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Assistive Technology Tools for Visually Challenged Students in Kenyan Public Universities: Availability, Usability, And the Path Toward Digital Equity

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Abstract- ***Specialized ICT hardware and software tools form the technological infrastructure upon which visually challenged students (VCS) depend for academic participation. This paper examines the availability, usability, and institutional deployment of such tools in two Kenyan public universities, drawing on empirical data collected through multi-informant interviews, structured questionnaires, and systematic observation at Kenyatta University and Maseno University. Adopting a human-computer interaction (HCI) lens informed by Donald Norman's principles of good design and Shneiderman and Plaisant's Golden Rules of Interface Design, the study evaluates the functional alignment between available tools, including screen readers, refreshable Braille displays, OCR systems, talking books, modified keyboards, and adaptive computers and the specific cognitive and interaction demands of non-visual academic computing. A comparative analysis reveals significant inter-institutional disparities in tool availability, a systemic disconnect between institutional tool inventories and day-to-day usability, and a critical gap in staff competence to support assistive technology deployment. The paper proposes a tool-needs matrix linking specific academic tasks to appropriate assistive technologies, and advances recommendations for a Kenya-wide assistive technology procurement consortium to address the structural cost barriers that perpetuate digital exclusion.***

Keywords: Assistive Technology Tools, Braille display, Screen Reader, HCI, Disability, Kenya, Inclusive Education, Adaptive Computing

I. INTRODUCTION

In the philosophy of universal design, a well-designed system functions optimally for the broadest possible range of users without adaptation or specialized modification. In practice, however, the computing environments that pervade contemporary universities have been architected around the modalities of sighted, able-bodied users, producing systems that are functional for the majority yet structurally exclusionary for those with visual challenges. The remediation of this exclusion requires specialized tools, -hardware and software assemblages that translate visual information into auditory or tactile modalities accessible to VCS.

The availability of such tools within educational institutions is not, however, a sufficient condition for digital inclusion. Tools must be functionally accessible, -available at the time and place of need, maintained in operational condition, accompanied by adequate user training, and compatible with the specific digital environments encountered in academic work. When these conditions are unmet, nominal tool availability translates into de facto inaccessibility, a distinction that has profound implications for how institutional provision is assessed and improved.

This paper addresses the second objective of the foundational research programme: to establish the specialized ICT tools available for use by visually challenged students in Kenyan public universities, and to evaluate their functional adequacy from an HCI perspective. The paper makes three principal contributions: (1) a comprehensive taxonomy of assistive technology tools relevant to university-level VCS; (2) an empirical assessment of tool availability and usability at Kenyatta and Maseno Universities; and (3) a tool-needs matrix linking academic task categories to appropriate assistive technology solutions.

1.1 Significance

The practical significance of this research extends beyond the two study institutions. As Kenya's public university system continues to expand admissions, driven by the transition to 100% primary-to-secondary school progression and increasing demand for higher education — the VCS population in universities will

grow. Without proactive, evidence-based investment in assistive technology infrastructure, this growth will intensify existing inequities. The tool-needs matrix and procurement recommendations developed in this paper provide university management, the Commission for University Education, and the Kenya Institute of Special Education with a concrete, actionable framework for inclusive technology planning.

II. CONCEPTUAL FRAMEWORK: TOOLS AND HUMAN-COMPUTER INTERACTION

2.1 Norman's Principles Applied to Assistive Technology

Donald Norman's (1988) principles of good design — visibility, feedback, good mappings, and constraints — provide a powerful diagnostic framework for evaluating the design quality of assistive technology tools. For VCS, the visibility principle takes on a counterintuitive dimension: the most important information must be rendered audible or tactile rather than visual. Screen readers that provide ambiguous or incomplete verbal descriptions of interface elements fail the visibility test as surely as a poorly labelled button fails it for sighted users.

Feedback - he continuous, timely confirmation of user actions is equally critical. A screen reader that fails to confirm keystrokes, a refreshable Braille display that does not indicate cursor position, or a talking book device that provides no indication of chapter location all violate the feedback principle in ways that are particularly disorienting for users who cannot supplement inadequate feedback with visual scanning. The good mappings principle, -the correspondence between controls and their effects demands that assistive tools provide control metaphors legible to non-visual cognition, a requirement that challenges designers accustomed to graphical representations of function.

2.2 Schneiderman’s Golden Rules in Non-Visual Context

Schneiderman and Plaisant's (2004) Golden Rules of Interface Design include consistency, universal usability, informative feedback, and reduction of short-term memory load. For VCS, the memory load criterion is of particular significance. Non-visual navigation of complex software environments imposes substantially higher working memory demands than visual navigation, because users cannot simultaneously survey the interface landscape and attend to specific content. Assistive tools that minimize the need to retain navigational state information — through well-designed keyboard shortcuts, consistent landmark structures, and predictable information architectures — directly reduce cognitive load and improve effective usability.

III. TAXONOMY OF ASSISTIVE TECHNOLOGY TOOLS

Based on literature synthesis and field findings, eight categories of assistive technology tools relevant to university-level VCS are identified:

Table 1: Taxonomy of Assistive Technology Tools for VCS

Category	Examples	Primary Function
Screen Readers	JAWS, NVDA, VoiceOver	Renders on-screen text and interface elements as synthesized speech
Refreshable Braille Displays	BrailleNote, Focus 40	Converts digital text to raised Braille pins for tactile reading
Optical Character Recognition	KNFB Reader, OmniPage	Converts printed/scanned text to digital format for screen readers

Text-to-Speech Systems	NVDA+eSpeak, Balabolka	Converts digital text files to spoken audio
Talking Books	DAISY format, Bookshare	Pre-recorded or structured audio textbooks
Modified Keyboards	Braille keyboard, large-print keyboard	Physical input adaptations for partial or full vision loss
Screen Magnification	ZoomText, MAGic	Enlarges on-screen content for low vision users
Adaptive Computers	Speech-input computers, Braille-output laptops	Integrated hardware-software platforms for non-visual computing

IV. EMPIRICAL FINDINGS

4.1 Tool Availability at Kenyatta and Maseno Universities

Screen reader software (JAWS) was confirmed available at both institutions, but the number of JAWS-enabled computers was insufficient relative to the VCS population. At Kenyatta University, with 44 VCS, three dedicated JAWS-enabled computers were identified, a ratio of approximately 1:15, compared to the internationally recommended ratio of 1:3 for accessible computing provision (ATIA, 2019). Maseno University's 6 VCS shared access to two JAWS-enabled machines, a more favourable ratio but still compromised by the fact that one machine was non-operational at the time of the study.

NVDA, as a FOSS screen reader, was installed on a broader range of computers at both institutions following researcher advocacy during the fieldwork period, illustrating the potential for low-cost rapid improvements in provision. Refreshable Braille displays were present at KENYATTA UNIVERSITY (one unit) but absent at Maseno. OCR capabilities were available via one dedicated workstation at KENYATTA UNIVERSITY. Talking books were available in limited quantities through the KENYATTA UNIVERSITY library's special needs collection; no equivalent provision was identified at Maseno University.

Modified keyboards, -specifically Braille keyboards, were available at both institutions in limited quantities. Screen magnification software was found installed on one computer at KENYATTA UNIVERSITY, serving the low vision rather than blind VCS sub-population. No adaptive computers (integrated speech-input/Braille-output platforms) were identified at either institution.

4.2 Functional Usability of Available Tools

The gap between tool availability and functional usability was a consistent theme across all respondent groups. ICT experts at both institutions noted that JAWS licences were tied to specific hardware, making it impossible to use the software on university-provided laptops or personal devices. This hardware-binding constraint is a well-documented limitation of proprietary screen reader licensing in institutional contexts (Shinohara & Wobbrock, 2011) and effectively limits VCS to accessing screen-reader functionality only at designated on-campus workstations.

Lecturer respondents reported that a significant proportion of course materials were distributed in PDF formats generated from scanned documents, which are structurally inaccessible to screen readers unless processed through OCR. The single OCR workstation at KENYATTA UNIVERSITY was thus a critical bottleneck: VCS requiring access to course materials faced queuing delays of up to three days during peak periods, with direct adverse implications for assignment submission deadlines.

Observation data revealed that the physical arrangement of ICT resource rooms was not optimized for VCS use. Navigation from room entrance to assistive technology workstations required orientation

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assistance, and ambient noise levels in open-plan ICT labs interfered with screen reader audio output. These environmental usability barriers are not captured in standard tool availability assessments but exert material effects on VCS access experiences.

4.3 Staff Competence and Support

A recurrent finding across interview data was the inadequacy of ICT support staff training in assistive technology. At both institutions, ICT support staff had received no formal training in screen reader operation, refreshable Braille display configuration, or the accessibility features of common software applications. Staff competence was therefore entirely self-developed, with quality varying considerably between individuals. This finding corroborates Gakuu et al. (2009), who identify staff knowledge deficits as a primary structural barrier to effective assistive technology provision in Kenyan educational institutions.

4.4 The Tool-Needs Matrix

Drawing on the task analysis conducted through VCS interviews and observations, the following tool-needs matrix links core academic task categories to the most appropriate assistive technology tool:

Table 2: Tool-Needs Matrix for VCS Academic Tasks

Academic Task	Recommended Tool	Current Provision Status
Reading digital course materials	Screen reader + accessible PDF	Partial — PDFs frequently inaccessible
Reading printed materials	OCR + screen reader	Inadequate — single OCR workstation
Writing assignments	Screen reader + word processor	Partial — limited accessible computers
Web research	Screen reader + accessible browser	Poor — university website not WCAG compliant
Note-taking in lectures	Braille display / note-taking software	Very limited
Library database access	Screen reader + accessible LMS	Absent

V. DISCUSSION AND RECOMMENDATIONS

5.1 Procurement Barriers and Consortium Solutions

The prohibitive cost of proprietary assistive technology tools — JAWS licences cost approximately USD 1,000 per seat, while refreshable Braille displays range from USD 1,500 to USD 5,000 — presents a structural barrier that individual institutions cannot overcome through incremental budget allocation. A Kenya-wide assistive technology procurement consortium, coordinating purchases across public universities under the auspices of the Commission for University Education, could achieve negotiated volume discounts and shared maintenance infrastructure. Comparable models have been implemented in the South African and Nigerian higher education systems and demonstrate cost reductions of 40–60% compared to institutional procurement (Borg et al., 2011).

5.2 Prioritizing FOSS as the Foundation Layer

Given fiscal constraints, FOSS tools — NVDA, LibreOffice Writer with accessibility features, Tesseract OCR, should constitute the foundational accessibility layer at all Kenyan public universities. These tools are free to deploy at scale, actively maintained by international developer communities, and functionally comparable to their proprietary

equivalents for the majority of VCS use cases. The additional investment required is not financial but human: training ICT support staff to deploy, configure, and troubleshoot FOSS accessibility tools, and training lecturers to produce digitally accessible course materials.

5.3 Environmental Design as an Accessibility Dimension

The observation-based finding that physical ICT lab environments present barriers to VCS through noise interference, navigation complexity, and inaccessible room layouts underscores the need for accessibility to be understood holistically, encompassing the built environment as well as the digital interface. Universal design principles applied to ICT resource room layout, acoustic management, and wayfinding infrastructure can significantly enhance the functional usability of tools that are otherwise technologically adequate.

VI. CONCLUSION

This paper has demonstrated that the specialized ICT tools available to visually challenged students in Kenyan public universities are inadequate in number, constrained in usability, and unsupported by adequately trained staff. The tool-needs matrix provides a practical instrument for aligning institutional tool investment with the specific digital demands of VCS academic tasks. The proposed procurement consortium and FOSS-centred foundation layer offer a financially realistic pathway to substantially enhanced provision. The realization of digital equity for VCS in Kenyan higher education requires not merely incremental improvements but a strategic reorientation of how institutions conceptualize, fund, and deliver assistive technology infrastructure.

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