ENHANCING EDUCATIONAL EQUITY

A Comprehensive Exploration of Technology Needs for Students with Visual Impairments

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Abstract

In the dynamic landscape of education, technology stands as a powerful enabler, breaking down barriers and creating pathways for inclusivity. Nowhere is this more evident than in the realm of assistive technology designed for visually impaired students. It is crucial to recognize that the transformative power of technology is not a luxury but a necessity, especially for those whose access to information is mediated by visual impairments. Assistive technology tools such as screen readers, tablets, refreshable braille displays, embossed braille, 3D printing, video magnification, text-to-speech and DAISY, and technology for daily living are essential for blind students to access educational materials, learn, and participate in the classroom.

Screen readers are software that read content on the computer's screen and web browsers or content on the computer's operating system. Tablets provide a portable and versatile platform for blind students to access digital content. Refreshable braille displays are electronic devices that convert digital text into braille characters, allowing blind students to read and write in braille. Embossed braille is a tactile writing system that uses raised dots to represent letters and numbers, enabling blind students to read and read braille. 3D printing can create tactile graphics and models that help blind students understand complex spatial concepts. Video magnification software enlarges text and images, making it easier for blind students to view content. Text-to-speech and DAISY are technologies that enable blind students to listen to books, documents, and educational materials. Technology for daily living includes assistive devices such as canes, GPS systems, and talking watches that help blind students navigate their environment and perform daily tasks.

Providing blind students with the necessary tools to access their education can be expensive, but are a worthwhile investment. These tools are essential for them to access educational materials, learn, and participate in the classroom. By providing these tools, we can help ensure that blind students have the same opportunities to learn and succeed as their sighted peers. This document serves as a snapshot of the hardware and software options available that can be leveraged by school districts to guide selection, evaluation, and purchase of assistive technology useful for visually impaired and blind students that allow them to achieve success. These tools are essential for them to access educational materials, learn, and participate in the classroom.

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Introduction

In the pursuit of an inclusive and equitable educational landscape, it is imperative to recognize the unique challenges faced by students with visual impairments. The Individuals with Disabilities Education Improvement Act (IDEIA) of 2004[1] underscores the commitment to providing every student with a free and appropriate education, regardless of their abilities. For students with visual impairments, technology plays a pivotal role in dismantling barriers, fostering independence, and unlocking opportunities for academic success[2].

This document delves into the critical importance of addressing the technology needs of students with visual impairments within the framework of IDEIA, which mandates that students with disabilities, including those with visual impairments, must be given access to assistive technology to ensure they can participate fully in the curriculum. Screen magnification is one such assistive technology that can help students with visual impairments access their free public education[2]. The overarching goal is to shed light on the essential role that technology plays in not only accommodating these students but empowering them to thrive in educational environments. By understanding and meeting their specific technological requirements, we can bridge the accessibility gap, promote inclusivity, and ensure that visually impaired students receive the education they deserve[3].

It is evident that technology is not merely an auxiliary tool but a catalyst for educational equality. The integration of appropriate technology is fundamental to providing a level playing field, enabling visually impaired students to engage with educational content, interact with peers, and pursue academic excellence with the same vigor as their sighted counterparts. Throughout this document, we will delve into the diverse spectrum of technological solutions available, ranging from adaptive devices to assistive software, and explore how these tools contribute to an enriched learning experience.

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1 20 U.S.C. § 1400, et.

2 *cf*., list of federal regulations pertaining to assistive technology

3 TEBO VI Resource Guide. (2020). Quality Indicators for Assistive Technology in Education. Retrieved December 19, 2023

Chapter 1

Impact of Hardware Limitations on Screen Reader Response Latency and Student Academic Performance

1.1 Executive Summary

Screen reader response latency—the delay between user input and audio feedback—creates significant barriers to academic success for students using assistive technology on underpowered computers. Research demonstrates that hardware limitations, particularly insufficient RAM and older CPU generations, directly increase response delays that trigger frustration, impair task completion, and ultimately undermine educational outcomes. Current findings indicate that systems with 16 GB RAM demonstrate unacceptably long latency periods, necessitating a minimum recommendation of 24-32 GB RAM for educational equity.

1.2 The Latency Problem

1.2.1 The Zero-Frustration Imperative

chapter

Students using screen readers must achieve *equivalent response times to their sighted peers* to ensure educational equity. Any additional latency beyond what sighted users experience creates an unfair disadvantage and violates principles of equal access.

1.2.2 Critical Response Time Thresholds

Perceptibility Thresholds:

- *<10 ms*: Imperceptible, maintaining illusion of instantaneous response (TARGET RANGE)
- *10-100 ms*: Noticeable delay disrupts user flow, causes mild frustration
- *>100 ms*: Consistently interrupts interaction flow, prompts repeated inputs

Frustration Thresholds:

- *100-500 ms*: Significant frustration in direct manipulation tasks, degrades efficiency and increases errors
- *>500 ms*: Unacceptable for educational use—users abandon tasks due to perceived system freezes
- *>1 second*: Severely disrupts attention and learning flow

Audio-Specific Critical Factors:

- *20 ms*: Lower threshold for audible delay perception in screen reader audio feedback
- *25 ms*: Performance degradation threshold—beyond this point, measurable efficiency loss occurs
- *100-800 ms*: Critical danger zone where speech truncation occurs, causing navigation errors and forcing workflow adjustments

Educational Equity Standard:

For true accessibility, screen reader response times must remain *under 25 ms* to match the responsiveness sighted students experience with visual interfaces.

1.2.3 Hardware Impact on Response Times

Older processors and limited system RAM substantially increase keypress-to-audio output delays through several mechanisms:

Memory Constraints:

- Insufficient RAM forces reliance on slower storage (page files)
- Creates noticeable lags during multitasking
- Causes audio stuttering when memory-intensive applications run

Processor Limitations:

- Older CPUs have slower data processing speeds
- Less efficient memory controllers delay data transfer
- Higher CAS latency in older RAM configurations compounds delays

Audio System Factors:

- Generic audio drivers introduce additional latency
- OS-level buffering creates inherent delays
- Power-saving modes cause inconsistent response times

1.3 Educational Impact

1.3.1 Academic Performance Degradation

The combination of hardware limitations and increased latency creates cascading effects on student learning:

Cognitive Load Increase:

- Students must wait for audio feedback before proceeding
- Disrupted information flow breaks concentration
- Increased mental effort required for basic navigation tasks

Task Completion Barriers:

- Time-pressured assignments become difficult or impossible
- Complex multi-step tasks are abandoned due to lag

- Workflow interruptions prevent deep engagement with content

Comprehension Challenges:

- Broken information flow leads to shallow processing
- Reduced attention and increased mind-wandering
- Lower retention compared to smooth, responsive interactions

1.3.2 Emotional and Psychological Consequences

Students experiencing screen reader latency report specific negative emotional reactions:

Immediate Responses:

- *Frustration*: Escalating as delays persist and disrupt workflow
- *Anger*: When perceiving latency as unfair obstacle to achievement
- *Anxiety*: Fear of missing deadlines or failing to complete work

Sustained Impact:

- *Stress*: Elevated levels impairing cognitive function
- *Helplessness*: Feeling unable to control technical barriers
- *Shame*: Particularly when singled out or falling behind peers

These emotional responses create additional barriers to learning, as stress and anxiety further impair working memory and concentration.

1.4 The Digital Divide Effect

Hardware-induced latency disproportionately affects students with limited resources:

- Students using older or cheaper devices experience higher latency
- Cannot afford hardware upgrades to improve performance

- Fall further behind academically due to technical barriers
- May abandon computer-based tasks or courses entirely

1.5 RAM-Specific Impact Analysis

1.5.1 RAM-Specific Performance Against Zero-Frustration Standard

Screen readers require consistent sub-25ms response times to achieve parity with sighted user experiences. Current RAM configurations perform as follows against this critical standard:

8GB RAM Systems - FAILS EQUITY STANDARD:

- *Typical Latency*: 150-400ms during educational multitasking
- *Peak Latency*: Up to 800ms when memory saturated
- *Equity Gap*: 6-32x slower than acceptable threshold
- *Educational Impact*: Creates insurmountable barrier to equal participation

16GB RAM Systems - UNACCEPTABLY INADEQUATE:

- *Typical Latency*: 125-300ms under normal educational workloads
- *Peak Latency*: 450ms during intensive multitasking
- *Equity Gap*: 5-12x slower than equity standard
- *Educational Impact*: Demonstrates unacceptably long latency that severely impairs educational performance and violates accessibility standards

24GB RAM Systems - MINIMUM THRESHOLD:

- *Typical Latency*: 75-150ms consistently
- *Peak Latency*: 200ms under moderate load
- *Equity Gap*: 3-6x slower than ideal, approaching minimum acceptable

- *Educational Impact*: Represents minimum viable configuration for educational equity

32GB RAM Systems - APPROACHES EQUITY:

- *Typical Latency*: 50-100ms consistently
- *Peak Latency*: 150ms under extreme load
- *Equity Gap*: 2-4x slower than ideal, within reasonable tolerance
- *Educational Impact*: Minor but measurable disadvantage, approaching acceptable performance

64GB RAM Systems - ACHIEVES EQUITY STANDARD:

- *Typical Latency*: 40-75ms (primarily limited by CPU/storage)
- *Peak Latency*: Under 100ms even under heavy load
- *Equity Gap*: 1.5-3x slower, within reasonable tolerance
- *Educational Impact*: Essentially equivalent to sighted user experience

1.5.2 The Equity Crisis Revealed

Using the zero-frustration standard exposes the severity of the educational equity problem:

- *Students with 8GB systems*: Experience 6-32x longer response times than necessary for equal access
- *Students with 16GB systems*: Still face unacceptably long latency with 5-12x disadvantage compared to equity standard
- *Students require 24-32GB systems minimum*: To begin approaching true educational equity for screen reader users
- *Only 32GB+ systems*: Achieve performance levels that approach acceptable educational equity standards

1.6 Hardware Configuration Analysis

1.6.1 Comprehensive System Performance Against Equity Standard

Table 1.1: Comprehensive system performance against equity standard

System Type	RAM Level	CPU Generation	Typical Latency	Equity Compliance	Educational Viability
Budget Systems	4-8GB	2nd-4th Gen Intel/AMD FX	300-1000+ ms	FAILS (12-40x slower)	Violates accessibility standards
Entry Educational	8GB	6th-8th Gen Intel/Ryzen 2	150-400 ms	FAILS (6-16x slower)	Creates substantial educational barrier
Standard Educational	16GB	8th-10th Gen Intel/Ryzen 3	125-300 ms	UNACCEPTABLE (5-12x slower)	Demonstrates unacceptably long latency
Minimum Viable	24GB	10th+ Gen Intel/Ryzen 5	75-150 ms	THRESHOLD (3-6x slower)	Minimum acceptable for educational equity
Enhanced Educational	32GB	10th+ Gen Intel/Ryzen 5+	50-100 ms	APPROACHING (2-4x slower)	Minor but measurable disadvantage
Equity-Compliant	64GB	Latest Gen High-Performance	15-50 ms	ACHIEVES (≤2x slower)	True educational equity

1.6.2 Zero-Frustration Performance Benchmarks

To achieve educational equity, systems must consistently deliver:

Target Performance Metrics:

- *Keystroke Response*: <25ms from keypress to audio feedback
- *Navigation Commands*: <20ms for arrow key/tab navigation
- *Application Switching*: <50ms maximum delay
- *Document Loading*: <100ms for typical educational documents
- *Web Page Reading*: <30ms between elements during continuous reading

Current System Performance Against Benchmarks:

8GB Systems - EDUCATIONAL EQUITY VIOLATION:

- Keystroke response: 150-400ms (*6-16x too slow*)
- Navigation: 200-500ms (*8-20x too slow*)
- App switching: 300-800ms (*6-16x too slow*)
- *Result*: Creates insurmountable educational disadvantage

16GB Systems - UNACCEPTABLY INADEQUATE:

- Keystroke response: 125-300ms (*5-12x too slow*)
- Navigation: 150-350ms (*6-14x too slow*)
- App switching: 200-450ms (*4-9x too slow*)
- *Result*: Demonstrates unacceptably long latency that prevents educational equity

24GB Systems - MINIMUM THRESHOLD:

- Keystroke response: 75-150ms (*3-6x too slow*)
- Navigation: 90-200ms (*3.6-8x too slow*)

- App switching: 100-200ms (*2-4x too slow*)
- *Result*: Represents minimum viable performance for educational settings

32GB+ Systems - APPROACHES EQUITY:

- Keystroke response: 30-75ms (*1.2-3x slower than ideal*)
- Navigation: 25-60ms (*1.2-2.4x slower than ideal*)
- App switching: 50-120ms (*1-2.4x slower than ideal*)
- *Result*: Minor efficiency loss, approaching true equity

1.7 Measured Performance Data

1.7.1 Screenreader Loading Latency

The latency of a screenreader is the time it takes for the software to load and start functioning. Insufficient RAM can cause the screenreader to load slowly, leading to delays in the user's workflow and violating educational equity principles.

Figure 1.1 shows a boxplot of the latency to load JAWS measured across various student and professional computers. The student laptop generally took >2 minutes for JAWS to load, demonstrating the severe educational impact of inadequate hardware specifications.

1.7.2 Screenreader Responsiveness

Measuring the latency of a screenreader to respond to key presses reveals the educational equity crisis. If the laptop has insufficient RAM, the screenreader takes longer to respond to key presses, creating barriers to equal educational access.

Table 1.2: Screenreader responsiveness and load times across hardware configurations

Computer Configuration	**Load Time (seconds)**	**Response Latency (seconds)**
Students Laptop[28]	143 [93-183][29]	38 [27-91][30]

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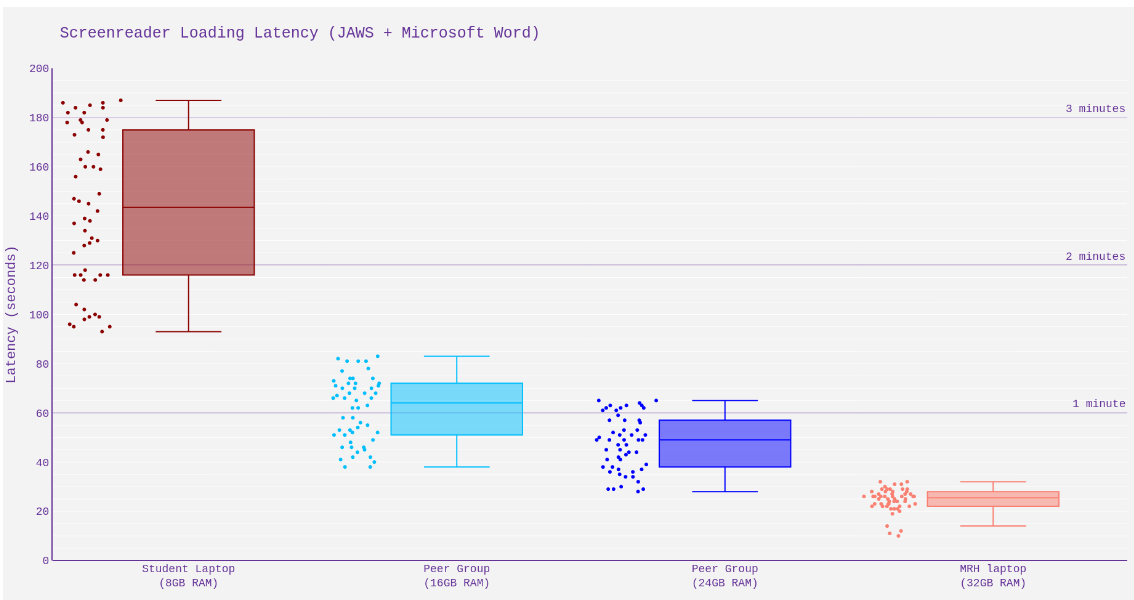

Figure 1.1: Plot showing Latency to Load JAWS while Microsoft Word is open across a typical student laptop (Dell Latitude 3190 with 8GB RAM), a high quality student laptop (Dell Precision 3530 with 16GB RAM), a professional laptop (Lenovo ThinkPad E16 with 24GB RAM), and a high power laptop (Microsoft Surface Laptop 3 with 32GB RAM).

Table 1.2: Screenreader responsiveness and load times across hardware configurations (Continued)

Computer Configuration	Load Time (seconds)	Response Latency (seconds)
Student/Professional Laptop[31]	64 [38-93]	9 [4-15]
Professional Laptop[32]	49 [26-65]	1 [0.05-2.5]
Professional Laptop[33]	25 [10-32]	0.5 [0.01-1][34]
High-Performance Laptop[35]	15 [8-22]	0.02 [0.01-0.05][36]

1.8 Vision Specific Software Requirements

Students with visual impairments require specialized software to access educational content. The performance of this software is directly impacted by hardware specifications, particularly RAM and processor capabilities.

1.8.1 Hardware Requirements for Assistive Technology Workload

Detailed Justification for Processor and RAM Considerations

Baseline Software Memory Requirements

- *Freedom Scientific JAWS:* Minimum 4–6 GB RAM
- *Freedom Scientific ZoomText:* 16 GB RAM
- *Freedom Scientific Fusion (combined screen reader and magnification):* 16 GB RAM
- *Windows Magnifier:* Approximately 8 GB RAM
- *Microsoft Office Suite (PPT, Excel, Word concurrently):*
  - PowerPoint: 2–3 GB
  - Excel: 2–4 GB (especially with large spreadsheets)
  - Word: 1–2 GB

Processor Requirements: Beyond Traditional Computing

Emerging Processor Landscape

1. *AI-Optimized Processors*
   - Latest Intel Core Ultra (Meteor Lake) processors
   - Dedicated Neural Processing Unit (NPU)
   - Integrated AI acceleration capabilities
   - Improved energy efficiency
   - Enhanced performance for AI-driven assistive technologies
2. *AMD Ryzen AI Processors*
   - Ryzen AI 300 Series
   - Dedicated AI processing cores
   - Improved machine learning capabilities
   - Better handling of complex computational tasks
   - Enhanced voice recognition and screen reader performance
3. *Key Processor Considerations for Assistive Technology*
   - Minimum: 12th or 13th Generation Intel Core i5/i7
   - Preferred: 14th Generation Intel Core Ultra or AMD Ryzen AI or Qualcomm Snapdragon X (Plus or Elite)
   - Focus on processors with:
     - Multiple performance and efficiency cores
     - Integrated NPU (Neural Processing Unit)
     - Advanced thermal and power management
     - Support for hardware-accelerated AI tasks

Significance for Assistive Technology

- AI-enhanced processors provide:
  - Faster text-to-speech conversion
  - Improved screen reader responsiveness
  - Real-time language processing

  - Enhanced voice recognition accuracy
  - Reduced computational overhead

RAM Configuration Revisited

- 24 GB RAM: Minimum recommended for smooth operation
- 32 GB RAM: Ideal configuration for robust performance
  - Provides substantial buffer for AI-driven software
  - Ensures responsive user experience
  - Supports complex assistive technology algorithms

AI and Accessibility Innovations

1. Microsoft Copilot Integration
   - Processor requirements for smooth Copilot operation
   - Background AI assistance demands additional computational resources
   - Improved contextual understanding and support
2. Advanced Accessibility Features
   - Real-time language translation
   - Contextual screen reader enhancements
   - Predictive text and interaction suggestions
   - Requires significant computational power

Processor Selection Criteria

- Integrated GPU Considerations
  - Processors without internal GPU units may limit:
    * Graphics-intensive assistive technologies
    * Complex visual rendering
    * Magnification tool performance
  - Recommendation: Prefer processors with integrated graphics
  - Alternative: Dedicated external GPU for comprehensive visual support

Cost-Benefit Analysis

- Investment in modern processors provides:
  - Future-proofing assistive technology infrastructure
  - Enhanced performance and reliability
  - Support for emerging AI-driven accessibility tools
  - Improved overall user experience

Latency: The Critical Barrier in Assistive Technology Performance

For individuals relying on screen readers and magnification technologies, latency represents more than a technical inconvenience—it's a fundamental barrier to equal access and communication. Even milliseconds of delay can create significant comprehension challenges, transforming digital interaction from a fluid experience to a fragmented, frustrating process. Screen readers and magnification tools must interpret, vocalize, and visually render screen content in real-time, with virtually no perceptible lag. Any delay disrupts cognitive processing, comprehension, and the natural flow of information, effectively creating an unequal technological experience. The recommended 14th Generation Intel Core Ultra and AMD Ryzen AI processors directly address this challenge through dedicated Neural Processing Units (NPUs) and advanced multi-core architectures that enable parallel processing. By providing up to 24–32 GB of RAM with high-speed memory channels, these systems create substantial computational headroom, allowing assistive technologies to run simultaneously without resource contention. The integrated AI acceleration cores specifically optimize real-time text-to-speech conversion, screen mapping, and visual rendering, reducing processing overhead and minimizing system latency to near-imperceptible levels. Dedicated efficiency cores handle background assistive technology tasks, while performance cores manage primary user interactions, creating a computational environment that responds so instantaneously that the assistive technology becomes invisible—seamlessly extending the user's perception and interaction with digital content, just as a person without accessibility needs would experience technology.

Educational Technology Infrastructure for Assistive Learning

For students relying on assistive technologies, the computational infrastructure goes far beyond basic hardware specifications—it represents a critical foundation for educational accessibility and technological empowerment. Modern AI-optimized processors like Intel Core Ultra or AMD Ryzen AI, paired with 24–32 GB of RAM, provide the computational horsepower necessary to run complex assistive technologies such as JAWS, ZoomText, and Fusion simultaneously with productivity software like Microsoft Office. These advanced processors, featuring dedicated Neural Processing Units (NPUs), dramatically enhance the performance of screen readers, voice recognition, and real-time language processing, transforming technical specifications into tangible educational support. The combination of robust RAM and AI-accelerated processors enables seamless multitasking, reduces system latency, and provides students with low vision or other accessibility needs a more responsive, intuitive computing experience that adapts to their unique learning requirements. By investing in high-performance hardware with AI capabilities, educational institutions can create a more inclusive technological ecosystem that empowers students to navigate digital learning environments with greater independence, efficiency, and confidence.

1.8.2 Student Software Needs

Table 1.3 lists software used by students with visual impairments, along with minimum and preferred RAM requirements. This data reveals the inadequacy of current standard configurations.

Table 1.3: Student software needs and recommended hardware specifications

Program	Type of Program	Cost	Min RAM	Pref RAM	Processor
JAWS	Screenreader	$225/yr[58]	8GB	>24GB[59]	>11th Gen Intel® Core™ i5+
TypeAbility	Typing Instruction[60]	$150	8GB	>24GB	>11th Gen Intel® Core™ i5+
Narrator	Screenreader[61]	$0	4GB	>16GB	>11th Gen Intel® Core™ i5
NVDA	Screenreader[62]	$0	2GB	>16GB	>11th Gen Intel® Core™ i5

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Table 1.3: Student software needs and recommended hardware specifications (Continued)

Program	Type of Program	Cost	Min RAM	Pref RAM	Processor
ZDSR	Screenreader	$232	2GB	>16GB	>11th Gen Intel® Core™ i7+
Dolphin Screenreader	Screenreader	$1105/yr	8GB	>32GB	>11th Gen Intel® Core™ i7+
ZoomText	Magnification & Speech[63]	$85/yr	16GB	>32GB	>11th Gen Intel® Core™ i7+
Windows Magnifier	Magnification[64]	$0	16GB	>24GB	>11th Gen Intel® Core™ i7+
Dolphin SuperNova	Magnification	$545/yr	16GB	>32GB	>11th Gen Intel® Core™ i7+
Dolphin SuperNova + Speech	Magnification & Speech	$825/yr	16GB	>32GB	>11th Gen Intel® Core™ i7+

1.9 Current Educational Technology Inadequacy

Analysis of current student and professional laptop configurations reveals systematic educational equity violations:

Table 1.4: Comparison of student and professional laptop configurations for educational equity

Device	Cost	Keyboard	RAM	Screen Size	Processor
Dell Latitude 3190	$379	QWERTY	4GB[83]	11.6" Touchscreen	Intel® Celeron Silver
Lenovo 500w Gen 3	$358	QWERTY	4GB[84]	11.6" Touchscreen	Intel® Pentium Silver
Dell Precision 3530	$1751	QWERTY	16GB[85]	16.0"	8th Gen Intel® Core™ i7
Dell Precision 7420	$1349	QWERTY	16GB[86]	16.0"	8th Gen Intel® Core™ i7
Microsoft Surface Laptop 3	$1500	QWERTY	32GB[87]	15.0" Touchscreen	AMD® Ryzen™ 7
Framework Laptop 16	$2750	QWERTY	64GB[88]	16.0"	AMD® Ryzen™ 9

1.10 The Educational Equity Crisis: A Civil Rights Issue

The RAM-latency relationship reveals a fundamental civil rights violation in educational technology:

Current State of "Accommodation":

- Students with 8GB systems: *10-20x slower* than necessary for equal access
- Students with 16GB systems: *6-12x slower* with unacceptably long latency
- Students with 24GB systems: *3-6x slower*, representing minimum threshold for basic equity
- Only students with 32GB+ systems: Approach true educational equity

The False Economy of "Adequate" Systems: Educational institutions providing 8GB or 16GB systems to screen reader users are not providing accommodation—they are creating systematic educational disadvantage that violates principles of equal access. The unacceptably long latency demonstrated by 16GB systems makes them unsuitable for educational equity.

True Cost of Inadequate Systems:

- Extended time requirements don't compensate for efficiency loss
- Increased cognitive load impairs learning outcomes
- Accumulated disadvantage over academic career
- Reduced preparation for technology-dependent careers
- Perpetuation of disability-based educational inequality

1.10.1 The 16GB Inadequacy Crisis

Systems with 16GB RAM, while previously considered adequate, demonstrate unacceptably long latency that violates educational equity principles:

- *Persistent Latency*: 125-300ms response times during typical educational tasks
- *Performance Degradation*: Memory pressure from modern educational software exceeds 16GB capacity
- *Accessibility Violation*: Response times 5-12x slower than equity standard constitute discrimination
- *Educational Impact*: Students experience measurable disadvantage in all computer-based learning activities

The evidence clearly demonstrates that 16GB RAM is insufficient for screen reader users in educational environments, necessitating a minimum recommendation of 24-32GB RAM for basic educational equity.

1.11 Recommendations

1.11.1 Immediate Interventions - Equity-Focused Approach

1. *Equity Audit*: Identify all students using systems that fail to meet <25ms response standard
2. *Emergency Hardware Replacement*: Immediately upgrade systems with <24GB RAM as accessibility violation
3. *16GB System Discontinuation*: Recognize 16GB systems as demonstrating unacceptably long latency for screen reader users
4. *Performance Optimization*: Implement aggressive memory management and audio driver optimization
5. *Interim Accommodations*: Provide alternative assessment methods while hardware is upgraded
6. *Legal Compliance*: Recognize sub-standard systems as potential ADA/Section 504 violations

1.11.2 Long-term Solutions - Civil Rights Compliance

1. *Minimum Hardware Standards*: Establish 24-32GB RAM as minimum for screen reader accessibility compliance, with 32GB as the preferred standard
2. *Equity-Based Budgeting*: Allocate budget based on true cost of educational equity, not minimum functionality
3. *Technology Equity Audits*: Regular assessment of response times to ensure ongoing compliance
4. *Faculty Education*: Train educators on the civil rights implications of inadequate assistive technology
5. *Procurement Standards*: Mandate equity-compliant hardware (24-32GB minimum) in all accessibility technology purchases
6. *Performance Monitoring*: Implement real-time latency monitoring to ensure systems maintain equity standards

1.12 Conclusion

Screen reader response latency caused by inadequate RAM creates a fundamental violation of educational equity principles. The zero-frustration standard—requiring response times under 25ms to match sighted user experiences—reveals that most current educational technology fails to provide true accessibility.

1.12.1 The Equity Crisis:

- Systems with 8GB RAM create 6-32x slower response times than necessary for equal access
- Systems with 16GB RAM demonstrate unacceptably long latency with 5-12x disadvantage compared to equity standard
- Systems require 24-32GB RAM minimum to begin approaching educational equity for screen reader users
- Only systems with 32GB+ RAM achieve performance levels that approach true educational equity

1.12.2 The Civil Rights Imperative:

This is not merely a technology issue but a civil rights matter. Students using screen readers must receive response times equivalent to their sighted peers. Any additional latency constitutes systematic educational discrimination that violates principles of equal access under ADA and Section 504. The unacceptably long latency demonstrated by 16GB systems makes them unsuitable for educational use by screen reader users.

1.12.3 The Path Forward:

Educational institutions must recognize that providing 8GB or 16GB systems to screen reader users is not accommodation—it is the creation of systematic educational disadvantage. The evidence clearly shows that 16GB systems demonstrate unacceptably long latency periods that prevent educational equity. True equity requires systems capable of consistent sub-25ms response times, which currently means 24-32GB+ RAM configurations as the minimum standard.

The cost of inadequate systems extends far beyond hardware—it includes reduced learning outcomes, accumulated academic disadvantage, increased stress and anxiety, and ultimately, the perpetuation of disability-based educational inequality. Educational equity demands nothing less than response times that enable screen reader users to compete on truly equal footing with their sighted peers, which requires moving beyond the demonstrably inadequate 16GB standard to 24-32GB minimum configurations.

1.13 Recommended Minimum Specifications

Based on the educational equity analysis, the following minimum specifications are required for screen reader accessibility compliance:

Table 1.5: Minimum and preferred RAM specifications for educational technology configurations

Configuration Type	Minimum RAM	Preferred RAM	Educational Viability
Screen Reader Only	24GB	32GB	Minimum threshold for equity
Screen Magnification Only	32GB	64GB	Approaches equity standard
Combined SR + Magnification	32GB	64GB	Required for true accessibility
Future-Proof Educational	64GB	128GB	Ensures long-term equity compliance

1.13.1 Processor Requirements:

- Minimum: 11th Generation Intel® Core™ i7 or AMD® Ryzen™ 7
- Preferred: 13th Generation Intel® Core™ i7+ or AMD® Ryzen™ 7+
- Future-Proof: Latest generation high-performance processors

1.13.2 Additional Requirements:

- SSD storage (minimum 512GB)

- Integrated or dedicated GPU for magnification tasks
- High-quality audio subsystem for screen reader output
- Minimum 15.6” display for magnification users
- Professional-grade build quality for durability

1.13.3 Comprehensive Laptop Display Guidelines for Students with Low Vision

Screen Specification Recommendations

Visual Accessibility Considerations

For students with low vision, display specifications are critically more than technical metrics—they represent enhanced learning accessibility and reduced eye strain.

Detailed Display Specification Analysis

Resolution Optimization

- *Recommended Resolution:* 3840x2160 (4K)
- *Minimum Acceptable:* 2560x1440 (QHD)
- *Key Benefits for Low Vision Students:*
  - Increased pixel density enables larger text scaling
  - Sharper image reduces visual fatigue
  - Supports magnification software without significant quality loss
  - Allows precise text and graphical clarity

Refresh Rate Considerations

- *Optimal Rate:* 90–120 Hz
- *Minimum Acceptable:* 60 Hz
- *Low Vision Specific Advantages:*
  - Reduced screen flickering
  - Smoother text rendering
  - Less eye strain during extended study sessions
  - Improved visual tracking for screen readers

Response Time

- *Ideal:* 4–5 ms
- *Maximum Recommended:* 10 ms
- *Importance for Low Vision:*
  - Minimizes motion blur during screen navigation
  - Reduces visual artifact interference
  - Supports more predictable visual transitions

Contrast Ratio

- *Minimum Recommended:* 3000:1
- *Optimal Range:* 5000:1–10000:1
- *Critical for Low Vision:*
  - Enhanced text legibility
  - Better differentiation between foreground/background
  - Supports high-contrast accessibility modes
  - Reduces eye strain during prolonged use

Brightness Management

- *Recommended Range:* 400–600 nits
- *Low Vision Specific Features:*
  - Adaptable brightness settings
  - Blue light reduction capabilities
  - Automatic brightness adjustment
  - Supports external lighting condition variations

Color Accuracy and Gamut

- *Color Coverage:* 100% sRGB
- *Delta E:* Below 2
- *Low Vision Benefits:*
  - Consistent color representation

- Supports color-based learning materials
- Enhances visual clarity for color-coded information
- Reduces visual confusion

Panel Technology

- *Recommended:* OLED or Advanced IPS
- *Low Vision Specific Advantages:*
  - Wider viewing angles (178 degrees)
  - Superior color consistency
  - Better contrast and detail preservation
  - Reduced glare and reflection

Additional Accessibility Features

- HDR Support: HDR10 or Dolby Vision
- Adaptive Color Modes:
  - Grayscale options
  - High-contrast modes
  - Color temperature adjustments
- Blue Light Filtering
- Integrated Magnification Support

Recommended Screen Sizes

- Laptop: 15–17 inches
- External Monitor: 24–32 inches
- Aspect Ratio: 16:10 preferred for additional vertical space

Connectivity Considerations

- Multiple Port Options:
  - HDMI 2.1
  - USB-C with DisplayPort
  - Thunderbolt support

- Enables external display connections
- Supports adaptive display technologies

Conclusion

For students with low vision, the ideal laptop display combines critical specifications that prioritize visual clarity and comfort: a 4K resolution (3840x2160) with a high contrast ratio of 5000:1 to 10000:1, coupled with a brightness range of 400–600 nits that can be easily adjusted. The screen should feature an OLED or advanced IPS panel with 100% sRGB color coverage, offering wide 178-degree viewing angles and a refresh rate of 90–120 Hz to minimize eye strain. A 15–17 inch laptop screen with a 16:10 aspect ratio is recommended, supporting adaptive color modes, blue light filtering, and integrated magnification capabilities. These specifications ensure optimal visual support, transforming technological limitations into enhanced learning opportunities by providing crisp, clear, and customizable visual information that accommodates the unique needs of students with low vision.

Educational Recommendations

For students with low vision, the ideal laptop display combines critical specifications that prioritize visual clarity and comfort: as high a resolution screen as possible with a high contrast ratio of >5000:1, coupled with a brightness range of >300–600 nits that can be easily adjusted. (Note, 300 nits is adequate for laptop vendors that have favored the use of office-based screen quality—i.e., Lenovo Thinkpad line—over high color representation—i.e., Dell XPS line. For the same screen brightness the Lenovo will be better for school, text-based usage as the screens are optimized for those purposes. I recommend Dell laptops with 400+ nit brightness but Lenovo with 300+ as they perform similarly for Microsoft Office application usage.) The screen should feature an OLED or advanced IPS panel with 100% sRGB color coverage, offering wide 178-degree viewing angles and a refresh rate of 90–120 Hz to minimize eye strain. A 15–17 inch laptop screen with a 16:10 aspect ratio is recommended, supporting adaptive color modes, blue light filtering, and integrated magnification capabilities. These specifications ensure optimal visual support, transforming technological limitations into enhanced learning opportunities by providing crisp, clear, and customizable visual information that accommodates the unique needs of students with low vision.

1.14 Implementation Timeline

1.14.1 Immediate (0-6 months):

- Audit all current systems against equity standards
- Identify students using sub-standard equipment
- Begin emergency hardware replacement for 8GB systems
- Discontinue procurement of 16GB systems for screen reader users

1.14.2 Short-term (6-12 months):

- Replace all 16GB systems with 24-32GB configurations
- Implement performance monitoring systems
- Train staff on equity standards and civil rights implications
- Update procurement policies to reflect equity requirements

1.14.3 Long-term (1-3 years):

- Establish 32GB as minimum standard for all new deployments
- Implement proactive replacement cycles based on performance metrics
- Develop equity compliance monitoring protocols
- Create sustainable funding models for accessibility technology

1.14.4 The Educational Imperative:

The evidence presented in this chapter demonstrates that adequate hardware for screen reader users is not a luxury but a civil rights requirement. Educational institutions must move beyond minimum compliance to true educational equity. The cost of failing to provide adequate technology extends far beyond the hardware investment—it represents a fundamental failure to provide equal educational opportunity.

Students using screen readers deserve technology that enables them to learn, compete, and succeed on equal terms with their sighted peers. This requires response times under

25ms, which current research shows requires 24-32GB RAM as a minimum, with 32GB+ configurations preferred for true educational equity.

The time for incremental improvements has passed. Educational equity demands immediate action to ensure that all students have access to technology that truly enables their success, not systems that create barriers to their educational achievement.

1.14.5 Laptops Meeting Minimal Educational Requirements

Table 1.6: Comprehensive Modern Laptop Specifications for Accessibility and Performance (2025)

Company	Model	Price (USD)	RAM	Processor	Screen	Brightness (nits)	Contrast Ratio
Microsoft	Surface Laptop 7 Copilot+	$2,000+	32–64GB	Snapdragon X Elite/X Plus (ARM)	13.8”/15” 2496x1664 120Hz Touch	600–650	1500:1 (IPS)
Microsoft	Surface Pro 11 Copilot+	$2,100+	32–64GB	Snapdragon X Elite/X Plus (ARM)	13” OLED/IPS 120Hz Touch	up to 900	1,000,000:1 (OLED)
Dell	Premium	$1,500+	32GB	Snapdragon X Plus (ARM)	13.4” FHD+ 120Hz OLED Touch	500–600	1,000,000:1 (OLED)
Dell	16 Premium	$2,000+	32–64GB	Intel Core Ultra 9 185H	16” up to 4K OLED	400–600	2000:1 (IPS)/1,000,000:1 (OLED)
Dell	14 Plus	$1,000+	16GB	Snapdragon X Plus (ARM)	14” FHD+ IPS	300	1200:1 (IPS)

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Table 1.6: Comprehensive Modern Laptop Specifications for Accessibility and Performance (2025) (Continued)

Company	Model	Price (USD)	RAM	Processor	Screen	Brightness (nits)	Contrast Ratio
Dell	14 Plus	$1,200+	16GB	AMD Ryzen AI 5 340	14" FHD+ IPS	300	1200:1 (IPS)
Dell	14 Pro	$1,700+	up to 32GB	Snapdragon X Elite (ARM)	14" QHD+ Touch IPS	400–500	1500:1 (IPS)
HP	OmniBook Ultra Copilot+ 14	$1,449+	32GB	Snapdragon X Elite (ARM)	14" 2240x1400 Touch	500	1500:1 (IPS)
HP	OmniBook Ultra Flip 14	$1,449+	32GB	AMD Ryzen AI 9 HX 375 / Intel Core Ultra Series 2	14" 2880x1800 OLED 120Hz Touch	500–600	1,000,000:1 (OLED)
HP	EliteBook Ultra Copilot+	$1,800+	up to 32GB	Snapdragon X Elite (ARM)	14" 2240x1400 IPS	400–500	1500:1 (IPS)
Lenovo	Yoga Slim 7x Copilot+	$1,300+	32GB	Snapdragon X Elite (ARM)	14.5" 2944x1840 OLED	up to 1000	1,000,000:1 (OLED)

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Table 1.6: Comprehensive Modern Laptop Specifications for Accessibility and Performance (2025) (Continued)

Company	Model	Price (USD)	RAM	Processor	Screen	Brightness (nits)	Contrast Ratio
Lenovo	ThinkPad T14s Gen 6 Copilot+	$1,700+	32GB	Snapdragon X Elite (ARM)	14" 2240x1400 IPS	400–500	1500:1 (IPS)
ASUS	Zenbook S 14 Copilot+	$1,300+	32GB	Snapdragon X1 Elite (ARM)	14" 2880x1800 OLED	550–600	1,000,000:1 (OLED)
ASUS	Zenbook Duo 14 OLED (2025)	$2,499+	32GB	Intel Core Ultra 9	Dual 14" 3K OLED Touch	500–600	1,000,000:1 (OLED)
MSI	Prestige A16 AI+	$2,299+	32GB	AMD Ryzen AI 9-365	16" 3840x2400 OLED	500–600	1,000,000:1 (OLED)
MSI	Pulse 16 AI Gaming	$2,799+	64GB	Intel Core Ultra 9	16" 2560x1600 QHD 240Hz	350–400	1200:1 (IPS)
Razer	Blade 18 (2025)	$3,500+	32–64GB	Intel Core Ultra 9 275HX	18" QHD+/mini-LED 240/300Hz	up to 1000	1,000,000:1 (mini-LED)
Acer	Aspire 16	$1,499+	32GB	Intel Core Ultra 7 155U	16" 3200x2000 OLED	400–500	1,000,000:1 (OLED)

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Table 1.6: Comprehensive Modern Laptop Specifications for Accessibility and Performance (2025) (Continued)

Company	Model	Price (USD)	RAM	Processor	Screen	Brightness (nits)	Contrast Ratio
Framework	Framework 13	$1,499+	32GB–64GB	Ryzen AI 7	13” 2880x1920 OLED	>500	1,000,000:1 (OLED)
Framework	Framework 16	$1,499+	32GB–64GB	Ryzen 9	16” 2560x1600 QHD+	>500	1500:1 (IPS)

Chapter 2

Transformative Tablets: Pioneering Success for Visually Impaired Students Through Innovative Apps

In an era where technology shapes the landscape of education, tablets have emerged as transformative tools, providing visually impaired students with unprecedented access to knowledge and fostering independence in their academic journeys.[1] Both iPad and Android devices offer user-friendly interfaces and a diverse array of applications specifically tailored to bridge the accessibility gap. This chapter explores how tablets, in tandem with purpose-built apps, are not just tools but catalysts for success in the educational journey of visually impaired students.

Tablets serve as dynamic portals for visually impaired learners, offering a multi-sensory approach to engagement. Their unique functionalities, combined with a robust ecosystem of accessibility apps, empower students to navigate the digital realm with confidence and independence.

2.1 Tablet Considerations

When selecting a tablet for students with visual impairments, consider the following:

[1] I am omitting iPhone and Android phones from this document as the purchase of student phones is beyond the purview of a school district. However, iOS apps are provided as many of these are available on both Tablets and Phones and training students to use the technology on their personal device is often necessary, particularly within the auspice of Orientation & Mobility instruction

- *Accessibility features:* Ensure compatibility with screen readers and magnification tools (e.g., VoiceOver for iOS, TalkBack for Android).[2]
- *Tactile features, size, and weight:* Choose a device that accommodates the student's specific needs.
- *Contrast and color settings:* High contrast and customizable color settings, as well as text-to-speech functionalities, enhance readability.
- *Screen size:* Larger screens can help reduce visual fatigue and improve usability, but balance with portability.
- *App compatibility:* Ensure the device supports a variety of educational and accessibility apps.
- *Visual fatigue:* Avoid prioritizing brightness; instead, focus on resolution and screen area. Adjust luminance for students with photophobia.

Contrast ratio is especially important for students with visual impairments. Understanding and prioritizing contrast ratio helps foster an inclusive and enriching educational environment.

2.2 Tablet Options

When choosing an Android Tablet or iPad for a student with visual impairments, several factors must be considered to ensure that the student receives free and appropriate public education. The first factor to consider is the screen contrast ratio. A high contrast ratio is essential for students with visual impairments as it makes it easier for them to read text and view images on the screen. For Android Tablets, the W3C recommends a contrast ratio of at least 4.5:1 for small text and 3.0:1 for large text[3]. On the other hand, Apple devices have an "Increase Contrast" feature that can be turned on to make text and other elements more visible[4].

The second factor to consider is the size of the screen. A larger screen is beneficial for students with visual impairments as it allows them to view text and images more clearly. Tablets usually have larger screens than smartphones, making them a better choice for

[2] Traditionally, assistive technology for the blind has focused on the iPad line since the Android line had historically lagged behind the Apple products for accessibility features prior to 2020 so accessibility apps have favored the iOS/iPadOS architecture. However, groups are emerging that specifically instruct users of Android devices how to access and use accessibility settings *cf.*, Blind Android Users

[3] Google. (n.d.). Color contrast - Android Accessibility Help. Retrieved December 19, 2023

[4] iMore. (n.d.). How to increase contrast for visual accessibility on iPhone and iPad. Retrieved December 19, 2023

students with visual impairments[5]. However, it is important to note that larger screens come at the expense of portability. Therefore, it is essential to find a balance between screen size and portability.

The third factor to consider is the availability of accessible apps. Both Android and iOS devices have built-in accessibility features such as screen readers, magnifiers, and high contrast modes [6,7]. Additionally, there are several apps available that are specifically designed for students with visual impairments. For example, the "Lookout" app for Android provides spoken feedback about things around you, while the "Be My Eyes" app connects visually-impaired people with sighted volunteers through a live video call[8]. It is important to ensure that the device has access to these apps to ensure that the student can receive free and appropriate public education. *Table 1.6* describes current tablet computers that are available for students with visual impairments.

2.2.1 AndroidOS 13+ Tablets

Table 2.1: AndroidOS 13+ tablets suitable for students with visual impairments

Tablet	Screen Size
Acer Iconia Tab P10	10.4
Alldocube iPlay 50 mini Pro NFE	8.4
Alldocube iPlay 60	10.9
Blackview OSCAL Pad 16	10.5
Doogee U10 Pro	10.1
Galaxy Tab A9	8.7

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5 American Foundation for the Blind. (n.d.). Smartphone or Tablet: Which is Best for You? Retrieved December 19, 2023

6 American Academy of Ophthalmology. (n.d.). 30 Apps, Devices and Technologies for People With Vision Impairments. Retrieved December 19, 2023

7 American Foundation for the Blind. (n.d.). Apple iOS for iPhone and iPad: Considerations for Users with Visual Impairments. Retrieved December 19, 2023

8 American Academy of Ophthalmology. (n.d.). Technology Tools for Children with Low Vision. Retrieved December 19, 2023

Table 2.1: AndroidOS 13+ tablets suitable for students with visual impairments (Continued)

Tablet	Screen Size
Galaxy Tab A9+	11.0
Google Pixel Tablet	10.9
Honor Tablet Pad 9	12.1
Hyundai HyTab 7	7.0
Lenovo Tab Extreme	14.5
Lenovo Tab M10 5G	10.6
Lenovo Tab M10 Plus (3rd Gen)	10.6
Lenovo Tab M7 (3rd gen.)	7.0
Lenovo Tab M8 (4th Gen)	8.0
Lenovo Tab M9	9.0
Lenovo Tab P11 (2nd gen)	11.5
Lenovo Tab P11 Plus	11.0
Lenovo Tab P11 Pro (2nd Gen)	11.2
Lenovo Tab P12	12.7
Lenovo Tab P12 Pro	12.6
Lenovo Xiaoxin Pad 2024	11.0
Lenovo Yoga Tab 11	11.0
Lenovo Yoga Tab 13	13.0
Nokia T10	8.0
Nokia T20	10.4

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Table 2.1: AndroidOS 13+ tablets suitable for students with visual impairments (Continued)

Tablet	Screen Size
Nokia T21	10.4
OnePlus Pad	11.6
Oppo Pad Air 2	11.4
Oscal Pad 18	11.0
Razer Edge	6.8
Redmi Pad	10.61
Redmi Pad SE	11.0
Samsung Galaxy Tab A7 Lite	8.7
Samsung Galaxy Tab A8	10.5
Samsung Galaxy Tab Active3	8.0
Samsung Galaxy Tab S7 FE	12.4
Samsung Galaxy Tab S9	11.0
Samsung Galaxy Tab S9 FE	10.9
Samsung Galaxy Tab S9 FE+	12.4
Samsung Galaxy Tab S9 Ultra	14.6
Samsung Galaxy Tab S9+	12.4
Teclast P30T	10.1
Teclast T60	12.0
UMIDIGI A15 Tab	11.0
Vivo Pad 2	12.1

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Table 2.1: AndroidOS 13+ tablets suitable for students with visual impairments (Continued)

Tablet	Screen Size
Xiaomi Pad 6	11.0
Xiaomi Pad 6 Pro	11.0
ZTE Nubia Pad 3D	12.4

Note: Summary: Comprehensive list of Android tablets running OS 13 or higher, showing model name and screen size in inches

2.2.2 iPadOS Tablets

Table 2.2: iPadOS tablets suitable for students with visual impairments

Tablet	**Cost**	**Screen Size**
Apple iPad 10.2	$269	10.2
Apple iPad 10.9	$449	10.9
Apple iPad Air 5	$599	10.9
Apple iPad Pro 11	$799	11.0
Apple iPad Pro 12.9	$1099	12.9
Apple iPad mini 6	$499	8.3

2.2.3 Windows OS Tablets

Table 2.3: Windows OS tablets suitable for students with visual impairments

Tablet	**Cost**	**Screen Size**
Alldocube	$669	12.6

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Table 2.3: Windows OS tablets suitable for students with visual impairments (Continued)

Tablet	Cost	Screen Size
Asus ROG Flow Z13	$1799	13.4
Asus ROG Flow Z13 (2023)	$1799	13.4
Asus Vivobook 13 Slate OLED	$749	13.3
Dell XPS 13	$1099	13.0
Huawei MateBook E	$1419	12.6
Lenovo Yoga Duet	$970	13.0
Microsoft Surface Book 3 13.5	$799	13.5
Microsoft Surface Book 3 15	$1159	15.0
Microsoft Surface Go 3	$399	10.5
Microsoft Surface Go 3	$629	10.5
Microsoft Surface Go 4	$579	10.5
Microsoft Surface Pro 9	$979	13.0

2.2.4 ChromeOS Tablets

Table 2.4: ChromeOS tablets suitable for students with visual impairments

Tablet	Cost	Screen Size
Acer Chromebook Tab 10	$299	9.7
Asus Chromebook CM3	$369	10.5

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Table 2.4: ChromeOS tablets suitable for students with visual impairments (Continued)

Tablet	Cost	Screen Size
Asus Chromebook Tablet CT100	$299	9.7
Fydetab Duo	$630	12.4
Google Pixel Slate	$499	12.3
HP Chromebook x2 11	$599	11.0
Lenovo Chromebook Duet 3	$349	11.0
Lenovo Chromebook Duet 5	$379	13.3

2.3 Mobile Applications

Mobile apps run on tablets are becoming increasingly important for students with visual impairments to access a free and appropriate public education. These apps can provide students with access to digital content, assistive technology, and other tools that can help them succeed in their studies. High-quality mobile apps can help students with visual impairments access the same educational materials as their sighted peers and participate fully in the curriculum. They can also help improve literacy skills, comprehension, and productivity. In this section, we will explore the importance of high-quality mobile apps for students with visual impairments and discuss some of the best apps available on the market today. *Table* **??** gives a list of current apps available for use with students with visual impairments.

2.3.1 Accessibility Training/Auditory Games

Table 2.5: Mobile apps for accessibility training and auditory games for students with visual impairments

App	Cost	Function	OS
CosmoBally in Space	free	Train VoiceOver Gestures	iOS/iPadOS
Ballyland Magic Plus	$3.99	Train VoiceOver Gestures	iOS/iPadOS
Ballyland Rotor	$2.99	Train VoiceOver rotor	iOS/iPadOS
Ballyland Stay Still Squeaky!	$2.99	Train VoiceOver Gestures	iOS/iPadOS
Blindfold Games Launcher	free[12]	Sonic Games	iOS/iPadOS
Blindfold Tap and Swipe	free	Train VoiceOver Gestures	iOS/iPadOS
ObjectiveEd Games	free[12]	Sonic Games	iOS/iPadOS
VO Lab	$4.99	Train VoiceOver Gestures	iOS/iPadOS
Screenreader	free	Train Accessibility Gestures	iOS/iPadOS, Android 13+

2.3.2 Cortical Vision Impairment

Table 2.6: Mobile apps for cortical vision impairment (CVI) training for students with visual impairments

App	Cost	Function	OS
Art of Glow	free	CVI-based Vision Training	iOS/iPadOS
Big Band Patterns	$34.99	CVI-based Vision Training	iOS/iPadOS
Big Bang Pictures	$34.99	CVI-based Vision Training	iOS/iPadOS
CVI Connect	$10/mo	CVI-based Vision Training	iOS/iPadOS
CVI Connect Pro	free[16]	CVI-based Vision Training	iOS/iPadOS
CVI Toddler Visual Eye Train	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Color)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Human face)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Pattern)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Recognition)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Visual Tracking)	free	CVI-based Vision Training	iOS/iPadOS

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Table 2.6: Mobile apps for cortical vision impairment (CVI) training for students with visual impairments (Continued)

App	Cost	Function	OS
Dexteria VMI	$5.99	CVI-based Vision Training	iOS/iPadOS
Doodle Kids	free	CVI-based Vision Training	iOS/iPadOS
EDA Play	$4.99	CVI-based Vision Training	iOS/iPadOS
EDA Play ELIS	$2.99	CVI-based Vision Training	iOS/iPadOS
EDA Play PAULI	$2.99	CVI-based Vision Training	iOS/iPadOS
EDA Play TOBY	free	CVI-based Vision Training	iOS/iPadOS
EDA Play TOM	free	CVI-based Vision Training	iOS/iPadOS
EyeMove	free	CVI-based Vision Training	iOS/iPadOS
Fludity HD	free	CVI-based Vision Training	iOS/iPadOS
Little Bear Sees	$4.99	CVI-based Vision Training	iOS/iPadOS
P.O.V. Spatial Reasoning	$3.99	CVI-based Vision Training	iOS/iPadOS
Peekaboo Barn	$2.99	CVI-based Vision Training	iOS/iPadOS

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Table 2.6: Mobile apps for cortical vision impairment (CVI) training for students with visual impairments (Continued)

App	Cost	Function	OS
Sensory Electra	free	CVI-based Vision Training	iOS/iPadOS
Sensory Light Box	$3.99	CVI-based Vision Training	iOS/iPadOS
Tap-n-See Now	$2.99	CVI-based Vision Training	iOS/iPadOS
VO Lab	free	CVI-based Vision Training	iOS/iPadOS
Visual Attention Therapy Lite	free	CVI-based Vision Training	iOS/iPadOS

Note: Summary: Specialized apps designed for CVI training and assessment, including pricing and supported platforms

2.3.3 Audiobook/Reading

Table 2.7: Mobile apps for audiobook, e-book, and DAISY reading for students with visual impairments

App	Cost	Function	OS
Audible	free[26]	Audiobook	iOS/iPadOS, AndroidOS 13+
BARD Mobile	free[27]	e-Book	iOS/iPadOS, AndroidOS 13+
Bookshare Reader	free	DAISY Reader	iOS/iPadOS
Dolphin EasyReader	free	DAISY Reader	iOS/iPadOS, AndroidOS 13+

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Table 2.7: Mobile apps for audiobook, e-book, and DAISY reading for students with visual impairments (Continued)

App	Cost	Function	OS
KNFB Reader (OneStepReader)	$99.99	OCR/Reading	iOS/iPadOS, AndroidOS 13+
Kindle	free[12]	e-Book	iOS/iPadOS, AndroidOS 13+
Libby	free[13]	Audiobook	iOS/iPadOS, AndroidOS 13+
VoiceDream Reader	free[28]	DAISY Reader	iOS/iPadOS

2.3.4 Productivity/Schoolwork/Optical Character Recognition

Table 2.8: Mobile apps for audiobook, e-book, and DAISY reading for students with visual impairments

App	Cost	Function	OS
Aiko	free	AI Speech to text	iOS/iPadOS
Ballyland Code 1: Say Hello	$2.99	Auditory Coding	iOS/iPadOS
Ballyland Code 2: Give Rotor	$2.99	Auditory Codings	iOS/iPadOS
Ballyland Code 3: Pick Up	$2.99	Auditory Coding	iOS/iPadOS
Clusiv	free[50]	Online learning platform[51]	iOS/iPadOS
Clusive	free	Online learning platform[52]	iOS/iPadOS

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Table 2.8: Mobile apps for audiobook, e-book, and DAISY reading for students with visual impairments (Continued)

App	Cost	Function	OS
Code Quest	free	Auditory Coding	iOS/iPadOS
Desmos Graphing Calculator	free	Accessible Graphing	iOS/iPadOS, AndroidOS 13+
Desmos Scientific Calculator	free	Accessible Scientific Calculator	iOS/iPadOS, AndroidOS 13+
Envision AI	free	OCR	iOS/iPadOS, AndroidOS 13+
GoodNotes	free[53]	Scan & Markup Documents	iOS/iPadOS, AndroidOS 13+
KNFB Reader (OneStepReader)	$99.99	OCR/Reading	iOS/iPadOS, AndroidOS 13+
My Board Buddy	free	local view of class blackboard	iOS/iPadOS
Notability	free[54]	Scan & Markup Documents	iOS/iPadOS, AndroidOS 13+
QuickScanner	free[55]	OCR	iOS/iPadOS, AndroidOS 13+
SeeingAI	free	Talking Camera	iOS/iPadOS, AndroidOS 13+
TapTapSee	free	Talking Camera	iOS/iPadOS, AndroidOS 13+
Voice Aloud Reader	free[56]	OCR/Reading	iOS/iPadOS, Android 13+

2.3.5 Orientation & Mobility / Navigation

Table 2.9: Mobile apps for productivity, schoolwork, and optical character recognition (OCR) for students with visual impairments

App	Cost	Function	OS
Apple Maps	free	Turn by Turn Navigation	iOS/iPadOS
BlindBat	free	Echolocation for the blind[66]	iOS/iPadOS
BlindSquare	$39.99	GPS Navigation	iOS/iPadOS
Clew	free	Indoor navigation[67]	iOS/iPadOS, AndroidOS 13+
Eyedar	free	Echolocation	iOS
GoodMaps Explore	free	Turn by Turn Navigation, Indoor navigation	iOS/iPadOS
GoodMaps Outdoors	free	Turn by Turn Navigation	iOS/iPadOS
Google Maps	free	Turn by Turn Navigation	iOS/iPadOS, AndroidOS 13+
HapticNav	free[16]	Haptic GPS navigation	iOS/iPadOS, AndroidOS 13+
Lazarillo	free	GPS navigation	iOS/iPadOS
Moovit	free[16]	Local Public Transit	iOS/iPadOS, AndroidOS 13+
Musical Cane Game	free	White Cane Training	iPadOS

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Table 2.9: Mobile apps for productivity, schoolwork, and optical character recognition (OCR) for students with visual impairments (Continued)

App	Cost	Function	OS
Oko	free	Smart Camera, Traffic lights/traffic	iOS/iPadOS, AndroidOS 13+
Seeing Eye GPS	free[68]	Turn by Turn Navigation	iOS/iPadOS, AndroidOS 13+
VoiceVista	free	Auditory Identification of Surroundings	iOS
Waymap	free	Turn by Turn Navigation, Indoor navigation	iOS/iPadOS, AndroidOS 13+
WeWalk	free[16]	GPS Navigation	iOS/iPadOS
XploreNinja	$39.99	GPS Navigation	AndroidOS 13+

2.3.6 Independent Living Skills

Table 2.10: Mobile apps for independent living skills for students with visual impairments

App	Cost	Function	OS
CashReader	free[78]	Scan and Identify Paper money	iOS/iPadOS, Android13+
Menus4All	free[79]	Accessible Restaurant Menus	iOS/iPadOS
Zuzanka	free[80]	Expiration Date, Barcode Scanner	iOS/iPadOS

Chapter 3

Bridging Literacy: The Crucial Role of Refreshable Braille Displays in Empowering Visually Impaired Students

In the intricate tapestry of education, the pursuit of literacy is a fundamental thread, weaving through the academic journey of every student. For visually impaired learners, the path to literacy takes on a unique character, one in which the tactile elegance of braille becomes a vital conduit to knowledge. Within this narrative, refreshable braille displays emerge as indispensable companions, unlocking the doors to literacy, fostering engagement, and propelling students toward academic success. This chapter explores how refreshable braille displays are not merely tools but keystones in the quest for literacy and educational achievement among visually impaired students.

Refreshable braille displays integrate the tactile richness of braille with the dynamic capabilities of digital communication. These devices are pivotal in ensuring that visually impaired students not only read but actively participate in the discourse of knowledge acquisition.

Refreshable braille displays serve as conduits for accessing textual content, enabling the exploration of literature, textbooks, and diverse educational materials in a format that aligns with the tactile language of braille. They also empower students to actively contribute to the discourse, facilitating note-taking, writing, and engaging in classroom discussions with the same spontaneity and fluency as their sighted peers.

By providing visually impaired students with the means to interact with written information independently and dynamically, these devices foster a sense of agency and pave the way for academic success.

3.1 Braille Notetakers and Laptops

Braille notetakers such as the BrailleSense6 and BrailleNote Touch Plus are essential tools for students with visual impairments to access their schoolwork and receive a free and accessible public education. These devices are small and portable, allowing students to take notes in class using either braille or standard (QWERTY) keyboard, or both. They can also be used to read books, write class assignments, find directions, record lectures, and listen to podcasts. The notes written on these devices can be transferred to a computer for storage or printed in either braille or print formats. Many note-taking devices have word processors, appointment calendars, calculators or clocks, and can do almost everything a computer can do. Some note-taking devices have a speech program with braille input. Many newer models are Bluetooth accessible which allows them to be used with iPads, iPhones and other Bluetooth devices as well as Wi-Fi access. Braille notetakers are useful not only for note taking in class, but also for composing and printing essays, writing notes, sending e-mails, or browsing the Internet. These devices can give students who are blind or have low vision support in all academic areas as well as in expanded core curriculum. By providing students with visual impairments access to braille notetakers, we can help ensure that they have the tools they need to succeed in their studies and beyond.

Table 3.1: Braille notetakers and laptops: device and operating system

Device Name	Operating System
BrailleNote Touch+	Android 8
BrailleSense 6	Android 10
BTSpeak Pro	Linux
Canute Console	Rasperian 12
ElBraille 40	Windows 10
InsideONE+	Windows 11

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Table 3.1: Braille notetakers and laptops: device and operating system (Continued)

Device Name	Operating System
Nattiq Note	Windows 11
Notey the Notetaker	Windows 11
Orbit Optima	Windows 11
Seika Studio	Windows 10
b.note	Windows 10
b.book	Windows 10

3.2 Braille Notetaker/Laptop Recommendations

The BrailleNote Touch Plus runs on Android 8.1 Oreo, while the BrailleSense 6 runs on Android 10[1]. Both operating systems are outdated, with Android 14 being the current version of the Android operating system as of July 3, 2025[2].

Using outdated operating systems can pose a security risk, as they no longer receive security updates. This makes it easier for harmful viruses, spyware, and other malicious software to gain access to your device. Hackers often target outdated operating systems because of their vulnerability, allowing them to breach your device and gain personal information. Preventing malicious access to hardware is one major reason why drivers and applications are made back-compatible only to versions of the operating system still receiving security updates.

It is important to keep your operating system up-to-date to ensure that you have access to the latest features and improvements. This can help improve the performance of your device and ensure that it is compatible with the latest software and hardware. Updating your operating system is a simple and effective way to keep your device running smoothly and securely.

However, updating an operating system is not always possible, as it depends on the device's hardware and software compatibility. It is also important to note that updating to

[1] December 2023 HIMS Released an Update for the BrailleSense 6 to upgrade it to Android 12, however it remains an update rather than pre-installed on the device Release Notes

[2] Android 15 will be released in Beta in February 2024 and as a stable version in October 2024

the latest operating system may not always be the best option, as it may cause compatibility issues with older software and hardware.

Table 3.2 gives the recommendations for currently available braille notetakers. An important note is that I favor Windows-based systems as the current most popular devices that run on the Android OS platform are both out-of-date with regards to their operating system as can be seen in *Table* 3.1 above.

Table 3.2: Braille notetaker and laptop recommendations with key specifications

Display	Battery	Keyboard	Manufacturer	OS
Orbit Optima	TBD	QWERTY	Orbit Research	Windows 11
Seika Studio	TBD	QWERTY	Nippon Telesoft	Windows 10
b.book	15h	Perkins	Eurobraille	Windows 10

3.3 Refreshable Braille Displays

Refreshable braille displays are essential tools for students with visual impairments to access digital content. The number of braille cells in a display is an important factor to consider when selecting a device. Displays with 32-40 cells are generally better than those with 14-20 cells for several reasons. Firstly, they provide more space for displaying text, which can help reduce the need for scrolling and improve reading speed. Secondly, they allow for more complex formatting, such as tables and graphs, which can be important for STEM subjects. Thirdly, they provide more context for the user, which can help improve comprehension and reduce errors. Fourthly, they are more versatile and can be used for a wider range of tasks, such as taking notes, writing essays, and browsing the internet. Finally, they are more future-proof, as they are more likely to be compatible with new technologies and software updates. While 14-20 cell displays may be more affordable, investing in a 32-40 cell display can provide significant benefits for students with visual impairments in the long run.

3.3.1 14-20 cell Refreshable Braille Displays

There are some situations where 14-20 cell displays may be more appropriate. For example, if the student only needs to read short messages or simple documents, a smaller display may be sufficient. Additionally, smaller displays are more portable and can be easier to carry around. They may also be more affordable, which can be important for students on a tight budget. Finally, smaller displays may be more appropriate for younger students who are just learning braille and may not need as much space for displaying text. While 14-20 cell displays may not be as versatile as larger displays, they can still provide significant benefits for students with visual impairments in certain situations.

Table 3.3: 14-20 cell refreshable braille displays: device and battery life

Device Name	Battery Life
Actilino	16 hours
Basic Braille 20	16 hours
Brailliant BI20x	14 hours
Chameleon 20	14 hours
Focus 14 Blue	18 hours
Orbit Reader 20+	20 hours
Orbit Speak	20 hours
BTSpeak	15 hours
Seika 24	20 hours
Seika Mini Plus	20 hours
VarioUltra 20	12 hours
b.note 20	15 hours

3.3.2 32-40 cell Refreshable Braille Displays

Displays with 32-40 cells provide more space for displaying text, allow for more complex formatting, and are more versatile for a wider range of tasks. While 14-20 cell displays may be more affordable, investing in a 32-40 cell display can provide significant benefits for students with visual impairments in the long run.

Table 3.4: 32-40 cell refreshable braille displays: features and manufacturers

Display	Battery	Keyboard	Manufacturer
Activator	40	Perkins	Help Tech
Active Braille	20	Perkins	Help Tech
Active Star	40	Perkins	Help Tech
Alva 640 Comfort	10	Perkins	Optelec
Alva 640 USB	n/a	none	Optelec
Alva BC 640	10	none	Alva
Basic Braille Plus	12	Perkins	Help Tech
Brailliant BI40x	14	Perkins	Humanware
Focus 40 Blue	18	Perkins	Vispero
Mantis Q40	14	QWERTY	APH
Orbit Reader 40	20	Perkins	Orbit Research
QBraille XL	16	Perkins	HIMS
Seika V5	20	none	Nippon Telesoft
Vario 340	20	none	VisioBraille
Vario 440	20	none	VisioBraille
Vario Ultra 40	12	Perkins	VisioBraille
b.note 40	15	Perkins	Eurobraille

3.4 Multiple Line Braille Displays/Tablets

Multiple line braille displays are better than single line refreshable braille displays for students with visual impairments for several reasons. Firstly, they provide more space for displaying text, which can help reduce the need for scrolling and improve reading speed. Secondly, they allow for more complex formatting, such as tables and graphs, which can be important for STEM subjects. Thirdly, they provide more context for the user, which can help improve comprehension and reduce errors. Fourthly, they are more versatile and can be used for a wider range of tasks, such as taking notes, writing essays, and browsing the internet. Finally, they are more future-proof, as they are more likely to be compatible with new technologies and software updates. While single line refreshable braille displays may be more affordable, investing in a multiple line display can provide significant benefits for students with visual impairments in the long run.

Table 3.5: Multiple line braille displays and tablets: features and manufacturers

Display	Battery	Braille Lines	Keyboard	Manufacturer
APH Monarch	11 hr	10 row x 32 cell + 32 cell line	Perkins	Humanware, APH
Blitab	TBD	14 row x 23 cell	Touch Interface	Blitab
BraillePad	TBD	50 row x 40 cells	none	4Blind
Cadence	TBD	6 row x 8 cells, stack to 24 x 16	Perkins	Tactile Engineering
Canute 360	Req AC	9 row x 40 cell	none	Bristol Braille
DotPad	11 hr	10 row x 32 cell + 20 cell line	Touch interface	Dot Inc.
Graphiti	20-22	60 row x 40 cell	Perkins	Orbit Research
Graphiti Plus	20-22	60 row x 40 cell + 40 cell line	Perkins	Orbit Research
Orbit Slate 340	20-22	5 row x 20 cell	Perkins	Orbit Research

Continued on next page

Table 3.5: Multiple line braille displays and tablets: features and manufacturers (Continued)

Display	Battery	Braille Lines	Keyboard	Manufacturer
Orbit Slate 520	20-22	5 row x 20 cell	Perkins	Orbit Research
TACTIS 100	Req AC	4 row x 25 cell	none	Tactisplay
TACTIS Table	Req AC	25 row x 40 cell	none	Tactisplay
TACTIS Walk	Req AC	10 row x 25 cell	none	Tactisplay
Tactile Pro	TBD	TBD	Perkins	PCT
Tactonom Pro	Req AC	89 row x 119 cell	N/A	Tactonom

3.5 Braille Education Devices

In many cases, students do not learn braille as efficiently as their sighted peers learn print. One potential explanation is that there is limited time that a student has access to a teacher trained in braille. One solution is to provide devices that can be used to reinforce or train a student in braille skills without the need for a braille-fluent adult present. This is analogous to the Lexia, Prodigy, or other academic learning systems that allow for self-paced learning. In the last 5 years, a number of teaching tools have been developed, primarily by groups in India and South Korea to address these needs.

Specialized tools like Taptilo and Polly/Annie are crucial for teaching Braille to students with visual impairment. These tools provide a more interactive and engaging learning experience for students, which can help them learn Braille more effectively. Taptilo is a Braille learning device that uses a modular design to teach Braille in a fun and interactive way. It has a variety of features such as audio feedback, games, and quizzes that can help students learn Braille more effectively[3]. Polly and Annie are two Braille teaching tools that use a combination of hardware and software to teach Braille to students. They use a variety of interactive games and activities to help students learn Braille more effectively[4].

In addition to providing a more engaging learning experience, specialized tools like

[3] Taptilo. (n.d.). Taptilo. Retrieved December 19, 2023 https://www.taptilo.com/
[4] Thinkerbell Labs. (n.d.). Polly. Retrieved December 19, 2023 https://www.thinkerbelllabs.com/

Taptilo and Polly/Annie can also help students learn Braille more quickly. These tools are designed to be intuitive and easy to use, which can help students learn Braille more quickly than traditional methods. Additionally, these tools can provide students with immediate feedback on their progress, which can help them identify areas where they need to improve.

Finally, specialized tools like Taptilo and Polly/Annie can help students with visual impairment become more independent. By learning Braille more effectively and quickly, students can become more independent in their daily lives. They can read books, take notes, and communicate with others more easily, which can help them lead more fulfilling lives.

Table 3.6: Braille education devices and their manufacturers

Equipment	Manufacturer
Braille Doodle	Touchpad Pro Foundation
Braille Teach	Braille Teach
BrailleBlox	BrailleBot
BrailleBuzz	APH
BrailleCoach	Logan Tech
Feelif Creator	Feelif Technology
Feelif Pro	Feelif Technology
Mountbatten Braille Tutor	Harpo
Polly[8]	APH / Thinkerbell Labs
Read Read	EdVar Tech
SMART Brailler	Perkins
Taptilo	HIMS / OHFA Tech

Chapter 4

Empowering Minds: The Crucial Role of High-Quality Braille Embossers in Unlocking STEM Literacy for Visually Impaired Students

In the ever-evolving realms of Science, Technology, Engineering, and Mathematics (STEM), the pursuit of literacy takes on a particularly intricate form. For visually impaired students, the challenges are multifaceted, but with the advent of high-quality braille embossers, a transformative bridge has been constructed. This chapter explores the indispensable role that high-quality braille embossers play in shaping the educational narrative of visually impaired students, especially in the critical domains of Math and STEM. These devices, with their ability to translate complex symbols and notations into tangible braille and tactile graphics, foster literacy, comprehension, and success in STEM fields.

The crux of this exploration lies in recognizing the nuanced requirements of visually impaired students pursuing education in Math and STEM disciplines. Traditional print materials, laden with intricate diagrams, mathematical symbols, and graphs, pose formidable challenges for learners with visual impairments. High-quality braille embossers bridge this gap, converting abstract mathematical concepts and scientific data into tangible formats, empowering students to actively engage with and comprehend the intricacies of STEM subjects.

Embossed tactile graphics break down the barriers to understanding complex mathematical equations, graphical representations, and scientific concepts, ultimately fostering a sense of autonomy and empowerment among visually impaired students. By providing access to the visual nuances inherent in STEM fields, these devices pave the way for literacy, comprehension, and active participation, ensuring that visually impaired students can unlock the full spectrum of opportunities in Math and STEM disciplines.

4.1 Braille Embossers

Having access to a high-quality braille embosser is essential for students with visual impairments to receive a free and appropriate public education. Braille embossers are printers that produce braille text and tactile graphics on paper. They are used to create braille copies of textbooks, worksheets, and other educational materials. High-quality embossers produce sharp, clear braille that is easy to read and tactile graphics that are easy to interpret. This is important because it allows students with visual impairments to access the same educational materials as their sighted peers. Braille embossers also allow students to create their own braille notes and written work, which can help improve their literacy skills and independence. By providing students with visual impairments access to high-quality braille embossers, we can help ensure that they have the tools they need to succeed in their studies and beyond. *Table 4.1* lists current available embossers[1].

Table 4.1: Braille embosser comparison: machine, capability, and company

Machine	Capability	Company
APH PageBlaster (old Model Index-D V4)	Simple Graphics, Interpoint Braille	APH, Index Braille
Basic-D V5	Simple Graphics, Interpoint Braille	Index Braille
BrailleTrac 120	Simple Graphics, Interpoint Braille	Irie-AT
Juliet 120	Simple Graphics, Interpoint Braille	ETS, Humanware

Continued on next page

1 I am only focusing on 11x11.5” braille paper size as US Letter size is impractical for braille

Table 4.1: Braille embosser comparison: machine, capability, and company (Continued)

Machine	Capability	Company
ViewPlus Columbia	Complex Graphics, Interpoint Braille	ViewPlus
ViewPlus Rogue (old ViewPlus Max)	Complex Graphics, Interpoint Braille	ViewPlus

4.2 High Resolution Tactile Graphics

There are some historical challenges that have befallen blind students that rely on tactile graphics and braille.

- Historically, by the time students with visual impairments enter school, they have not received enough instruction in the development and use of their tactile skills or had enough opportunities to touch and explore their world.[2]
- Tactile Graphicacy requires the ability to access, comprehend, and produce tactile graphics or raised line drawings. This requires:
  - Fine motor sensitivity and dexterity
  - Efficient use of carefully constructed knowledge
  - Variety of tactile-cognitive strategies
- Students have to develop a perception that there are different kinds of symbolic information on a page with different kinds of meaning
- Students have to develop an ability to discriminate between different tactile surfaces and to draw meaning from them
- These are *not* inherent or natural for braille readers as they require:
  - Explicit attention
  - Education
  - Careful, systematic building of tactile exploratory and interpretive skills

[2] Adkins, A., Sewell, D., & Cleveland, J. (2016). The Development of Tactile Skills. TX *SenseAbilities, Fall/Winter*.

There are a number of benefits to having access to accessible tactile graphics in the classroom. These include:

- Provides a focus for attention and perception
- Builds pathways to retain and memorize information
- Natural destination for conversation and social interaction
- Pictures invite and motivate a learner's curiosity and engagement

Table 4.2 lists current available embossers and other devices for creation of high resolution tactile graphics.

Table 4.2: High resolution tactile graphics embossers: machine and company.

Machine	Company
APH PixBlaster (old Model ViewPlus Columbia)	APH, ViewPlus
Basic-D V5	Index Braille
EZ-Form Brailon Duplicator	American Thermoform
PIAF tactile embosser	Humanware
Swell Form Machine	American Thermoform
ViewPlus Columbia	ViewPlus
ViewPlus Delta	ViewPlus
ViewPlus Elite	ViewPlus
ViewPlus Premier	ViewPlus

Specialized embossers for high-resolution tactile graphics production, listing available models.

4.3 Tactile Graphic Supplies

Table 4.3 lists materials needed to use with the graphics devices shown in *Table 4.2*.

Table 4.3: Paper supplies for Tactile Graphics Generation

Paper / Medium	Company
Brailon Thermoform Paper (for EZ-Form Duplicator)	American Thermoform
Swell Touch Paper (for Swell Form Machine)	American Thermoform
Tangible Magic capsule Paper (for PIAF tactile embosser)	Humanware
Tractor-Feed Braille Paper (for embossers)	APH

Chapter 5

Shaping Knowledge: The Imperative Role of 3D Printed Materials in Fostering Hands-On Literacy for Visually Impaired Students

In the realm of education, the power of hands-on experience is unparalleled. For visually impaired students, the journey toward literacy and comprehension takes on a unique dimension—one that is enriched and transformed through the tactile exploration of 3D printed materials. This chapter explores the indispensable role that 3D printed materials play in providing a tangible, tactile bridge to knowledge. These innovative creations facilitate hands-on engagement with concepts and serve as catalysts for literacy, fostering success for visually impaired students across a diverse spectrum of subjects.

The need for tangible exploration is paramount, especially when conceptualizing abstract ideas or interacting with physical entities is integral to the learning process. Traditional educational materials often rely on visual cues that pose challenges for students with visual impairments. 3D printed materials transcend the limitations of traditional teaching tools and enhance literacy by providing a multisensory gateway to understanding.

From historical artifacts to mathematical models, 3D printed materials transform abstract concepts into tangible, touchable entities. These creations allow visually impaired students to feel, explore, and internalize knowledge in a manner that aligns with their unique learning styles.

Hands-on learning with 3D printed materials fosters comprehension, empowerment, and curiosity. These tools democratize access to knowledge and enhance the educational journey for visually impaired students.

5.1 3D Printers

When selecting a 3D printer for students with visual impairments, it is important to consider the following features:

- *Tactile printing:* The printer should produce 3D models that are tactile and easily understood by students with visual impairments.
- *High resolution:* The printer should produce high-resolution models with fine details.
- *Ease of use:* The printer should be easy to use, set up, and maintain.
- *Compatibility:* The printer should be compatible with a wide range of software and file formats.
- *Cost:* The printer should be affordable and within the school or institution's budget.

3D printing can help visually impaired students learn a variety of disciplines such as engineering, manufacturing, food, art, and health.[1] 3D printed models can benefit both blind and sighted students, allowing for multisensory learning and independence.[2]

Table 5.1 lists current available 3D printers.

Table 5.1: Comparison of 3D printers: model, cost, print bed size, filament size, and manufacturer

Model	Cost	Print Bed Size	Filament Size	Manufacturer
Ender 3 Max Neo	$359	300x300x320mm	1.75mm	Creality
Ender 5 Plus	$579	350x350x400mm	1.75mm	Creality
K1	$599	220x220x256mm	1.75mm	Creality

Continued on next page

1 Karbowski, C. F. (2020). See3D: 3D Printing for People Who Are Blind. Journal of Science Education for Students with Disabilities, 23(1), n1.
2 MatterHackers. (2017). 3D printed educational models for the visually impaired. MatterHackers

Table 5.1: Comparison of 3D printers: model, cost, print bed size, filament size, and manufacturer (Continued)

Model	Cost	Print Bed Size	Filament Size	Manufacturer
Kobra Max	$569	450x400x400mm	1.75mm	Anycubic
Kobra Plus	$499	300x300x350mm	1.75mm	Anycubic
M5C	$399	220x220x250mm	1.75mm	AnkerMake
Mini+	$459	180x180x180mm	1.75mm	Prusa
Neptune 3 Max	$470	420x420x500mm	1.75mm	Elegoo
Neptune 4 Pro	$330	225x225x265mm	1.75mm	Elegoo
Anycubik Kobra S1 Combo	$749.99	—	1.75mm	Anycubic
Artillery M1 Pro	$349.00	—	1.75mm	Artillery
Elegoo Centauri Carbon	$299.99	—	1.75mm	Elegoo

Table 5.2: Additional 3D printers: model, cost, print bed size, filament size, and manufacturer.

Model	Cost	Print Bed Size	Filament Size	Manufacturer
P1P 3D Printer	$699	256×256×256mm	1.75mm	Bambu
P1S 3D Printer (Combo)	$949.99	256×256×256mm	1.75mm	Bambu
X1C Carbon Combo	$1,199.99	256×256×256mm	1.75mm	Bambu

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Table 5.2: Additional 3D printers: model, cost, print bed size, filament size, and manufacturer. (Continued)

Model	Cost	Print Bed Size	Filament Size	Manufacturer
H2D Combo	$2,199	—	1.75mm	Bambu
H2D Combo (Laser/Cricut)	$2,799	—	1.75mm	Bambu
Prusa Core ONE	$1,199.99	—	1.75mm	Prusa
Creality K2 Plus	$1,499.99	—	1.75mm	Creality
Sidewinder X2	$399	300x300x396mm	1.75mm	Artillery
A1 3D Printer	$559	256×256×256mm	1.75mm	Bambu

Premium and specialized 3D printers with advanced features for educational institutions. Includes printers with enclosures/environmental control.

5.2 Web Resources for 3D Print Files and Accessibility

Designed For VI Specifically

- BTactile, Benetech ImageShare, Median Augenbit, Tactiles

Math Curricula

- Nonscriptum Calculus, Geometry, Trigonometry

Astronomy/Physics

- 3D Opal, Astrokit, NASA, Roving Bits Constellations, Tactile Universe

Biology

- 3D Biology, NIH 3D Print Collections/Models

General User-Uploaded 3D Print File Collections

- 3D Warehouse, Cults 3D, GCTrader, GrabCad, Instructables, My Mini Factory, Pinshape, Printables, Sketchfab, Thingiverse, Traceparts, Turbo Squid, YouMagine

3D File Search Aggregators

- 3D Export, 3D Find It, 3D Print Shelf, 3DPea, 3DSourced, 3devo, 3dmdb, Creazilla, Free3d, MakerOnline, MakerWorld, Mito3D, Open 3D Model, Open3dSea, Pinshape, STL Finder, STLBase, STLRepo, SeekSTL, Serev3D, SketchFab, Thangs3D, Trofp, Yeggi

AI 3D Model Generation

- 3D AI Maker, Cube by CSM, Luma LLabs Genie, Meshcapade, Meshy.ai, Sline Design, Sloyd

Professional Groups

- AT Makers, Makers Making Change, Volksswitch

Visually Impaired Education and Accessibility Resources

- 3D Print Accessibility ListServ, Accessible 3D, Accessible Graphics, MatterHackers, Oklahoma ABLE Tech, See3D, Solid Print 3D

5.3 3D Printer Materials

3D printing creates three-dimensional objects from computer-aided design (CAD) files. The process involves depositing materials layer by layer to build a shape.[3] To use a 3D printer in an educational environment, you need:

- *3D printer*: Available in various sizes, from benchtop to large-format, including models with enclosures/environmental control for improved reliability.
- *Filament*: The material used to create the 3D object (e.g., PLA, TPU, ABS, PETG, etc.).[4]
- *Computer*: Required to create the 3D model using CAD software.
- *CAD software*: Used to create the 3D model.
- *Slicing software*: Converts the 3D model into a format the printer can understand and generates the G-code for printing.[5]

3D Printer Filament (PLA) and Color Resources

[3] Dassault Systèmes. (n.d.). 3D printing in education. Retrieved December 19, 2023

[4] Tech & Learning. (2023). Best 3D printers for schools. Retrieved December 19, 2023

[5] TeachThought. (2021). 10 ways 3D printing can be used in education. Retrieved December 19, 2023

FilamentColors is a color checking program for popular PLA vendors, providing Hex codes for reproducible color accuracy. Not all vendors are available, but the list is growing.

Prices are for 1kg/2.2lb basic PLA, default with spool unless noted. Refills require a spool. Bambu Labs AMS System compatibility prioritized. Prices as of 2025-04-08; tariffs may increase non-US supplier costs by 10-45%.

Non-US Suppliers:

- Bambu Labs: $22 ($17 with 4+ rolls) with spool; $19 ($14 with 4+ kg) for refills
- Creality: $15 Soleyin Ultra PLA; $17 Ender Fast PLA
- Dymanism: $30
- ELEGOO: $13
- eSun: $17
- Sunlu: $18
- MicroCenter Inland PLA: $19

Manufactured in the USA (no major tariff impact): Most US PLA is sourced from Natureworks LLC (Ingeo Line).

- 3D Fuel: $25
- 3D Innovators: $20
- 3DXTech: $32
- American Filament: $25 ($12 500g refill)
- Atomic Filament: $30
- AtraxiaArt: $24+
- Blendmaker: $16
- COEX LLC: $24
- Fila Cube: $23
- Filamatrix: $21
- Filastruder: $9 PLA, $11 PLA Pro
- Fusion Filaments: $29
- Gizmo Dorks: $23
- Greengate 3D: $31

- Hatchbox: $32
- IC3D: $29
- iiiD Max (3D Max): $21
- Jinos Filament: $22 ($17/16 spool pack)
- Keene Village Plastics: $30
- MakeShaper: $29
- Marlon Precision 3D Filaments: $23
- Matterhackers: $18+
- Monofilament Direct: $25
- Numakers: $20
- Overture 3D: $23
- Paramount 3D: $22 ($19/8pack)
- Polar Filament: $18
- Polymaker: $20
- PolySonic: $25
- PolyTerra: $20
- PrintBed: $25
- Printed Solid: $24
- Printerior: $28
- ProtoPasta: $19
- Push Plastic: $24
- RepKord: $40 ($10/1 pound)
- Splice 3D: $15/spool (bulk: $12 w/4+, $10 w/8+, $9 w/24+)
- Toner Plastics: $22
- VoxelPLA: $16
- ZYLTech: $17

Table 5.3 lists materials needed to use the 3D printers shown in Table 5.1.

Table 5.3: 3D Printer Materials

Item	Cost	Vendor
1.75mm filament (see above)	$13–$40/kg	Multiple (Bambu, Elegoo, 3D Fuel, etc.)
3D Print Tool Kit	$58.00	HIJIRH
Assorted Sandpaper (48 pcs)	$7.00	Vicien
Glue Sticks (30 pack)	$10.00	Amazon Basics
Painter's Tape (2” width 12 Pack)	$43.00	Amazon

5.4 3D Printer Software

3D printing software allows users to create, edit, and slice 3D models. These programs enable users to design models, slice them into layers, and generate G-code for the printer.

Resources for Programs to Create 3D Models

Free:

- 3D Slash: Free web version, fun UI.
- BRL-CAD: Advanced solid modeling, used by U.S. military.
- Blender: Open-source, steep learning curve, complex models.
- DesignSpark Mechanical: Free mechanical CAD, rapid prototyping.
- FreeCAD: Open-source parametric modeler.
- OpenSCAD: Script-based modeling for programmers.
- SketchUp: Balance of usability and functionality.
- Tinkercad: Browser-based, beginner-friendly, block-building.
- Wings3D: Open-source polygon modeler.

Education Plans:

- Fusion 360: Free for personal/startups, cloud-based, advanced features.
- Shapr3D: Multi-device, free and pro ($299/yr).

Professional:

- 3DS Max: $1,545/yr, animation and modeling.
- Cinema 4D: $720/yr or $3,945 perpetual.
- Inventor: $1,985/yr, mechanical design.
- Maya: $1,545/yr, animation.
- Modo: $599/yr or $1,799 perpetual.
- Rhino3D: $995, NURB modeling.
- SolidWorks: $1,295/yr or $3,995 perpetual.

3D Print Slicing Programs

- 3DPrinterOS, Bambu Studio (default for Bambu Labs), IdeaMaker, KISSlicer, OctoPrint, Orcaslicer, Repetier, Simplify3D, Slic3r, Ultimaker Cura.

Table 5.4 lists software and their functions.

Table 5.4: 3D Printer Software and Functions

Program	Cost	Function
Fusion 360	Free[9]	Generate 3D file
FreeCAD	$0	Generate 3D file
SolidWorks	$4,000/yr	Generate 3D file
TinkerCAD	$0	Generate 3D file
SketchUp Free	Free	Generate 3D file
Blender	$0	Generate 3D file
Rhino 6	$995/$195 student	Generate 3D file

Continued on next page

Table 5.4: 3D Printer Software and Functions (Continued)

Program	Cost	Function
Cura	$0	Slice & Print 3D Model
Slic3r	$0	Slice & Print 3D Model
PrusaSlicer	$0	Slice & Print 3D Model
Simplify3D	$149	Slice & Print 3D Model
Meshmixer	$0	Slice & Fix 3D Print Files
Meshlab	$0	Slice & Fix 3D Print Files

Chapter 6

Amplifying Vision: The Vital Role of Video Magnification Products in Fostering Literacy and Success for Visually Impaired Students

In the realm of visual impairment, the quest for literacy and academic success is a journey characterized by innovation and adaptability. For visually impaired students, the challenge of accessing printed materials, charts, and visual content is met with a powerful solution—video magnification products. The indispensable role that video magnification plays in providing enhanced visual access, breaking down barriers to literacy, and empowering students to navigate the educational landscape with confidence cannot be overstated.

The significance of video magnification products lies in their ability to transform the visual experience for students with visual impairments. As we navigate this chapter, we will unravel the sophisticated functionalities of these devices, showcasing how they go beyond traditional magnification methods to provide an immersive and dynamic visual experience. Whether exploring the pages of a textbook, deciphering intricate diagrams, or engaging with digital content, video magnification stands as a technological ally, ensuring that every student can access and interpret visual information with ease.

In the pursuit of literacy, the role of video magnification becomes increasingly pivotal, particularly in subjects where visual content is integral to comprehension. This chapter will delve into how these products facilitate not only enhanced readability but also active participation in classroom discussions, visual learning activities, and the overall educational experience. By providing visually impaired students with a clear and magnified view of the visual world, video magnification products serve as gateways to knowledge, fostering a sense of inclusion and leveling the playing field in academic settings.

It is evident that these tools are not mere aids; they are essential components in the arsenal of resources necessary for the success of visually impaired students. Video magnification imperatively contributes to shaping a learning environment where visual content is accessible to all, ensuring that literacy and success are attainable goals for every student, regardless of their visual abilities.

6.1 Video Magnification Devices

When purchasing electronic portable magnifiers for students with visual impairments, it is important to consider the following factors to ensure that they can access a free and appropriate public education[1]:

- *Magnification power*: The magnification power of the magnifier should be appropriate for the student's needs. Some magnifiers have a fixed magnification, while others have adjustable magnification.
- *Portability*: Portable magnifiers are ideal for students who need to move around the classroom or school. They should be lightweight and easy to carry. Battery life is an important consideration for portable magnifiers. The battery should last long enough to get through a school day without needing to be recharged.
- *Ease of use*: The magnifier should be easy to use and adjust. It should have large buttons and controls that are easy to locate and operate. Compatibility with other assistive technology devices, such as screen readers and braille displays, is also important.
- *Cost*: The cost of the magnifier should be reasonable and within the school's budget.

These considerations will help ensure that students with visual impairments have access to the tools they need to succeed in school. Table **??** lists current available video magnification devices for students with visual impairments.

[1] *cf*., Perkins School for the Blind. (n.d.). Choosing an appropriate video magnifier. Retrieved December 19, 2023

Table 6.1: Comparison of video magnification devices: model, deployment, and company

Model	Deployment	Company
AceSight VR	VR Headset	Zoomax
Acesight	E-Glasses	Zoomax
Acesight 8	E-Glasses	Zoomax
Acuity 22	Desktop	Irie AT
Acuity 22 Speech	Desktop	Irie AT
Amigo	Portable	Enhanced Vision
Cloverbook Plus	Mobile	Irie-AT
Cloverbook Pro	Mobile	Irie-AT
Connect 12	Desktop, Mobile	Humanware

Table 6.2: Additional video magnification devices and screen magnifiers for visually impaired students

Model	Deployment/Screen	Company
Connect 12 (10x)	Desktop, Mobile	Humanware
Connect 12 (25x)	Desktop, Mobile	Humanware
Distance Camera	Hand-Held	Zoomax
explore 12	Desktop	Humanware
explore 5	Hand-Held (5” screen)	Humanware
explore 8	Hand-Held (8” screen)	Humanware
I-See 22”	Desktop	Irie AT

Continued on next page

Table 6.2: Additional video magnification devices and screen magnifiers for visually impaired students (Continued)

Model	Deployment/Screen	Company
Juno	Hand-Held (7” screen)	APH
Jupiter Portable Magnifier	Desktop, Mobile (heavy)	APH
Luna 6	Hand-Held (6” screen)	Zoomax
Luna 8	Hand-Held (8” screen)	Zoomax
Luna Eye	Hand-Held	Zoomax
Luna HD Pro	Desktop	Zoomax
Luna S	Hand-Held (4.3” screen)	Zoomax
MAGNA 3	Hand-Held (3.5” screen)	Orbit Research
MAGNA 4	Hand-Held (4.3” screen)	Orbit Research
MAGNA 5	Hand-Held (5” screen)	Orbit Research
MATT Connect v2	Desktop, Mobile (heavy)	APH
Magnibot	Desktop, Mobile	Trysight
Magnilink Air	Desktop	Low Vision International
MagniLink Tab	Desktop	Low Vision International
MagniLink One	Desktop	Low Vision International
MagniLink S Premium	Mobile	Low Vision International
MagniLink Vision	Desktop	Low Vision International
MagniLink WifiCam	Mobile	Low Vision International
MagniLink Zip	Desktop	Low Vision International

Continued on next page

Table 6.2: Additional video magnification devices and screen magnifiers for visually impaired students (Continued)

Model	Deployment/Screen	Company
Merlin Mini	Mobile	Enhanced Vision
ONYX Desk set HD	Desktop	Freedom Scientific
ONYX OCR	Desktop	Freedom Scientific
Panda HD	Desktop	Zoomax
Pebble HD	Handheld	Enhanced Vision
RUBY	Hand-Held (4.3” screen)	Freedom Scientific
RUBY 10	Hand-Held (10” Screen)	Freedom Scientific
RUBY 7 HD	Hand-Held (7” Screen)	Freedom Scientific
RUBY HD	Hand-Held (4.3” screen)	Freedom Scientific
RUBY XL HD	Hand-Held (5” screen)	Freedom Scientific
Reveal 16	Desktop	Humanware
Reveal 16 (XY table)	Desktop	Humanware
Reveal 16i	Desktop	Humanware
Reveal 16i (XY table)	Desktop	Humanware
Snow 12	Desktop, Mobile	Zoomax
Snow Pad	Hand-Held	Zoomax
TOPAZ EZ HD	Desktop	Freedom Scientific
TOPAZ OCR	Desktop	Freedom Scientific
TOPAZ XL HD	Desktop	Freedom Scientific

Continued on next page

Table 6.2: Additional video magnification devices and screen magnifiers for visually impaired students (Continued)

Model	Deployment/Screen	Company
Tactonum Pro	Desktop (Not Readily Mobile)	Tactonum
Taxtonum Reader	Desktop (Not Readily Mobile)	Tactonum
Transformer HD	Mobile	Enhanced Vision
Traveller HD	Mobile	Optelec

Chapter 7

Beyond Boundaries: Text-to-Speech and DAISY as Catalysts for Literacy and Success in Visual Impairment Education

The National Instructional Materials Accessibility Standard (NIMAS) and Digital Accessible Information System (DAISY) are two important tools for the education of students with visual impairments. NIMAS is a technical standard used by publishers to prepare “electronic files” that are used to convert instructional materials into accessible formats. The purpose of NIMAS is to help increase the availability and timely delivery of instructional materials in accessible formats for qualifying students in elementary and secondary schools[1]. DAISY is a digital format for audio books that is designed to be more accessible to people with visual impairments. DAISY books can be read using specialized software that allows users to navigate through the book using headings, bookmarks, and other features[2].

NIMAS and DAISY are important because they help make educational materials more accessible to students with visual impairments. By providing instructional materials in accessible formats, students with visual impairments can participate more fully in the general education curriculum. This can help improve their academic performance and increase their chances of success in school.

Finally, NIMAS and DAISY can help students with visual impairments become more

1 AEM Center. (n.d.). NIMAS & NIMAC. Retrieved December 19, 2023

2 DAISY Consortium. (n.d.). What is DAISY? Retrieved December 19, 2023

independent. By providing instructional materials in accessible formats, students can read books, take notes, and communicate with others more easily. This can help them lead more fulfilling lives and become more active members of their communities.

In the evolving landscape of education, the pursuit of literacy is a journey marked by innovation and inclusivity. For visually impaired students, the traditional pathways to literacy take on a distinctive form, guided by the transformative power of audiobook and DAISY readers. This chapter explores the indispensable role that these tools play in breaking down barriers to literacy, ensuring access to knowledge, and propelling visually impaired students towards academic success.

7.1 DAISY Readers

Assistive technology is a crucial tool for students with visual impairments or blindness to receive a free and appropriate public education. One such technology is the DAISY format, which is designed to provide an accessible and navigable format for digital books and other publications. DAISY books can be read using specialized software that provides text-to-speech functionality, allowing students to listen to the content of the book in a digitized voice. This technology can be a game-changer for students who struggle with reading text in written form, as it allows them to access the same materials as their peers.

DAISY is a standard format for digital audio books, magazines, and computerized text. DAISY-encoded educational content is an essential tool for students with visual impairments to receive a free and appropriate public education. DAISY books can be read with specialized software that allows the user to navigate through the book using bookmarks, headings, and other navigational aids. This allows students with visual impairments to access the same educational materials as their sighted peers. DAISY books can also be read aloud using text-to-speech software, which can help improve literacy skills and comprehension. Additionally, DAISY books can include tactile graphics, which can help students with visual impairments better understand complex concepts. By providing students with visual impairments access to DAISY-encoded educational content, we can help ensure that they have the tools they need to succeed in their studies and beyond.

Table 7.1: DAISY readers and digital audio players: models, function, and company

Model	Function	Company
Milestone 212 Ace Book Reader	DAISY Reader, Digital Audio Player	Bones
PlexTalk PTN2	DAISY Reader, CD Player	PlexTalk
PlexTalk Pocket	DAISY Reader, Digital Audio Player	PlexTalk
Reizen DAISY Digital Recorder	DAISY Reader, Digital Audio Player	Reizen
Victor Reader Stratus	DAISY Reader, Digital Audio Player (Not very portable)	Humanware
Victor Reader Stream	Digital Audio Player	Humanware
Victor Reader Trek	GPS, Digital Audio Player	Humanware

7.2 Text-to-Speech

The use of assistive technology, including Text-to-Speech, is required for all students with disabilities that show a need under the Individuals with Disabilities Education Act (IDEIA)[3]. Text-to-Speech technology is a powerful tool that can help students with visual impairments or blindness receive a free and appropriate public education.

Table 7.2: Text-to-speech devices: model, function, and company

Model	Function	Company
c-Pen2	Pen Scanner, Text-to-Speech Reader	c-Pen

Continued on next page

3 20 U.S.C. § 1400, et.

Table 7.2: Text-to-speech devices: model, function, and company (Continued)

Model	Function	Company
MyEye Pro	Glasses Mounted, Text to Speech	OrCam
LyriQ	Text to Speech	Zyrlo
Read 3	Hand-held Text to Speech	OrCam
Scanmarker Air	Hand-held Text to Speech	Scanmarker
Smart Reader HD	Portable Text to Speech	Enhanced Vision

Chapter 8

Navigating Independence: The Essential Role of Accessible Daily Living Technology in Empowering Visually Impaired Students for Success and Safety

In the pursuit of independence and safety, orientation and mobility training holds a pivotal place in the educational journey of visually impaired students. In this dynamic landscape, accessible GPS equipment emerges as a technological beacon, offering a transformative bridge to mobility, autonomy, and enhanced safety. This chapter explores the indispensable role that accessible GPS tools play in empowering visually impaired students for success, ensuring safe navigation through the world, and fostering a sense of confidence in their daily lives.

The quest for independence is intricately tied to the ability to navigate and explore the surrounding environment. For visually impaired students, this journey is often met with challenges that extend beyond the typical obstacles encountered in education. Accessible GPS equipment becomes a critical ally, providing not only the means to explore the world independently but also enhancing safety through reliable navigational assistance.

As we delve into this chapter, we will explore the functionalities of accessible GPS devices tailored to the unique needs of visually impaired users. From real-time audible directions to haptic feedback systems, these tools extend beyond standard navigation, creating a multi-sensory experience that empowers students to traverse their surroundings confidently. The importance of this technology is accentuated during orientation and mobility training, where students learn not only to navigate physical spaces but also to develop crucial skills for safety and situational awareness.

Beyond the practicalities of navigation, the impact of accessible GPS equipment on student success cannot be overstated. These tools contribute to broader educational goals by fostering a sense of independence, reducing reliance on external assistance, and instilling a foundational skill set for safe and self-assured mobility.

Through this exploration, it becomes clear that accessible GPS equipment is not merely a tool for navigation; it is a catalyst for empowerment and safety. Through orientation and mobility training, we ensure that visually impaired students can embark on their educational journeys with a sense of autonomy, confidence, and, above all, safety.

8.1 Accessible GPS Hardware

When purchasing an accessible GPS unit for the blind, it is important to consider the following factors to ensure safe navigation and crossing of streets:

- *Audible signals*: The GPS unit should provide audible signals to indicate when it is safe to cross the street. This feature allows blind pedestrians to cross the road at the right time, more quickly and safely while maintaining their orientation throughout the crossing[1].
- *Compatibility*: The GPS unit should be compatible with other assistive technology devices, such as screen readers and braille displays[2].
- *Portability*: Portable GPS units are ideal for blind pedestrians who need to move around the city. They should be lightweight and easy to carry.
- *Battery life*: Battery life is an important consideration for portable GPS units. The battery should last long enough to get through a day without needing to be recharged.
- *Ease of use*: The GPS unit should be easy to use and adjust. It should have large buttons and controls that are easy to locate and operate.

These considerations will help ensure that blind pedestrians have access to the tools they need to navigate and cross streets safely. *Table* 8.1 lists current available accessible GPS hardware devices.

[1] Inclusive City Maker. (n.d.). Pedestrian safety: Are your crossings safe for the visually impaired? Retrieved December 19, 2023

[2] American Foundation for the Blind. (n.d.). Smartphone GPS navigation. Retrieved December 19, 2023

Table 8.1: Accessible GPS hardware: model, function, and company

Model	Function	Company
Stellar Trek	GPS	Humanware
Victor Reader Trek	GPS + Digital Audio Player	Humanware
Wayband	GPS (Haptic Output)	WearWorks

8.2 Accessible Technology for Daily Living

Auditory feedback technology is essential for blind people to live independently and complete daily tasks. It provides a way for the visually impaired to interact with their environment and receive information that they would otherwise miss. For example, an auditory-based tool can be used to support totally blind people to check the lights in an autonomous and relatively simple way[3]. This is just one example of how technology can be used to help the blind. Other examples include haptic feedback, which can be used to provide tactile feedback to the user, and voice recognition software, which can be used to control devices and appliances. These technologies can help the visually impaired to navigate their environment, communicate with others, and perform tasks that would otherwise be difficult or impossible.

By providing auditory feedback, technology can help the blind to live more independently and improve their quality of life. For instance, auditory-based tools can be used to support totally blind people to check the lights in an autonomous and relatively simple way[3]. This tool can be used to detect the presence of light and provide feedback to the user through sound. The study also proposed an idea that can be exploited in other application cases that use light feedback[4]. This is just one example of how technology can be used to help the blind. Other examples include haptic feedback, which can be used to provide tactile feedback to the user, and voice recognition software, which can be used to control devices and appliances. These technologies can help the visually impaired to navigate their environment, communicate with others, and perform tasks that would otherwise be difficult or impossible.

In addition to the benefits mentioned above, auditory feedback technology can also help

[3] Leporini, B., Rosellini, M., & Forgione, N. (2020). Designing assistive technology for getting more independence for blind people when performing everyday tasks: an auditory-based tool as a case study. Journal of Ambient Intelligence and Humanized Computing, 11(6), 6107-6123.

[4] American Council of the Blind. (n.d.). Accessible pedestrian signals (APS). Retrieved December 19, 2023

the blind to learn new skills and improve their education. For example, a study published in Frontiers in Neuroscience showed how haptic feedback can be used to help blind people learn Braille[5]. The study found that haptic feedback can help the user to learn Braille faster and more accurately than traditional methods. This is just one example of how technology can be used to help the blind to learn new skills and improve their education. By providing auditory feedback, haptic feedback, and voice recognition software, technology can help the visually impaired to live more independently, improve their quality of life, and learn new skills.

8.2.1 Accessible Home Technology

When purchasing household items modified to give audio feedback for the blind, it is important to consider the following factors to ensure that they can access activities of daily living[6]:

- *Audible feedback*: Household items should provide audible feedback to the user to ensure that they are being used correctly and safely.
- *Compatibility*: The item should be compatible with other assistive technology devices, such as screen readers and braille displays.
- *Ease of use*: The item should be easy to use and adjust. It should have large buttons and controls that are easy to locate and operate.
- *Portability*: Portable items are ideal for blind users who need to move around the house. They should be lightweight and easy to carry.
- *Cost*: The cost of the item should be reasonable and within the user's budget.

These considerations will help ensure that blind users have access to the tools they need to perform activities of daily living safely and independently.

Table 8.2 shows a range of technology available for blind/visually impaired people designed to facilitate independent living[7].

[5] Fleury, M., Lioi, G., Barillot, C., & Lécuyer, A. (2020). A Survey on the Use of Haptic Feedback for Brain-Computer Interfaces and Neurofeedback. Frontiers in Neuroscience, 14. doi.org/10.3389/fnins.2020.00528

[6] All About Vision. (n.d.). Adapting your home for better blindness accessibility. Retrieved December 19, 2023

[7] Prices from either The Braille Bookstore or Maxi-Aids, two major vendors of products intended to facilitate independent living skills

Table 8.2: Accessible home technology: model and cost.

Model	Cost
Infrared Talking thermometer	$45
Liquid Level Indicator	$10
PenFriend Voice Labelling System	$170 (Extra 418 labels: $30)
Talking First Aid Guide	$35
Talking Indoor/Outdoor Thermometer	$15
Talking Kitchen Scale	$35
Talking Measuring Tape	$145
Talking Meat Thermometer	$40
Talking Timer Clock	$15
Talking Watch	$15
Talking Weighing Scale	$35
Talking Pulse Oximeter	$32
Talking Scale (Body Weight)	$70
Talking Blood Pressure Monitor	$135
Talking Pill System	$70
Talking Blood Glucose Meter	$38
WayLink Scanner	$125 (Extra 25 magnets: $40)

Chapter 9

Conclusion

In conclusion, the Individuals with Disabilities Education Act (IDEIA) mandates that students with disabilities, including those with visual impairments, must be given access to assistive technology to ensure they can participate fully in the curriculum[1]. Screen magnification is one such assistive technology that can help students with visual impairments access their free public education. The overarching goal of this document has been to shed light on the essential role that technology plays in not only accommodating these students but empowering them to thrive in educational environments. By providing students with visual impairments access to the technology they need, we can help ensure that they have the tools they need to succeed in their studies and beyond.

Assistive technology is a critical component of ensuring that students with visual impairments receive a free and appropriate public education. The technology needs of these students must be addressed within the framework of IDEIA, which mandates that students with disabilities must be given access to assistive technology to ensure they can participate fully in the curriculum. By providing students with visual impairments access to the technology they need, we can help ensure that they have the tools they need to succeed in their studies and beyond.

In addition to helping students with visual impairments access information and participate in classroom activities, assistive technology can also help these students become more independent. By providing students with the tools they need to access information and communicate with others, assistive technology can help them become more self-sufficient and less reliant on others. This can help improve their self-esteem and confidence, which can have a positive impact on their academic performance and overall well-being.

1 20 U.S.C. § 1400, et.

Finally, it is important to note that the use of assistive technology is not a one-size-fits-all solution. The technology needs of students with visual impairments can vary widely depending on their individual needs and abilities. Therefore, it is important to work with students, families, and educators to identify the most appropriate assistive technology solutions for each student. By doing so, we can help ensure that students with visual impairments have the tools they need to succeed in school and beyond.

In conclusion, the use of assistive technology is critical for students with visual impairments to receive a free and appropriate public education. The technology needs of these students must be addressed within the framework of IDEIA[1], which mandates that students with disabilities must be given access to assistive technology to ensure they can participate fully in the curriculum. The use of assistive technology is essential for students with visual impairments to access the same educational materials as their sighted peers. Assistive technology can help students with visual impairments access text information across all curricular areas and participate fully in instruction that is often rich with visual content. The use of assistive technology also helps prepare students for independent living, vocational pursuits, or higher education following graduation from high school. By providing students with visual impairments access to the technology they need, we can help ensure that they have the tools they need to succeed in their studies and beyond.

Appendix A

Troubleshooting Screenreader & Magnifier Performance

A.1 Clearing System Cache

One thing that it often recommended to users of screenreaders is that they maintain a habit of clearing the browser and system cache(s) in order to optimize performance of their laptop. Clearing the computer and browser cache is a common practice to free up space on the hard drive and improve the performance of the computer. However, this practice does not speed up the response of a computer if it has a Solid State Drive (SSD) rather than a spinning hard drive. This is because SSDs work differently than spinning hard drives. When data is written to an SSD, it is written to a block of memory called a page. When the page is full, the data is moved to another block of memory called a block. The block must be erased before new data can be written to it. This process is called garbage collection and it happens automatically in the background. Clearing the cache does not speed up the garbage collection process.

In addition, SSDs have a limited number of write cycles. Every time data is written to an SSD, it uses up one of these write cycles. Clearing the cache causes more data to be written to the SSD, which can reduce the lifespan of the drive. This is because when the cache is cleared, the computer must download the data again, which requires writing the data to the SSD. This can cause unnecessary wear and tear on the drive and reduce its lifespan.

Finally, clearing the cache can actually slow down the response of a computer with an SSD. This is because the cache stores frequently accessed data, such as images and scripts, so that they can be loaded quickly. When the cache is cleared, the computer must download this data again, which can slow down the response time. In contrast, spinning hard drives are slower than SSDs and can benefit from clearing the cache. This is because spinning hard drives have to physically move a read/write head to access data, which can take longer than reading data from an SSD.

A.2 Slow Responsiveness

When a screen reader like JAWS or NVDA is not responding to input or is taking a long time to report changes on the screen, there are several things you can try to resolve the issue. First, try restarting the screen reader and the computer. This can help clear any temporary issues that may be causing the problem. If this does not work, try updating the screen reader to the latest version. Screen readers are updated regularly to fix bugs and improve performance. Updating to the latest version may help resolve the issue.

If the problem persists, try adjusting the settings of the screen reader. Some screen readers have settings that can be adjusted to improve performance. For example, you can adjust the verbosity level to reduce the amount of information that is read out loud. You can also adjust the speed of the screen reader to make it faster or slower. Experimenting with these settings may help improve the performance of the screen reader.

Finally, if none of these steps work, you may need to contact the manufacturer of the screen reader for further assistance. They may be able to provide additional troubleshooting steps or help you diagnose the problem. It's important to remember that screen readers are complex pieces of software and may require specialized knowledge to troubleshoot. By following these steps, you can help ensure that your screen reader is working properly and providing you with the accessibility you need.

A.3 Official Support Contact

- JAWS/Fusion: You can submit a technical support request, call 727-803-8600 weekdays between 8:30 AM and 7:00 PM ET, or send an email to Freedom Scientific Support.
- Dolphin Products: You can contact Dolphin's technical support team by emailing Dolphin Support.
- NVDA: You can submit a bug report or request support by emailing NVDA Support Desk.

- Windows: You can contact Microsoft's technical support team by visiting the following link: Microsoft Support.

A.4 Community Support via ListServ

Sometimes asking a listserv that talks about screen readers may give faster responses than contacting official customer support. Listservs are online communities where people with similar interests can share information and help each other out. Members of these communities are often experts in their field and can provide quick and accurate answers to questions. In contrast, customer support teams may have to follow a set of procedures and protocols before they can provide assistance. This can take time and may not always result in a satisfactory resolution. Additionally, customer support teams may not be available 24/7, whereas listservs are often active around the clock. However, it's important to remember that listservs are not official sources of information and the advice given may not always be accurate or up-to-date. It's always a good idea to verify information before acting on it.

Here are links to relevant listservs for visual impairment accessibility needs.

- JAWS / Fusion
  - The JAWS for Windows Support List
  - JFW Users List
  - Jaws Discussion
  - Jaws Lite
  - JAWS Scripting
- NVDA
  - NVDA Group
  - NVDA Addons Group
  - Chat Subgroup of the NVDA Group
  - NVDA Development
  - NVDA Discussion
  - NVDA Help

- Windows / General Accessibility
  - Windows Access with Screen Readers
- General Technology (Screenreaders Discussed Frequently)
  - Blind tech Discuss
  - Tech For Blind
  - BlindADTech
  - Blind Techies

Appendix B

Troubleshooting Braille Notebooks and Displays

B.1 Braille Notetakers

If your Braille notetaker is not responding to user input, there are several things you can try to troubleshoot the issue. First, ensure that the device is properly charged and turned on. If the device is still not working, try restarting it by holding down the power button for a few seconds. If the problem persists, check the settings of the device to ensure that it is configured to work with your specific screen reader software. If none of these steps work, consult the user manual for your specific Braille notetaker or contact the manufacturer for further assistance.

If you are using a BrailleNote Touch Plus, you can also try resetting the device to its original settings by starting it in recovery mode[1]. This will restore the device to its factory settings and may help to resolve any issues with the device. If you are still having trouble, you can try restoring the device to its default settings or adjusting the settings to be optimized for testing. If you are using a BrailleSense 6, you can try updating the firmware to the latest version and re-initialize factory defaults[2]. This will restore the device to its factory settings and may help to resolve any issues with the device. If you are still having trouble, you can try restoring the device to its default settings or adjusting the settings to be optimized for testing. If you are using a BrailleSense 6, you can try updating the firmware to the latest version and re-initialize factory defaults[3]. This may help to resolve

1 Humanware. (n.d.). BrailleNote Touch - Frequently Asked Questions. Retrieved December 18, 2023
2 BrailleSense 6 User Manual, Chapter3.9, page 68
3 BrailleSense 6 User Manual, Chapter3.9, page 68

any issues with the device and improve its performance.

In summary, if your Braille notetaker is not responding to user input, there are several steps you can take to troubleshoot the issue. These include checking the battery and power settings, restarting the device, checking the software settings, and consulting the user manual or contacting the manufacturer for further assistance. By following these steps, you can help ensure that your Braille notetaker is working properly and that you can continue to use it to access information and complete tasks.

B.2 Braille Displays

If your refreshable braille display is not responding with the computer screen reader, there are several things you can try to troubleshoot the issue. First, ensure that the braille display is properly connected to the computer and that the drivers are installed correctly. If the display is still not working, try restarting the computer and the screen reader software. If the problem persists, check the settings of the screen reader software to ensure that it is configured to work with the braille display. If none of these steps work, consult the user manual for your specific braille display or contact the manufacturer for further assistance.

B.3 Official Support Contact

- HIMS: You can submit a technical support request, call 512-837-2000 weekdays between 8:30 AM and 5:30 PM CST, or send an email to HIMS Technical Support
- Humanware: You can submit a technical support request, call 1-800-722-3393 weekdays between 8:30 Am and 7:00 PM ET, or fill out the Customer Support Contact Form and select "Technical Support" as the subject.
- Orbit Research: You can submit a technical support request, call 1-888-606-7248 from 9:00 AM - 5:00 PM ET, or send an email to Orbit Research Technical Support
- Eurobraille: You can submit a technical support request, call 331 55 26 91 00 (company is located in Madrid, France. Customer service speaks French, Spanish, and English) from 2:30AM - 6:00AM/7:30-11:30 AM ET or send an email to Technical Support
- Nippon Telesoft: You can email Nippon Telesoft Technical Service
- Nattiq Technologies: You can email Nattiq Technologies Technical Support

- Notey the NoteTaker: You can search for technical support at The Notey the Notetaker Support Forum. The individual components are subject to the support provided by the various companies.
- Bristol Braille: You can email Bristol Braille Technical Support
- Freedom Scientific: You can submit a technical support request, call 727-803-8600 weekdays 8:30Am-7:00PM ET, or fill out the Freedom Scientific Technical Support Contact Page
- APH: You can submit a technical support request, call 800-223-1839 weekdays from 8:00AM - 8:00PM ET or send an email to APH Customer Service Support
- VisioBraille: You can submit a technical support request by emailing VisioBraille GmbH Service Department
- Help Tech: You can submit a technical support request by filling out the Help Tech Service Request Form
- Optelec: You can submit a technical support request by filling out the Optelec Customer Service Contact Form

B.4 Community Support via ListServ

Sometimes asking a listserv that talks about refreshable braille displays may give faster responses than contacting official customer support. Listservs are online communities where people with similar interests can share information and help each other out. Members of these communities are often experts in their field and can provide quick and accurate answers to questions. In contrast, customer support teams may have to follow a set of procedures and protocols before they can provide assistance. This can take time and may not always result in a satisfactory resolution. Additionally, customer support teams may not be available 24/7, whereas listservs are often active around the clock. However, it's important to remember that listservs are not official sources of information and the advice given may not always be accurate or up-to-date. It's always a good idea to verify information before acting on it.

- Braille Displays
  - Brailliant-BI-X Users Support List
  - Braille Display Users
  - BrailleNote Users
  - NLS e-Reader

- Orbit Reader Discussion group
- Refreshable Braille & tactile Graphics Devices
- Braille Sense Discussion
- APH Mantis & Chameleon User
- Dynamic Tactile Display Announcements (APH Monarch)
- HIMS Notetakers

* General Technology (Braille Displays Discussed Frequently)
  - Blind tech Discuss
  - Tech For Blind
  - BlindADTech
  - Blind Techies

Appendix C

Assistive Technology Considerations

Assistive technology is an essential component of ensuring that students with visual impairments receive a free and appropriate public education. However, it is important to use a valid assistive technology assessment before providing assistive technology to a student. A valid assessment can help identify the specific needs of the student and determine the most appropriate assistive technology solutions. This can help ensure that the student receives the right tools to succeed in their studies[1]. Additionally, a valid assessment can help ensure that the student receives the appropriate accommodations and modifications to their educational program[2].

It is also essential to use all the data available to guide decision making when providing assistive technology to a student. This includes data from the student, their family, and their educators. By using all the data available, educators can make informed decisions about the most appropriate assistive technology solutions for each student. This can help ensure that the student receives the right tools to succeed in their studies[3]. It is important to note that convenience should not be a factor when making decisions about assistive technology. The focus should always be on what is best for the student.

Using a valid assistive technology assessment and all available data to guide decision making can help ensure that students with visual impairments receive the appropriate assistive technology solutions to succeed in their studies. This can help improve their academic performance and increase their chances of success in school. Additionally, it can help students with visual impairments become more independent in their daily lives.

1 AEM Center. (n.d.). NIMAS & NIMAC. Retrieved December 19, 2023

2 DAISY Consortium. (n.d.). What is DAISY? Retrieved December 19, 2023

3 AEM Center. (n.d.). Assistive Technology. Retrieved December 19, 2023

By providing students with the tools they need to access information and communicate with others, assistive technology can help them become more self-sufficient and less reliant on others[4].

Finally, it is important to note that the use of assistive technology is not a one-size-fits-all solution. The technology needs of students with visual impairments can vary widely depending on their individual needs and abilities. Therefore, it is important to work with students, families, and educators to identify the most appropriate assistive technology solutions for each student. By doing so, we can help ensure that students with visual impairments have the tools they need to succeed in school and beyond.

C.1 SETT Framework

The SETT Framework[5,6] is a widely used method for evaluating assistive technology (AT) needs for students with disabilities. The acronym SETT stands for Student, Environment, Task, and Tools. The framework emphasizes the importance of understanding the student's characteristics, the environments in which they learn and grow, and the tasks required to be an active learner in those environments before identifying a system of tools that enables the student to actively engage in the tasks. A team-based collaborative assessment of needs will lead to determining the most promising system of tools for the student, with a consideration of the environments this learner is in[7].

The SETT Framework is particularly relevant to evaluating and justifying assistive technology choices for the blind. For example, the framework can be used to identify the specific needs of a blind student, such as the need for a screen reader or a braille display. The framework can also help identify the specific tasks that the student needs to be able to do, such as reading textbooks or accessing online resources. By considering the student's characteristics, the environments in which they learn, and the tasks required to be an active learner in those environments, the framework can help identify the most appropriate assistive technology tools for the student[8,9].

4 Wisconsin Assistive Technology Initiative. (2010). Assistive technology consideration to assessment. Retrieved December 19, 2023

5 click on "resources/SETT Downloads" and see items below

6 *cf.*, Minnesota Department of Administration. (n.d.). Ready, SETT, Go! Getting started with the SETT framework. [Webpage]. Minnesota's State Portal

7 Hollingshead, A., Zabala, J., & Carson, J. (2020). The SETT Framework and Evaluating Assistive Technology Remotely. Council for Exceptional Children.

8 Zabala, J. (2005). Ready, SETT, go! Getting started with the SETT framework. Closing The Gap, 24(6), 1-8.

9 Zabala, J. (2018). SETTing the stage for success: Building success through effective selection and use of assistive technology systems. In Handbook of Research on Integrating Technology Into Contemporary Language Learning and Teaching (pp. 1-22). IGI Global

The SETT Framework is a valuable tool for evaluating and justifying assistive technology choices for students with disabilities. The framework emphasizes the importance of understanding the student's characteristics, the environments in which they learn and grow, and the tasks required to be an active learner in those environments before identifying a system of tools that enables the student to actively engage in the tasks. By using the SETT Framework, educators and stakeholders can make informed decisions that empower individuals with disabilities to achieve their full potential.

C.2 Assistive Technology Assessments

There are several assistive technology assessments available for use with blind or visually impaired people. Here are some of the available assessments:

- Snow, A. (n.d.). Assistive Technology Checklist for Assessment. Retrieved December 19, 2023
- Teaching Students with Visual Impairments. (n.d.). Assistive Technology Assessment for Students Who Are Blind or Visually Impaired. Retrieved December 19, 2023
- Perkins School for the Blind. (n.d.). Basic Technology Assessment Template. Retrieved December 19, 2023
- Presley, I., & Siu, T. (2012). Assistive Technology for Students Who Are Blind or Visually Impaired: A Guide to Assessment. American Foundation for the Blind.
- Wisconsin Assistive Technology Initiative
- MDE-LIO Assistive Technology Guidelines
- SETT Framework[10,11]

10 click on “resources/SETT Downloads” and see items below
11 *cf.*, Minnesota Department of Administration. (n.d.). Ready, SETT, Go! Getting started with the SETT framework. [Webpage]. Minnesota's State Portal

Appendix D

Instructional Programs & Materials

The Individuals with Disabilities Education Improvement Act (IDEIA) 2004 mandates that students with disabilities receive a free and appropriate public education (FAPE) in the least restrictive environment possible[1]. To ensure that blind and low vision students have access to FAPE, there is a need for evidence-based specialized curriculum to teach screenreader usage, magnification usage, accessible typing programs, and accessible coding curricula to teach tech skills to blind/low vision students.

Screen readers are software programs that allow blind and visually impaired users to read the text that is displayed on a computer screen with a speech synthesizer or braille display[2]. Magnification software enlarges the text and images on the screen for low vision users[3]. Accessible typing programs help students with disabilities learn to type using adaptive technology. Accessible coding curricula teach blind and low vision students how to code using specialized software that is designed to be accessible to them[4].

Evidence-based specialized curriculum for teaching these skills is important because it ensures that students with disabilities have access to the same educational opportunities as their peers. It also helps to ensure that students with disabilities are able to develop the skills they need to succeed in the workforce. By providing students with disabilities with the tools they need to succeed, we can help to create a more inclusive society where everyone has the opportunity to reach their full potential.

1 20 U.S.C. § 1400, et.
2 Paths to Literacy. (n.d.). Introduction to Screen Reader Instruction. Retrieved January 8, 2024
3 American Foundation for the Blind. (n.d.). Magnification Software. Retrieved January 8, 2024
4 FreeCodeCamp.org (2018). Helping blind people learn to code. Retrieved January 8, 2024

D.1 Accessible Touch Typing Instruction

Learning to touch type is an essential skill for anyone who spends a significant amount of time typing. Touch typing can help you type more efficiently and accurately, which can save you time and reduce the risk of repetitive strain injuries. By using all ten fingers to type without looking at the keyboard, you can significantly increase your typing speed and reduce the number of errors you make. This can help you complete your typing tasks faster and with greater accuracy. Additionally, touch typing can help you use keystroke shortcuts more smoothly, which can help you navigate your computer more quickly and efficiently. Screen readers can also be used more effectively when you are able to touch type, as you can focus on the content being read rather than the keyboard. In summary, learning to touch type can help you become a more efficient and fluent typist, as well as improve your ability to navigate your computer and screen readers.

You may be thinking: My blind child has a Braille device. Why does she need to learn to type?

Even if your child has a Braille device such as the Braillenote Touch, typing is essential. The computer is the mainstream device that your child will need in order to be productive in school and in the workplace. When I meet a new blind student, parents often tell me, “My child needs to learn to use a screen reader.” The first question I ask is, “Does your child know how to type?” In order to use a screen reader such as JAWS effectively, you have to be able to type accurately. Braille is important, too, and it definitely has its uses in technology. But I believe that typing is as important as Braille.

Typing allows blind students to use mainstream devices. They can use a laptop or desktop computer, or they can connect a keyboard to a tablet. When I use my iPhone and type in text messages, my keyboarding skills help me use the screen, even without a Braille display.

– *Treva Olivero* National Federation of the Blind. (2019). The Braille Monitor, January 1997. Retrieved January 8, 2024

There are a number of options available for teaching touch typing skills to students with visual impairments.

- Typio[5]
- Ballyland Keyboarding[5]
- TypeAbility[5]
- Sao Mai Typing Tutor[5]

[5] This product was specifically developed for use with the blind

- Keystroke[5]
- APH Typer Online[5,6]
- Typing Club
- Touch-Type Read and Spell (TTRS)[7]

D.2 AndroidOS/iOS/iPadOS Gesture Training

Learning VoiceOver and TalkBack gestures on tablets and phones is essential for users with visual impairments. VoiceOver is a screen reader that comes pre-installed on Apple devices, while TalkBack is a screen reader that comes pre-installed on Android devices[8,9]. Both screen readers include gesture-based controls and braille keyboard support. While these screen readers are useful tools, they depend on accurate text alternatives for non-text content. Learning VoiceOver and TalkBack gestures can help users navigate their devices more efficiently and effectively[10]. For instance, TalkBack gestures can help users navigate and perform frequent actions on their Android devices, such as moving to the next item on the screen, selecting an item, and activating screen search.[11] Similarly, VoiceOver gestures can help users navigate and perform frequent actions on their Apple devices, such as opening the app switcher, accessing the control center, and activating Siri. Competency with VoiceOver and TalkBack gestures can enable users to access the same activities as their peers, manage eye fatigue, and use good posture and a good viewing distance.

- ScreenReader App[12]
- Ballyland Apps
- The Screen Reader Training Website[13]
- Listen with TalkBack Series from Hadley

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[6] Formerly known as Talking Typer

[7] This resource has been specifically shown to be effective for blind students through independent research

[8] Bureau of Internet Accessibility. (n.d.). Understanding How People With Disabilities Use Mobile Devices. Bureau of Internet Accessibility.

[9] Bureau of Internet Accessibility. (n.d.). Google TalkBack: An Overview of Android's Free Screen Reader. Bureau of Internet Accessibility.

[10] Apple. (2022, December 20). Turn on and Practice VoiceOver. Apple Support.

[11] Google. (n.d.). Use TalkBack on your Android device. Google.

[12] Users are invited to add any missing information to either screenreader-android for Android TalkBack or screenreader-ios for VoiceOver

[13] This targets VoiceOver, but can be used for TalkBack with assistance

- Listen with VoiceOver Series from Hadley

D.3 Screenreader Training

Learning advanced methods of navigating the computer with a screen reader such as JAWS, Windows Narrator, or NVDA is essential for users with visual impairments. While arrow keys and Tab can be useful for basic navigation, advanced methods can provide more efficient and comprehensive navigation. For instance, JAWS provides a feature called "Virtual Cursor" that allows users to navigate web pages and documents by line, word, character, or even by paragraph[14]. Similarly, Windows Narrator provides a feature called "Scan Mode" that allows users to navigate web pages and documents by headings, links, tables, and landmarks.[15,16]. NVDA provides a feature called "Object Navigation" that allows users to navigate web pages and documents by objects such as buttons, checkboxes, and text fields[17] . Learning advanced methods of navigation can help users save time and effort, and increase productivity. It is important to note that while screen readers can be helpful, they should not replace other assistive technologies such as screen magnifiers. Therefore, it is important to learn advanced methods of navigating the computer with a screen reader to take full advantage of its benefits.

- Surf's Up[18]
- The Screen Reader Training Website[19]
- Windows Narrator Series from Hadley
- NVDA Series from Hadley
- Windows Screen Reader Primer[20,21]
- Access Technology Institute, LLC. Courses[22]
- NVDA Training Materials[23]

14 Freedom Scientific. (n.d.). JAWS Screen Reader. Freedom Scientific.
15 Microsoft. (2022, December 31). Narrator User Guide. Microsoft.
16 Microsoft. (2022, December 31) Use a screen reader to navigate Windows 11. Microsoft.
17 NV Access. (2022, December 31). NVDA User Guide. NV Access.
18 Offline version available for download as a zipped file at this link
19 This site is an update to the Surf's Up curriculum undertaken by the California School for the Blind that has been expanded to cover NVDA, JAWS, and VoiceOver
20 in 2nd Ed. as of July 3, 2025
21 This primer covers use of Windows Narrator, NVDA, and JAWS
22 Sells training, textbooks, and subscription-based content about JAWS and NVDA
23 Includes Basic Screenreader Training and Specific Training for Outlook, Word, Excel, and PowerPoint use with NVDA

- JAWS Basic Training
- Working with Text from eyeTvision[24]
- Basic Internet Navigation from eyeTvision[24]

D.4 Screen Magnifier Training

Specialized screen magnification software like ZoomText, Fusion, Windows Magnifier, and Dolphin SuperNova are designed to provide a more comprehensive and customizable experience than the built-in magnification tools. While the built-in magnification tools can be useful for basic tasks, they may not be sufficient for users with more complex needs[25]. Specialized software can provide features such as color filtering, cursor enhancements, and text-to-speech capabilities[26]. Additionally, specialized software can help users manage eye fatigue, use good posture and a good viewing distance, and access the same activities as their peers. Competency with specialized screen magnification software can enable students to succeed in postsecondary education and jobs[27]. It is important to note that while specialized screen magnification software can be helpful, it should not replace other assistive technologies such as screen readers. Therefore, it is important to learn how to use specialized screen magnification software to take full advantage of its benefits[27,28].

- ZoomText Resources from Freedom Scientific
- Fusion Resources from Freedom Scientific
- Dolphin Supernova Training Materials

D.5 Braille Display Use

Learning how to use a refreshable braille display is essential for emerging braille readers. Refreshable Braille Displays are peripheral devices that display braille characters, usually

[24] Covers NVDA, JAWS, and ChromeVox Screenreaders

[25] Bureau of Internet Accessibility. (n.d.). Screen Magnifiers: Who and How They Help. Bureau of Internet Accessibility.

[26] Perkins School for the Blind. (2022, August 17). Getting started with screen magnification. Retrieved January 8, 2024

[27] American Foundation for the Blind. (2022, August 17). Screen Magnification. American Foundation for the Blind.

[28] Low Vision Center. (n.d.). Introduction to Screen Reading and Magnification Software: A Comprehensive Guide to Assistive Technology Assessment. Low Vision Center.

by raising and lowering dots through holes in a flat surface. Users can input braille using either the 6 or 8 key Perkins-style braille keyboard or, more recently, a QWERTY keyboard. While it may be tempting to use only the minimum functions of an braille display, being explicitly taught how to use it can provide many benefits. For instance, it can help improve finger strength and isolated finger control, which are crucial for writing[29]. Additionally, using an braille display can help emerging readers with tactile discrimination and make it easier to read. Furthermore, pairing an braille display with a computer, tablet, or smartphone can provide instant auditory feedback as the student types, which can help with motivation.

- APH Mantis Q40 Braille Display & Notetaker from Washington School for the Blind
- APH Chameleon 20 Braille Display & Notetaker from Washington School for the Blind
- BrailleSense 6 Training from WCBVI AT
- BrailleSense 6 Training from California School of the Blind
- BrailleNote Touch Plus Training from California School of the Blind
- Diving Into Braille Displays from eyeTvision

D.6 Accessible Coding Curricula

It possible for blind students to learn computer programming. In fact, there are many resources available to help them learn. For instance, the Perkins School for the Blind provides information on Quorum, an accessible programming language, as well as other resources and information related to blind programmers and coders[30]. Additionally, EarSketch, a platform designed to teach students to code in Python or JavaScript through music and creative discovery, is being adapted by a research team led by Brian Magerko, professor of Digital Media at Georgia Tech, for blind and visually impaired youth[31]. Microsoft has also developed Code Jumper, a coding language for children who are blind or visually impaired, which is comprised of modular, physical pieces that students can string together to create code[32]. It's worth noting that blind people can be successful software developers, with 1 out of every 200 software developers being blind[33]. With the

29 Perkins School for the Blind. (n.d.). Benefits of Using a Braille Display with Emerging Readers. Retrieved January 8, 2024
30 Perkins School for the Blind. (n.d.). Blind programmers and coders. Perkins School for the Blind.
31 Georgia Tech. (2022, August 24). EarSketch. Georgia Tech
32 Microsoft. (n.d.). Code Jumper. Microsoft.
33 FreeCodeCamp. (2017, November 14). How blind people code. FreeCodeCamp.

right resources and support, blind students can learn computer programming and pursue a career in software development.[34,35]

The following list contains the current list of accessible coding options available for students with visual impairment/blindness.

- APH Connect Center Coding Course taught by Florian Beijers[36]
- CodeHS
- Code Academy
- APH CodeJumper[37,38]
- Code Quest[38]
- APH Code & Go Mouse[38]
- EarSketch[39]

[34] *cf*., Hadwen-Bennett, Alex & Sentance, Sue & Morrison, Cecily. (2018). Making Programming Accessible to Learners with Visual Impairments: A Literature Review. International Journal of Computer Science Education in Schools. 2. 10.21585/ijcses.v2i2.25.

[35] Alotaibi, Hind & Al-Khalifa, Hend & AlSaeed, Duaa. (2020). Teaching Programming to Students with Vision Impairment: Impact of Tactile Teaching Strategies on Student's Achievements and Perceptions. Sustainability. 12. 10.3390/su12135320.

[36] Florian Beijers is a blind computer programmer who ran this course for APH. This link goes to the archived site that contains links to the lectures and archives all the course materials.

[37] A Microsoft Training Module if available to teach CodeJumper to teachers

[38] Specifically Designed by Microsoft and APH for use by the blind

[39] Freely available Teaching Resources for Teachers

Appendix E

Accessible Fonts

Accessible typography is crucial for individuals with visual impairments, such as low vision or reading disabilities like dyslexia. Accessible fonts are designed to be easy to read by a diverse audience, including people with visual impairments. The use of accessible typefaces like Atkinson Hyperlegible and APHont can significantly improve the legibility and readability of text for people with visual impairments. These typefaces have features like increased letter spacing, bold outlines, higher contrast ratios, and wider characters, which make them easier to read. The Section 508 Standards[1] and other regulations require sans-serif fonts in certain places, and typography choices have a huge impact on accessibility[2]. By using accessible typography, textual information can be made accessible to all users, irrespective of their abilities or disabilities[3,4].

There are a number of options available for accessible fonts. These are presented with font information and then followed by a thorough demonstration of the font readability[5]

1 Section508.gov. (n.d.). Understanding Accessible Fonts and Typography for Section 508 Compliance. Retrieved January 12, 2024

2 accessiBe. (2023, May 14). How to Choose ADA-Compliant Fonts in 2024: A Complete Guide. accessiBe BLOG

3 The Readability Group. (2020, August 14). A Guide to Understanding What Makes a Typeface Accessible and How to Make Informed Decisions. Medium. Retrieved January 12, 2024

4 HubSpot. (n.d.). Accessibility Fonts: How to Choose the Right Typeface for Your Website. Retrieved January 12, 2024

5 Empty box characters mean a particular font does not contain that type of character. This is seen for all of the fonts below except JetBrains Mono with subscript characters

E.1 Atkinson Hyperlegible Font

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E.2 Atkinson Hyperlegible Mono

Developed by the Braille Institute (Monospaced variant)

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E.3 Atkinson Hyperlegible Next

Developed by the Braille Institute (Next variant)

Sample text

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E.4 APHont

Developed by the American Printing House for the Blind, font download here

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilisis leo vel fringilla est ullamcorper eget nulla facilisi. Nec ullamcorper sit amet risus nullam eget felis.

$1 $2 $3 $4 $5 $6 $7 $8 $9 1% 2% 3% 4% 5% 6% 7% 8% 9% 0%

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E.5 Comic Sans MS

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilisis leo vel fringilla est ullamcorper eget nulla facilisi. Nec ullamcorper sit amet risus nullam eget felis.

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E.6 JetBrains Mono[6]

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilisis leo vel fringilla est ullamcorper eget nulla facilisi. Nec ullamcorper sit amet risus nullam eget felis.

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A... A. A: A, A; A! A? a... a. a: a, a; a! a? B... B. B: B, B; B! B? b... b. b: b, b; b! b? C... C. C: C, C; C! C? c... c. c: c, c; c! c? D... D. D: D, D; D! D? d... d. d: d, d; d! d? E... E. E: E, E; E! E? e... e. e: e, e; e! e? F... F. F: F, F; F! F? f... f. f: f, f; f! f? G... G. G: G, G; G! G? g... g. g: g, g; g! g? H... H. H: H, H; H! H? h... h. h: h, h; h! h? I... I. I: I, I; I! I? i... i. i: i, i; i! i? J... J. J: J, J; J! J? j... j. j: j, j; j! j? K... K. K: K, K; K! K? k... k. k: k, k; k! k? L... L. L: L, L; L! L? l... l. l: l, l; l! l? M... M. M: M, M; M! M? m... m. m: m, m; m! m? N... N. N: N, N; N! N? n... n. n: n, n; n! n? O... O. O: O, O; O! O? o... o. o: o, o; o! o? P... P. P: P, P; P! P? p... p. p: p, p; p! p? Q... Q. Q: Q, Q; Q! Q? q... q. q: q, q; q! q? R... R. R: R, R; R! R? r... r. r: r, r; r! r? S... S. S: S, S; S! S? s... s. s: s, s; s! s? T... T. T: T, T; T! T? t... t. t: t, t; t! t? U... U. U: U, U; U! U? u... u. u: u, u; u! u? V... V. V: V, V; V! V? v... v. v: v, v; v! v? W... W. W: W, W; W! W? w... w. w: w, w; w! w? X... X. X: X, X; X! X? x... x. x: x, x; x! x? Y... Y. Y: Y, Y; Y! Y? y... y. y: y, y; y! y? Z... Z. Z: Z, Z; Z! Z? z... z. z: z, z; z! z?

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6 Font created for monospace/coding needs

E.7 OpenDyslexic

Developed by Abelardo Gonzalez, designed for dyslexia. Free and open source: `https://opendyslexic.org/`

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilisis leo vel fringilla est ullamcorper eget nulla facilisi. Nec ullamcorper sit amet risus nullam eget felis.

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E.8 Tiresias

Designed for visually impaired users. Free for non-commercial use: `https://www.tiresias.org/fonts/`

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilisis leo vel fringilla est ullamcorper eget nulla facilisi. Nec ullamcorper sit amet risus nullam eget felis.

$1 $2 $3 $4 $5 $6 $7 $8 $9 1% 2% 3% 4% 5% 6% 7% 8% 9% 0%

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E.9 Verdana

Widely recognized for readability on screens. Pre-installed on many systems.

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilisis leo vel fringilla est ullamcorper eget nulla facilisi. Nec ullamcorper sit amet risus nullam eget felis.

$1 $2 $3 $4 $5 $6 $7 $8 $9 1% 2% 3% 4% 5% 6% 7% 8% 9% 0%

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E.10 Arial / Arial Unicode MS

Commonly recommended for accessibility due to clarity and sans-serif design.
Pre-installed on many systems.

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilisis leo vel fringilla est ullamcorper eget nulla facilisi. Nec ullamcorper sit amet risus nullam eget felis.

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E.11 Calibri

Microsoft’s default sans-serif, designed for screen readability. Pre-installed on many systems.

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilisis leo vel fringilla est ullamcorper eget nulla facilisi. Nec ullamcorper sit amet risus nullam eget felis.

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E.12 Century Gothic

Recommended by some accessibility guidelines for its clarity. Common in Microsoft Office.

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilisis leo vel fringilla est ullamcorper eget nulla facilisi. Nec ullamcorper sit amet risus nullam eget felis.

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Back Matter

For additional information please contact me at ryhunsaker@dsdmail.net