenyan Government and other stakeholders in education are increasingly focusing on the needs of the learners with VI as a strategy to promote access and inclusivity in education for all (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2020). Lack of adequate focus on usability of digital assistive devices and strategies for adequate resourcing, continue to undermine inclusivity of learners with VI in developing nations. To enhance access and sustainable availability of assistive devices for the learners with VI, various organizations have introduced digital braille assistive devices: - for instance Kilimanjaro Blind Trust Africa (KBTA) introduced the Orbit Reader 20, in mid-2018. Their aim was to positively impact the lives of the VI learners who are mostly marginalized due to poverty (KBTA, 2023).

As digital braille assistive devices continue to evolve, the learners with VI can interact seamlessly with their teachers and other learners including the sighted using the emerging digital braille that are mobile enabled (Kamaghe,

2021). Use of digital braille devices is instrumental in increasing access to educational resources due to its interoperability with computers and mobile phones. These elements increase access and inclusivity, development of digital skills and competence among learners with VI which are core to quality education (Kasiram & Subrayen, 2014; United Nations, 2015). Use of digital braille devices is therefore instrumental in increasing access to educational resources. However, the usability of these assistive devices determines to what extent they are used productively to enhance access and inclusivity in education (Kasiram & Subrayen, 2014; United Nations, 2015). Usability has not been holistically researched in previous studies particularly because it has not been adequately linked to the concept of sustainability which is very important in promoting inclusive education for the learners with VI. Therefore, the current study focused on examining the usability of digital braille assistive devices in improving inclusivity of learners with VI in secondary schools and at university level.

1.1 Research Objectives

i. To examine the usability of digital braille assistive devices in improving inclusivity of learners with VI in secondary schools and University level
ii. To examine sustainability of access to digital braille assistive devices for the learners with VI in secondary schools and University level

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Universal Design for Learning and Assistive Technology Theory

This study is founded on the theoretical perspectives advanced by Rose (2001) and Rose et al. (2005) for developing an inclusive learning environment for the visually impaired. This study specifically focuses on assessing the usability of digital assistive technologies for the learners with VI in relation to the use of assistive digital devices in enabling of inclusive learning environments for the learners with visual impairment (the Blind and partial visual impairment) that enable them to reach their full potential in school and beyond.

The concept oof assistive device usability aligns with the Universal Design for Learning (UDL) theoretical perspectives and the assistive technology theory which are attributed to the works of Rose, Meyer, and colleagues at the Center for Applied Special Technology (CAST) in 1997 (Rose, 2001). Rose suggested that the basis of UDL is grounded in emerging insights about brain development, learning, and digital media. The fundamental perspective is that the disconnect between an increasingly diverse student population and a “one-size-fits-all” curriculum limits academic achievement gains that are being sought in relevance to education for all. This idea was advanced later by Rose and Colleagues by focusing on the intersection between UDL and assistive digital technologies towards providing an inclusive learning environment for learners with special needs including the learners with VI (Rose 2001; Rose et al., 2005). The UDL concept offers the basis for understanding diversity and applying technology to facilitate learning diverse learners and at the same time on a continuum emphasize the complementary role of assistive digital technologies enable room for differentiated learning environment based on specific special needs for an individual learner, for instance, the learner with Visual impairment.

Universal design is a process for designing devices/ products that can be used by anyone in such a way as to reduce barriers for any individual (either with or without disabilities) with the aim to increase opportunities for the widest possible range of users. To fit the general use, universal designs are therefore engineered for flexibility, and designed to anticipate the need for alternatives, options, and adaptations (Rose et al., 2005). This implies that UDL are variable rather than dedicated; they are universal and inclusive to accommodate diversity. Correspondingly, assistive technology is digital technology that increases, improves, or maintains the functional capabilities of students with disabilities such as visual impairment. Usually, assistive technology is specifically designed to assist individuals with disabilities in overcoming barriers in their environment and in increasing their opportunities for independence (Rose et al., 2005). This means it can be specifically tailored and uniquely adapted or dedicated to the specific strengths and weaknesses of each person based on their individual limitations.

2.2 Empirical Review

Many developing Nations are increasingly reformulating their policies and strategies to promote the inclusion of students with disabilities into mainstream schooling. This has brought to focus the concept of inclusive education which implies that the students with disabilities join the regular classroom settings to learn together with other fully abled learners. Proponents of inclusive education also acknowledge that when necessary and justifiable, learners with disabilities can be facilitated with some specialized instructional support including use of assistive devices (Jagota, 2018; Matraf et al., 2023).

It is important to note that the similarity between assistive devices for people living with disabilities and the conventional digital technologies relates to the key activities of input, processing and output (Jagota, 2018; Matraf et al., 2023). In achieving these activities, the people living with disabilities usually select a combination of conventional and assistive technologies based on their needs. In particular, the access features in the device influence their choices. While the distinction between assistive and conventional technologies continues to narrow because of the emerging concept of universal design, the needs of the VI remain unique and they require purposeful focus especially on usability. Today, as the demand from the assistive technology users is increasing for universal access, manufacturers have been responding accordingly to offer devices with easy accessibility features. In the pursuit of universal designs, it is apparent that that what is a necessity for some may be a convenience for all (Al-Razgan et al., 2021; Jagota, 2018). For example, voice recognition systems which offer controlling a digital device through verbal commands can be used by people who cannot use a keyboard to provide input.

Interacting with the emerging digital assistive devices can often be challenging for the VI learners due to the poor usability of some mobile applications (Al-Razgan et al., 2021). One of the key objectives of this study is to evaluate the usability of the modern digital assistive devices for the VI such as Orbit Reader 20, a Digital Braille Assistive Device. This is from the perspective of how ease of use for these devices can support inclusive education for VI learners, thus promoting access to quality education for all. The following sub-sections review the key technological features in such devices and criteria that can be applied to evaluate usability of assistive devices for the VI. The key capabilities that relate to usability in the context of assistive devices for the VI include navigation, accessibility, audio guidance, and gestures (Al-Razgan et al., 2021). Table 1 shows an example of a criteria that can help to assess the usability of assistive technology devices.

Table 1

Criteria to Evaluate Usability of Assistive Devices for the Visual Impaired

Effectiveness	How much the device improves the user's living situation and enhances functional capability and independence
Reliability	The degree to which a device is dependable, consistent and predictable in its performance and levels of accuracy for a reasonable amount of time
Portability	The device's size and weight on the user's ability to move, carry, relocate and operate it in varied locations.
Learnability	The device's ease of assembly, initial learning requirements and time & effort to master use.
Comfort & Acceptance	The extent to which a user feels physically comfortable with the device and doesn't experience pain or discomfort with use; how aesthetically appealing the user finds the device and the user's psychological comfort when using it in private or public.
Operability	The extent to which the device is easy to use, is adaptable and flexible, and affords easy access to controls and displays

Adapted from Matraf et al. (2023)

III. METHODOLOGY

3.1 Research Design

This study adopted a mixed methodology approach within which a descriptive survey design was employed. The mixed-method approach has been previously recognized by various researchers (Hakkarainen, 2009; Pole, 2007). Quantitative data was specifically used to measure the usability of the digital assistive device in relation to meeting the goal of enhanced inclusivity of learners with VI while qualitative data was used to explain the process and products of the intervention and the reasons that led to the observed outcomes. Thus, qualitative techniques were used to provide an opportunity for an in-depth understanding of how the usability of assistive devices influence educational benefits for learners with VI.

3.2 Scope of the Study, Target Population and Sampling Design

This research was conducted as a pilot study that was delimited within 2 purposefully selected institutions in Kenya. The targeted population for this study were the institutions that were using digital assistive devices. The two institutions that were selected in this pilot study are: 1 special secondary school and 1 mainstream private University.

The participants were sampled purposefully from the population of special needs students in the 2 selected institutions as outlined in Table 2. The study participants' categories included: Learners with visual impairments who had previous access to digital braille devices, selected teachers, and technical support staff. The targeted students' population were learners with visual impairment who were either blind or with low vision and they mainly relied on assistive devices (manual or digital) for their studies and information access. The sampled students were the learners with VI who had previous experience in use of Manual Braille devices and access to digital assistive devices and had

used a digital assistive device for at least one year. It is important to note the sampled students had access to digital assistive devices (commonly Orbit Reader 20) for one year prior to the start of this study. Therefore, the sampled students had common characteristics in relation to use of a common digital assistive device and they mainly relied on assistive devices for their studies and information access. They were all above the age of 18 years and therefore they were able to express their views/ experiences independently.

Table 2

Target Population and Sample Size

No.	Name of Institution	Category	County	Target Population (Learners)	Sample Size Learners	Sample (Teachers and Technicians)
1	S.A. Thika High School	Special	Kiambu	430	19	3 teachers and 1 technician
2	Mount Kenya University	Integrated	Kiambu	20	15	One Lecturer and 1 technician

3.3 Data Collection and Analysis

At the outset of the study, the Researchers sought clearance from relevant authorities in adherence to research ethical issues. Identification of relevant participants for piloting the research instruments was conducted prior to actual data collection to test for validity and reliability. The adopted descriptive survey design provides an opportunity to utilize both qualitative and quantitative data collection techniques to gather evidence from variety of sources, which facilitated triangulation of data for purposes of corroborating the evidence obtained. Survey questionnaire and semi structured interviews were utilized as the data collection instruments.

The data analysis technique was guided by the research design which entailed integrating quantitative and qualitative data analysis techniques to comprehensively assess usability of digital assistive devices. For quantitative data, descriptive statistical analysis using SPSS version 26 was utilized. Qualitative data were analyzed through thematic analysis, a flexible method for identifying, analyzing, and reporting patterns within the collected interview and observational data.

The triangulation of findings entailed combining quantitative statistical results with qualitative thematic analyzed findings. This approach enhanced the depth and validity of the study's findings. Triangulation allows for a more nuanced understanding by comparing and cross-validating data from different sources and methods.

3.4 Ethical Considerations

The researchers addressed the ethical issues that relate to matters of access, informed consent, confidentiality and anonymity of the participants. Special consideration was taken when dealing with minors as majority of the study participants are learners who are vulnerable due to their special needs.

IV. FINDINGS & DISCUSSION

4.1 Response Rate

4.1.1 Overview of the respondents

The interview participants were six in number. These were considered as key informants and they included a male university technician (KI01), a male high school technician (KI02), a male university lecturer (KI03), a male high school teacher (KI04), and two female high school teachers (KI05 and KI06). All the key informants were above the age of 30 years old and had had prior training in the use of Digital Assistive devices.

Learners with VI were also key participants in this study. Thirty-four students responded to the open-ended questions; notably the university students offered more elaborate narrative responses about their perceptions and experiences with assistive digital devices. Out of the 15 University learners, 5 of them answered open-ended questions (anonymously coded as KI07, KI08, KI09, KI10, KI11. KI07); they indicated that they had used Orbit Reader 20 and they also preferred other digital devices. The secondary school students also expressed their perceptions and experiences in the open-ended questionnaire responses. They cited exposure to various assistive digital devices including Dot Min, Focus, Orbit Reader 20.

4.1.2 Usability of Digital Assistive Devices

The third objective of the study was to assess the ease of use of the assistive device across all age groups and school levels. The questionnaire respondents were asked to rate their level of agreement on ease of use (Usability) of the assistive device across all age groups and school levels on a scale. The item consisted of 22 statements measured on

a scale 1= Strongly Disagree, 2= Disagree, 3=Undecided, 4= Agree, 5 =Strongly Agree. The findings were presented in Table 3.

Table 3

Usability of Digital Assistive Devices

Statement	N	Min	Max	Mean	StDev
Digital Assistive Devices for the VI features are easily accessible	34	1.00	5.00	2.7941	1.06684
Digital Assistive Device for the VI offers useful queues that are useful when using the device	34	3.00	5.00	3.9412	.34300
Digital Assistive Device for the VI supports Independent Text Reading	34	2.00	5.00	4.2647	1.05339
Provision of clear, sound feedback for all actions/interactions	34	1.00	5.00	2.2059	1.59125
Users can stop feedback	34	4.00	5.00	4.1765	.38695
Users can navigate the Digital Assistive Device for the VI randomly (i.e., by using forward and backward or navigation bar)	34	4.00	5.00	4.8824	.32703
The size and weight of the device makes it portable	34	4.00	5.00	4.9412	.23883
Digital Assistive Device for the VI has easily usable audio guidance	34	1.00	5.00	2.0000	1.41421
Digital Assistive Device for the VI offers useful Queues that are helpful when using the device	34	1.00	5.00	2.0588	1.39134
Digital Assistive Device for the VI has screen magnification features- Text enlargement/ Zooming	34	1.00	5.00	2.2941	1.71499
Digital Assistive Device for the VI has a descriptive video services feature/Provides meaningful alternative descriptions to interface elements and images	34	1.00	5.00	2.2353	1.61543
Digital Assistive Device for the VI has text-to-speech feature	34	1.00	5.00	2.3235	1.78751
Users can select various attributes of text and background (i.e., size, color, font type, line spacing, etc.)	34	1.00	5.00	2.2941	1.80117
Digital Assistive Device for the VI is easy to navigate	34	1.00	5.00	4.5294	1.07971
Users can navigate the Digital Assistive Device randomly (i.e., by using forward and backward or navigation bar)	34	1.00	5.00	2.0882	1.46407
Digital Assistive Device for the VI supports Independent Text Reading	34	1.00	5.00	2.1765	1.58536
Digital Assistive Device for the VI has Braille note-takers which translates the Braille into standard text	34	1.00	5.00	2.0000	1.51757
Digital Assistive Device for the VI has Braille Scanning Software	34	1.00	5.00	2.0588	1.53625
Easily adjustable brightness/contrast/color controls	34	1.00	4.00	1.3824	.77907
Users can adjust the setting of OR 20 his preferences (voice, volume, speed)	34	1.00	4.00	2.7647	1.43672
User can store and organize their content/reading materials	34	3.00	5.00	4.5000	.74874
Users can search the device contents with ease	34	3.00	5.00	4.1765	.45863

Table 3 shows the usability of digital assistive devices, evaluated across several key features and with varying degrees of user satisfaction. One notable feature, the accessibility of the Digital Assistive Device for visually impaired users, received a mean score of 2.79, with responses ranging from 1 to 5 and a standard deviation of 1.07. This indicates that while some users found the features accessible, most respondents had mixed or less favorable experiences.

The mean score for the device offering useful queues was 3.94, with a very narrow standard deviation of 0.34, signaling that most users agreed the device was effective in providing helpful cues during use. Regarding supporting independent text reading, the device garnered a high mean score of 4.26 (with a standard deviation of 1.05), suggesting intense user satisfaction in this area, as it facilitated independent learning for visually impaired users.

However, the feature of providing clear, sound feedback for actions or interactions received a mean score of 2.21, with a relatively high standard deviation of 1.59, which points to dissatisfaction or uncertainty regarding the usefulness of the sound feedback. Similarly, while users agreed that they could stop feedback (mean score of 4.18, standard deviation of 0.39), the sound-related features of the device appeared to need further refinement for greater effectiveness.

The ease of navigation on the Digital Assistive Device was highly rated, with the mean score for random navigation being 4.88 and a very low standard deviation of 0.33, indicating strong consensus among users regarding the ease with which they could move through the device. Additionally, the size and portability of the device were highly appreciated, receiving a near-perfect score of 4.94, with minimal variation in responses, highlighting that the users found the device to be very convenient for transport and use.

On the other hand, the effectiveness of the audio guidance, screen magnification, and zooming features was less favorable, with mean scores of 2.00, 2.29, and 2.32, respectively. These features pose challenges for users, as reflected in the low scores and high standard deviations, which suggest that many users found these aspects either inadequate or

difficult to use. Additionally, the device's Braille note-taking and scanning software features were rated poorly, with both receiving a mean score of 2.00, indicating dissatisfaction with these functions.

Regarding user preferences and customization, the adjustable settings for brightness, contrast, and color controls received a mean score of 1.38, showing that users were mainly dissatisfied with these options. Furthermore, the ability to adjust device settings such as voice, volume, and speed had a mean score of 2.76, which indicates that some users found these settings helpful, but the overall response was mixed.

Regarding content organization, users rated the ability to store and organize reading materials highly, with a mean score of 4.50 and a relatively small standard deviation of 0.75, signifying that most users found this feature beneficial. Similarly, the device's search functionality was also positively received, with a mean score of 4.18 and a low standard deviation of 0.46, indicating that users found it easy to search through their device's contents.

Overall, the results highlight a mix of strengths and weaknesses in the usability of the Digital Assistive Devices. While certain features like random navigation, portability, and independent text reading were highly appreciated, others, particularly related to sound feedback, audio guidance, and specific customization options, indicated areas for improvement.

Related to the qualitative findings, the key informants pointed out the extent to which the digital devices being used by learners in their schools are easy to use (Learnability). KI01 pointed out that the device is easy to use if the student has basic ICT/ computer skills; KI05 posited that the device is learner friendly, assisting the learners to interact with others and build self-confidence. KI02 noted that the device is NOT easy to use if the student has no basic ICT/ computer skills. For KI04, the students can carry notes, portability of the devices and easy to use were the learnability aspects but also noted that the devices are expensive.

Regarding how the respondents would rate the Reliability of assistive devices being used by learners in your school, one teacher posited:

> *"The devices have both positive and negative impacts thus reliability is half and half. See the positive and negative aspects of the devices noted in the questions. For instance, they are reliable because they are portable, and it can carry all the notes in one SD Card" (KI04).*

KI02 indicated that the devices are effective; but this will only happen when they are enough devices while KI01 indicated that they are effective; they improve access to content, interactivity and enhance self-dependency.

On whether the assistive devices being used by learners in schools offer sufficient Comfort to the users, KI01 noted that they offer comfort especially because they're not bulky, enhances and they are flexible /dynamic features. KI05 and KI06 indicated that the devices offer comfort and are not bulky; KI02 opined that they offer comfort especially because they're not bulky and they are flexible /dynamic features. One the same aspect, KI04 observed that the devices were 50% effective.

The study reveals a nuanced landscape of digital assistive device usability for visually impaired learners, characterized by notable strengths and significant areas for improvement. The most striking positive features include exceptional portability (mean 4.94), ease of random navigation (mean 4.88), and support for independent text reading (mean 4.26), which align with critical user needs in assistive technology (Matraf et al., 2023).

The device's content management capabilities, particularly storage and search functionality (means of 4.50 and 4.18 respectively), demonstrate significant potential for enhancing learning experiences. These findings resonate with existing literature emphasizing the importance of adaptive technological solutions for visually impaired learners (Chambers, 2020).

However, the study uncovers substantial challenges in auxiliary features. Audio-related functionalities, including guidance, sound feedback, and screen magnification, received notably low ratings (mean between 2.00-2.32). Customization options for brightness, contrast, and device settings were particularly problematic, suggesting a critical need for more user-centered design approaches.

The quantitative results on accessibility rating of 2.79 indicates mixed user experiences, highlighting the complex nature of designing truly inclusive technological solutions. This finding underscores the need for ongoing research and iterative design processes that prioritize user experience and individual variations in technological interaction.

About the level of acceptability of assistive devices being used by learners in schools, the key informants, on average rated it 50%. KI04 gave some positive reasons including "Shifting from braille to the digital braille is easy as they have similar functional keys. The negative reasons included:

> *"Training was not sufficient, cumbersome to operate, with large classes, swapping memory cards that stored classroom notes during exams can be quite cumbersome, and keeping them untouched may result in the potential for exam malpractices. Other were technical challenges in technical subjects, storage of many memory cards but have no names but have notes, transcribing for technical subjects is very difficult, and when the device breaks down, it has to be taken to the supplier, a lengthy process before the device is repaired and brought back to the learners" (KI04).*

KI04 went ahead and emphasized the extent to which the digital devices being used by learners in their school life need to be adaptable and flexible. Unlike traditional Braille, digital devices enable users to seamlessly transfer and access content from multiple sources, including the internet, across different devices. This technological evolution transforms how visually impaired individuals interact with written information, offering unprecedented convenience, mobility, and content accessibility that transcends the limitations of traditional Braille communication systems.

4.1.3 Sustainability and Scalability of the Digital Braille Assistive Device

The last study objective was to assess the sustainability and scalability of the orbit reader 20 device for Kenya. The questionnaire respondents were asked to describe the sustainability and scalability of the Digital Braille Assistive Device on a rating 1= Strongly Disagree, 2= Disagree, 3=Undecided, 4= Agree, 5 =Strongly Agree. The findings were presented in Table 4.

Table 4

Sustainability and Scalability of the Digital Braille Assistive Device

Statement	N	Min	Max	Mean	StDev
The orbit readers can sustain a charge for a long time	34	3.00	5.00	4.0000	.34816
The orbit reader works all the time	34	1.00	5.00	4.1765	1.16698
I take my device to the teacher in charge for repair many times	34	2.00	5.00	2.9706	1.24280
It takes long for my device to be repaired	34	1.00	5.00	2.4118	1.76012
How easily available is the technician to repair the device	34	1.00	5.00	2.4412	1.72664
To what extent is the device affordable	34	1.00	5.00	2.3824	1.59573
To what extent is the device durable	34	2.00	5.00	2.5294	.70648

Table 4 reveals the sustainability and scalability of the Digital Braille Assistive Device, which were assessed across several vital factors. Regarding the device's ability to sustain a charge for long periods, the mean score was 4.00 with a very low standard deviation of 0.35, suggesting that users generally found the device capable of maintaining a charge for a sufficient time. This indicates strong satisfaction with the device's battery life.

However, when evaluating whether the Orbit reader works consistently, the mean score was 4.18, accompanied by a higher standard deviation of 1.17, which implies some variability in the users' experiences, with some expressing concerns about its reliability. This contrasts with the satisfaction with the device's charge sustainability. The frequency of device repairs was a notable issue. The mean score for the frequency at which users took their devices to the teacher for repairs was 2.97, suggesting that users were somewhat dissatisfied with the need for frequent repairs. However, the standard deviation 1.24 indicates a response spread, with some users not experiencing frequent repairs. When considering the repair time, the mean score was 2.41, indicating that users generally found the repair process to be slow. The significant standard deviation of 1.76 reflected a wide range of experiences with repair duration. Similarly, the availability of technicians to repair the devices could have been rated better, with a mean score of 2.44 and a standard deviation of 1.73, pointing to challenges in accessing repair services promptly.

Another concern was the device's affordability, as reflected by a mean score of 2.38, indicating that most users felt the device was not affordable. The high standard deviation of 1.60 also suggests that affordability perceptions varied widely among respondents. Furthermore, the device's durability was rated similarly, with a mean score of 2.53 and a lower standard deviation of 0.71, showing some level of concern about the device's long-term reliability and barrier to widespread adoption of assistive technologies for visually impaired learners.

While the Digital Braille Assistive Device scored well in areas like charge sustainability and consistent functioning, there were notable concerns about its affordability, durability, and ease of accessing repair services, which could hinder its broader scalability and long-term sustainability.

The analysis reveals a complex landscape of sustainability and scalability for the Digital Braille Assistive Device, characterized by significant strengths and notable challenges. The device's most positive attribute is its battery performance, with a mean score of 4.00 and minimal variation, indicating reliable power sustainability.

Despite strong charge capabilities, the device's operational consistency shows variability (mean 4.18, SD 1.17), suggesting inconsistent reliability that could potentially undermine user confidence. The repair-related metrics emerge as critical pain points, with concerning implications for long-term device utility. This variability indicates that, despite its potential, the device's performance may not be reliable enough for users to fully depend on it and this leads to user frustration which also affects their confidence.

The repair frequency (mean 2.97) and repair time (mean 2.41) highlight significant infrastructural challenges in maintaining these assistive technologies. The low scores are compounded by limited technician availability (mean 2.44), indicating systemic support deficiencies that could substantially impede device adoption and sustained use. The finding

reveals significant infrastructural challenges in maintaining assistive technologies, with high repair frequency compounded by limited technician availability.

In relation to the quantitative findings, the key informants had varied views about the sustainability and scalability of the digital braille assistive device for Kenya. According to KI01, digital braille assistive devices are sustainable in the long term if they are properly used and purposed strategies on device safety. On the other hand, KI02 noted that the devices are sustainable to some extent because they are fragile, and yes, if they are proper and purposed strategies on device safety- they need proper handling.

Further, regarding the factors contributing to the sustainability of the digital braille assistive device, KI02 and KI01 synonymously noted that training policy, software upgrades availability and other support software/device like screen readers' speech to text software were so critical. KI01 pointed out that repairs are not immediate in terms of access because they must be outsourced for the device vendor/ provider. KI02 pointed out that the devices are not durable, especially with multiple users- unless they are very well maintained. They need proper handling and maintenance as they are fragile. KI04 commented on the availability of spare parts for Orbit readers as very rare - schools find it difficult to find them. The same interviewee noted that there are limited spare parts and repairing is difficult. In cases of malfunctioning devices, the printing will be illegible, and very often, the repair and maintenance is by the Service Provider thus causing delay.

On recommendations for sustainability of the orbit reader, KI05 opined that "The management should be made aware about device functionality. Moreover, there should be more gadgets to take care of the learners needs when there are breakages/ or when they are undergoing repairs/maintenance". On the same theme (recommendation for sustainability), KI04 noted;

Using laptops curated for the visually impaired students instead of the orbit reader would prove to be more sustainable. To be used alongside the braille machine, Training to be carried out on all the stakeholders, teachers, students and assessors (KI04).

KI04 was further asked whether the device can improve access to education for visually impaired students. He answered 'Yes' and explained how the scalability of the Orbit Reader device can be enhanced in Kenya by addressing all the challenges highlighted, including providing more gadgets and training the learners and the teachers.

Another key informant went ahead and provided recommendations for inclusion and enhanced learning for VI by using laptops because they are easily compatible with other assistive gadgets. KI05 and KI06 responses also indicated that the device could improve access to education for visually impaired students by enhancing access to educational opportunities. They added that the device "also enhances self-esteem and increases opportunities to enhance performance". They also advised that the scalability of the Orbit Reader device can be enhanced in Kenya through "organizing workshops to increase awareness and capacity building on device maintenance". As the findings illustrate this far, the sustainability and scalability of the digital braille assistive device face both opportunities and challenges.

4.2 Discussion

The usability of digital assistive devices for visually impaired learners reveals both strengths and weaknesses. This underscores the need to consider muti-faced features of inclusion and usability including adaptable device design to fit diverse learners' needs and ensuring sustained support systems (Le Fanu et al., 2022; Scottish Government**,** 2019**)**. Positive features include high ratings for portability (mean 4.94), ease of random navigation (mean 4.88), and independent text reading (mean 4.26), aligning with user needs for mobility and autonomy. Additionally, content management features like storage and search functionality received favorable scores. However, significant challenges exist with audio-related features, such as sound feedback and screen magnification, which received low ratings (mean 2.00-2.32). This confirms that interacting with the emerging digital assistive devices can often be challenging for the VI learners due to the poor usability of some mobile applications (Al-Razgan et al., 2021). Customization options for brightness and contrast also showed dissatisfaction. Key informants noted the devices' effectiveness in promoting independence but pointed to issues such as inadequate training, technical difficulties, and repair delays, highlighting the need for more user-centered designs and ongoing improvements in these devices' functionality and support systems. Impact of device maintenance has been underscored as an important aspect in promoting usability and sustainability (Oldfrey et al., 2021; Oldfrey et al., 2024).

The key capabilities that relate to usability in the context of assistive devices for the VI include navigation, accessibility, audio guidance, and gestures (Al-Razgan et al., 2021). The study reveals that the most likely outcome of the proposed solutions is attaining independent learning (Mahmoudi-Dehaki et al., 2025), with the current findings revealing a mean score of 4.76. This indicates strong confidence in the solutions' ability to lead to learners achieving independence in their learning. This finding concurs with the literature adults (Alnajashi et al., 2023; Arslantas & Gul, 2022). The Orbit Reader was also highly likely to enhance users' experiences, with a mean score of 4.74. Enhanced learning and exposure to more opportunities including social interactions were seen as quite likely, but perceptions of its likelihood were more variable. The results suggest that the proposed solutions are expected to be effective in

promoting assistive device usability for independent learning and providing positive user experience, but there is less certainty about their impact on social interactions and career development, indicating areas for potential improvement. Existing literature on the relevance of user confidence in technology aligns the current findings, as inconsistency in performance can lead to reduced trust and user dissatisfaction (Chambers, 2020). Additionally, the focus on repair-related issues aligns with research that emphasizes the importance of durability and ease of maintenance in ensuring long-term product utility (Chambers, 2020; Shoaib et al., 2023). When devices require frequent repairs, users may experience frustration, which can influence the perceived value and affect adoption rates (Dos Santos et al., 2022). Addressing these operational inconsistencies and improving repair metrics is crucial to enhancing both user confidence and the device's overall utility.

In relation to enhancing the usability of assistive devices, some participants interestingly suggested transitioning to laptops specifically curated for visually impaired students, arguing they offer greater compatibility, affordability, and easier maintenance. The laptops are perceived as more scalable, with readily available spare parts and free assistive software. The core objectives remain consistent: enhancing educational access, improving self-esteem, and creating performance opportunities for visually impaired students. Recommendations emphasize not just technological solutions, but holistic approaches including capacity building, awareness workshops, and comprehensive training programs. The findings underscore the importance of adaptive technologies that truly meet the specific needs of visually impaired learners, prioritizing accessibility, usability, and comprehensive support systems.

The sustainability and scalability of the digital braille assistive device is dependent on both strengths and challenges such as battery life, repair frequency, durability and affordability issues which emerged as significant barriers, with users finding the device costly and fragile, hindering long-term adoption (Mahmoudi-Dehaki et al., 2025; Shoaib et al., 2023). The finding reveals significant infrastructural challenges in maintaining assistive technologies, with high repair frequency compounded by limited technician availability. Existing literature supports this, indicating that maintenance issues and limited technical support can severely hinder the adoption and long-term use of assistive devices (Oldfrey, et al., 2024; Takshara & Bhuvaneswari, 2025). Inadequate support systems can lead to user frustration and reduced device reliability, which, according to Takshara & Bhuvaneswari (2025) impacts overall technology acceptance. Addressing these challenges is essential to improving the effectiveness and sustainability of assistive technologies.

The findings indicate that affordability and durability are significant barriers to the widespread adoption of assistive technologies for visually impaired learners. This implies that high costs and limited durability are key obstacles in ensuring equitable access to such technologies (Gathu, 2024, Takshara & Bhuvaneswari, 2025). Economic constraints often prevent visually impaired individuals from acquiring necessary devices, and poor durability may discourage long-term use (Oldfrey, et al., 2024). Addressing these barriers through cost-effective, robust solutions is essential to promoting inclusive education and ensuring sustainable technology use.

The key informants also highlighted the need for proper handling, training, and maintenance, with some suggesting special laptops for visually impaired students as a more sustainable alternative. They recommended improving repair access, raising management awareness, and increasing device availability for broader scalability. Despite these concerns, the device’s portability, functionality, and potential for enhancing educational access were seen as valuable, particularly if improvements are made in support systems and device durability. Policy directions by the Ministry of Education in relation to communication and coordination are among the key requirements for successful and sustainable use of digital assistive devices (Alananbeh & Asha, 2023).

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The findings underscore the critical importance of a holistic approach to assistive technology design towards promoting disable usability. Holistic approaches emphasize the need to also focus on sustainability and scalability elements in relation to the use of assistive technology. This is consistent with the literature that underscores the muti-faced features of inclusion and usability including adaptation of device design to fit diverse learners’ needs and ensuring sustained support systems.

5.2 Recommendations

The study recommends improving repair access, raising management awareness, and increasing device availability for broader usability and scalability. Despite these concerns, the device’s portability, functionality, and potential for enhancing educational access were seen as valuable, particularly if improvements are made in support systems and device durability.

Moreover, in order to address issues of sustainability and scalability, the schools and educational other stakeholders should explore alternative assistive devices, such as laptops specially designed for visually impaired learners. Laptops could offer greater flexibility, compatibility, and ease of maintenance, while providing a more cost-

effective and scalable solution. This approach would also enable better access to online resources and educational materials, ensuring that visually impaired learners can fully engage with the curriculum. For sustainable use and adequacy of digital assistive technology, it is important for the key stakeholders to consider a robust funding model. Policy directions by the Ministry of Education as the key stakeholders are also important for successful and sustainable use of digital assistive devices.

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