

ENHANCING EDUCATIONAL EQUITY

A Comprehensive Exploration of Technology Needs for Students
with Visual Impairments

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EXECUTIVE SUMMARY

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 2004¹ 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 success².

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 education². 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 deserve³.

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

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:

Navigating Success: The Indispensable Role of Screen Readers and Magnification Programs for Visually Impaired Students

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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. Among the myriad tools at their disposal, screen readers and magnification programs emerge as keystones, indispensable in shaping an environment where success is not just attainable but expected.

For visually impaired students, these tools represent a digital gateway to a world of knowledge, interaction, and independent learning. This chapter endeavors to illuminate the significance of screen readers and magnification programs, highlighting their essential roles in fostering student success. As the educational landscape continues to evolve, 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.

Screen readers, with their adept ability to convert digital text into synthesized speech, empower visually impaired students to engage with written content. As we delve into the intricacies of these tools, we will uncover their pivotal role in granting students access to textbooks, online resources, and educational materials that are the bedrock of academic achievement. Simultaneously, magnification programs play a crucial role in enhancing visual content, allowing students to explore images, charts, and diagrams with a level of detail that might otherwise be elusive.

Screen magnification is another crucial tool for students with visual impairments, as it enables them to access text and other visual content in the classroom. By magnifying the text and images on the screen, students can read and view the content more easily, which can help them keep up with their peers and achieve academic success. In this chapter, we will explore the importance of screen magnification for students with visual impairments and how it can help them access their free public education.

Through the lens of accessibility, this exploration seeks to underscore the imperative nature of these technologies, not as mere tools but as companions on the road to success for visually impaired students navigating the educational landscape.

1.1: Vision Specific Software Needs

As a student with visual impairments, accessing a free and appropriate public education can be challenging. However, with the help of special software, students can overcome these challenges and achieve academic success. Assistive Technology has improved the lives of students and adults living with visual impairments by providing access, connectedness, and engagement. The use of assistive technology can facilitate a learning environment where students are able to better access their educational program through low or high technology accommodations.

Incorporating special software can help students with visual impairments to access the same educational resources as their peers. It can also help them to learn at their own pace and in their own way. For instance, screen readers and magnification options built into mainstream tablets and smartphones can help students with visual impairments to read and write emails, texts, and documents.

In addition, technology can help students with visual impairments to become active learners. Traditional lectures may not be the optimal learning style for visually impaired students. However, hands-on engagement through technology can help them to better understand and complete assignments and tests.

By using special software, students with visual impairments can have equal access to educational opportunities and can be better prepared for the real world. It can also help them to acquire the skills required for independent living and getting higher education.

1.1.1: Student Software Needs

Table 1.1 is a list of software used to access material as well as necessary academic software used by students with visual impairments^{1,2}. This information will be used to determine necessary laptop specifications for students using these software to access their schoolwork at the same time as their sighted peers.

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- ¹ We focus on Windows-based laptops due to the ubiquity of Windows-based software used in schools. MacOS-based laptops are more than adequate to run software along with the built in VoiceOver screenreader To date there are no additional screenreaders for MacOS, however one is currently in development called VOSH. There are multiple Linux distributions that are actively working to improve ORCA screenreader accessibility within the GNOME desktop environment. There are also a number of independently developed screenreaders for Linux architectures as well as Chromebooks
- ² This includes the TVI teaching how to use the software skills, but primarily refers to programs visually impaired students need to access the curriculum

Program	Type of Program	Cost	Min RAM	Pref RAM	Processor
JAWS	Screenreader	\$225/yr ³⁴	8GB	>16GB	>11th Gen Intel® Core™ i5+
TypeAbility	Typing Instruction ⁵	\$150 ⁶	8GB	>16GB	>11th Gen Intel® Core™ i5+
Narrator ⁷	Screenreader	\$0	4GB	>16GB	>11th Gen Intel® Core™ i5
NVDA	Screenreader	\$0 ⁸	2GB	>8GB	>11th Gen Intel® Core™ i5
ZDSR	Screen Reader	\$232	2GB	>8GB	>11th Gen Intel® Core™ i7+
Dolphin Screenreader	Screenreader	\$1105/yr	8GB	>32GB	>11th Gen Intel® Core™ i7+
ZoomText	Magnification & Speech	\$85/yr ^{9 10}	16GB	>32GB	>11th Gen Intel® Core™ i7+
Windows Magnifier ¹¹	Magnification	\$0	16GB	>16GB	>11th Gen Intel® Core™ i7+

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³ Typically purchased via through APH quota funds

⁴ Prior to October 2024 this was \$95/yr, however Freedom Scientific altered the policy so that JAWS, ZoomTEXT, and/or Fusion as a bundle are th only purchase option

⁵ TypeAbility requires JAWS or Fusion to run as it uses the JAWS voice engine in order to run

⁶ as of version 4.7.0 the following is the pricing structure: \$150.00 each, \$130.00 per unit for buying at least 5, \$120.00 per unit for buying at least 10, \$110.00 per unit for buying at least 15, \$105.00 per unit for buying at least 20, \$100.00 per unit for buying at least 30, \$95.00 per unit for buying at least 40, \$90.00 per unit for buying at least 50, \$85.00 per unit for buying at least 60, \$80.00 per unit for buying at least 70, \$75.00 per unit for buying at least 80, \$70.00 per unit for buying at least 90, \$65.00 per unit for buying at least 100

⁷ Windows Narrator is a built in to Windows 10 and Windows 11

⁸ NVDA is free, but if you want Eloquence, Acapella, or Vocalizer Expressive TTS Voices, they have to be purchased from CodeFactory for \$70

⁹ Typically purchased via through APH quota funds

¹⁰ Prior to October 2024 this was \$85/yr, however Freedom Scientific altered the policy so that JAWS, ZoomTEXT, and/or Fusion as a bundle are th only purchase option

¹¹ Windows Magnifier is a built in to Windows 10 and Windows 11

Vision Department Technology Needs

Program	Type of Program	Cost	Min RAM	Pref RAM	Processor
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+
Fusion	Screenreader & Magnification	\$225/yr ^{12 13}	16GB	>32GB	>11th Gen Intel® Core™ i7+
Dolphin Screenreader +SuperNova	Screenreader & Magnification	\$1665/yr	8GB	>32GB	>11th Gen Intel® Core™ i7+
Java JDK 8 ¹⁴	Dependency ¹⁵	\$0	4GB	>8GB	>9th Gen Intel® Core™ i3+
Microsoft 365 ¹⁶	Work Completion	\$7/mo	4GB	>16GB	>11th Gen Intel® Core™ i5
Windows 11	Operating System	Home \$139 Pro \$199	4GB	>16GB	>11th Gen Intel® Core™ i7+
Windows 11 (CoPilot PC) ¹⁷	Operating System	Home \$139 Pro \$199	16GB	>24GB	>14th Gen Intel® Core™ i7+

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¹² Typically purchased via through APH quota funds

¹³ Prior to October 2024 this was \$170/yr, however Freedom Scientific altered the policy so that JAWS, ZoomTEXT, and/or Fusion as a bundle are the only purchase option

¹⁴ This JDK is no longer considered up to date but has been designated as receiving long term support until 2030, however most modern accessibility tools are developed using Java 11, 17, or 21. *cf.*, Java SE Support Roadmap

¹⁵ JAWS and NVDA screenreaders often communicate with the Operating System using custom modifications to the JAVA Access Bridge. As such, JAVA is a dependency for most software packages addressing accessibility

¹⁶ Microsoft is adding OpenAI based tools called Microsoft CoPilot to their products, which takes an extra 1-3GB of RAM in order to concurrently run Office applications and screenreaders smoothly

¹⁷ Current tech reports

Program	Type of Program	Cost	Min RAM	Pref RAM	Processor
Microsoft Teams	Web Meeting	\$0 ¹⁸	4GB	>16GB	>11th Gen Intel® Core™ i7+
Zoom	Web Meeting	\$0 ¹⁹	4GB	>16GB	>11th Gen Intel® Core™ i7+
Notepad++	Coding ²⁰	\$0	512MB	>4GB	>11th Gen Intel® Core™ i7+
Visual Studio Code	Coding ²¹	\$0	4GB	>8GB	>11th Gen Intel® Core™ i7+
Python ²²	Coding	\$0	4GB	>8GB	>11th Gen Intel® Core™ i7+
Adobe Reader	PDF Reader	\$0	2GB	>16GB	>11th Gen Intel® Core™ i7+
MuseScore	Music braille	\$0	8GB	>32GB	>11th Gen Intel® Core™ i7+
Sibelius	Music braille	\$0 ²³	8GB	>32GB	>11th Gen Intel® Core™ i7+
MalwareBytes ²⁴	Computer Security	\$0	2GB	>8GB ²⁵	>11th Gen Intel® Core™ i7+

Table 1.1: Software used by Vision Students to Access and Complete Academic Tasks¹⁸ free for a limited set of features, \$5/mo for advanced features¹⁹ free for a limited set of features, \$17/mo for advanced features²⁰ Notepad++ is accessible with all screenreaders²¹ Visual Studio Code is accessible with all screenreaders²² This is accessed through the Windows Terminal or Command Line²³ Sibelius ONE is free but very limited in capability, \$10/mo for advances features²⁴ Davis School District installs this on all laptops²⁵ Recent reports suggest that this program occasionally can use >12GB of RAM for larger/comprehensive scans

1.1.2: Teacher Software Needs

Table 1.2 is a list of software used by Teachers of Students with Visual Impairments (TVIs) to generate materials for students with visual impairments²⁶. These software programs are often memory intensive and benefit from use of command-line tools originally developed for Linux or MacOS environments but are available in the Windows environment using tools such as the Windows Subsystem for Linux and/or Git Bash.

²⁶ This list should be assumed to include all of the software from *Table 1.1* in order for TVIs to be able to teach the software

Program	Function	Cost	Min RAM	Pref RAM	Processor
Duxbury DBT 12.7 ^{27,28}	Braille Transcription	\$695/yr	not given	not given	not given
Braille2000 ²⁹ <i>Basic Ed</i>	Braille Transcription	\$21/mo \$439/yr ³⁰	not given	not given	not given
Braille2000 <i>Direct Entry Ed</i>	Braille Transcription	\$21/mo \$749/yr ³¹	not given	not given	not given
Braille2000 <i>Document Process Ed</i>	Braille Transcription	\$32/mo \$1149/yr ^{32,33}	not given	not given	not given
Braille2000 <i>The Talking Ed</i> . ³⁴	Braille Transcription	\$40/mo \$1299/yr	not given	not given	not given
Dotify	Braille Transcription	\$0	8GB	>16GB	>11th Gen Intel® Core™ i7+
BrailleBlaster ^{35,36}	Braille Transcription	\$0	8GB	>16GB	>11th Gen Intel® Core™ i7+
Sao Mai Braille	Music Braille Braille Transcription	\$0	4GB	>8GB	>11th Gen Intel® Core™ i7+
Tiger Software Suite ³⁷	Tactile Graphics	\$195/yr	1GB	>4GB	>11th Gen Intel® Core™ i7+
TactileView	Tactile Graphics	\$484/yr	4GB	>8GB	>11th Gen Intel® Core™ i7+

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²⁷ Duxbury is considered the "Gold Standard" print to braille transcription program, largely due to being present in the field since 1969

²⁸ NimPro 3.0 must be purchased for \$295 to import and work with NIMAS files from NIMAC

²⁹ Braille2000 is preferred by braille proofreaders as the "Gold Standard" program for editing .brf files in place

³⁰ Braille to Print Interpreter requires an extra \$2/mo or \$49/yr

³¹ Children's Braille Grade Relaxer requires an extra \$4/mo or \$149/yr

³² required to import NIMAS files from NIMAC.

³³ An extra \$7/mo \$239/yr must be purchased for MathML support

³⁴ This gives built in text to speech for Braille2000 as three are known issues with JAWS and NVDA

³⁵ BrailleBlaster has been developed by APH in order to more readily import and format NIMAS files from NIMAC

³⁶ BrailleBlaster has weaknesses in custom braille formatting. Built-in features only allow formatting following the official Braille Association of North America formatting standards published in 2016

³⁷ Requires Microsoft Word for some functions of the software

Vision Department Technology Needs

Program	Function	Cost	Min RAM	Pref RAM	Processor
FireBird	Tactile Graphics	\$0	4GB	>8GB	>11th Gen Intel® Core™ i7+
QuickTac	Tactile Graphics	\$0	1GB	>4GB	>11th Gen Intel® Core™ i7+
GoodFeel 4 ³⁸	Music braille	\$1545	8GB	>16GB	>11th Gen Intel® Core™ i7+
Audiveris ³⁹	Music braille	\$0	8GB	>16GB	>11th Gen Intel® Core™ i7+
Ultimaker Cura	3D modeline 3D Printing	\$0	8GB	>16GB	>11th Gen Intel® Core™ i7+
PrusaSlicer	3D modeline 3D Printing	\$0	8GB	>16GB	>11th Gen Intel® Core™ i7+
Blender	3D modeling	\$0	8GB	>16GB	>12th Gen Intel® Core™ i7+
Docker	Programming Interface ^{40,41}	\$0	8GB	>16GB	>11th Gen Intel® Core™ i7+
OpenBook	Optical Character Recognition	\$1000	8GB	>16GB	>11th Gen Intel® Core™ i7+
Adobe Acrobat Pro	Optical Character Recognition	\$14/mo	2GB	>16GB ⁴²	>11th Gen Intel® Core™ i7+
ABBYY FineReader	Optical Character Recognition	\$177/yr	8GB	>16GB	>11th Gen Intel® Core™ i7+

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³⁸ A Software Suite including GOODFEEL, Lime, Lime Aloud and SharpEye2

³⁹ requires java jdk>17, jdk21 preferred

⁴⁰ This requires Windows Subsystem for Linux and Windows Hyper-V activated for use.

⁴¹ Docker allows a user to use any Linux-based program locally through a command-line interface. However, this can be rather resource intensive

⁴² This recommendation comes from Crucial

Program	Function	Cost	Min RAM	Pref RAM	Processor
Adobe Indesign	Typesetting ePub Creation	\$23/mo	8GB	>16GB	>11th Gen Intel® Core™ i7+
Scribus	Typesetting ePub Creation	\$0	2GB	>8GB	>Pentium III
Adobe Illustrator	Tactile Graphics	\$32/mo	8GB	>16GB	>11th Gen Intel® Core™ i7+
Inkscape	Tactile Graphics	\$0	8GB	>16GB	>11th Gen Intel® Core™ i7+
Corel Draw	Tactile Graphics	\$16/mo	8GB	>16GB	>12th Gen Intel® Core™ i7+
DAISY Pipeline	ePub Creation	\$0	4GB	>8GB	>11th Gen Intel® Core™ i7+
TeXStudio	Math Transcription Math Typesetting	\$0	4GB	>8GB	>11th Gen Intel® Core™ i7+

Table 1.2: Software used by Teachers of Students with Visual Impairments to transcribe, typeset, and generate materials for students with visual impairments.

1.2: RAM Requirements

Having a computer with sufficient RAM and processor speed is crucial for the effective functioning of a screen reader, which serves as a vital assistive technology for individuals with visual impairments. A screen reader relies heavily on processing power and memory to rapidly convert textual information into synthesized speech or refreshable braille displays, allowing users to access and navigate digital content. A computer with inadequate RAM or a slow processor may struggle to process and relay information in real-time, resulting in delayed responses, sluggish navigation, and an overall compromised user experience. Insufficient hardware specifications can significantly hinder the screen reader's ability to provide timely and accurate information, rendering it an inadequate accommodation for individuals with visual impairments. Therefore, ensuring that the computer meets or exceeds the recommended RAM and processor speed is essential to guarantee an optimal and seamless user experience, empowering individuals with visual impairments to access and engage with digital content effectively. The information in *Table 1.3* is from Crucial, in an article discussing RAM needs for different scenarios.

If this is how you use your computer	Here's how much memory we recommend
Casual User	
Internet browsing Email Listening to music Watching videos	At least 8GB
Intermediate User	
Internet browsing Email Word Processing Spreadsheets Music Videos Multitasking	At least 16GB
Professional User⁴³	
High performance gaming Multimedia editing High-definition video Intensive multitasking	At least 32GB

Table 1.3: How Much RAM is Needed?

From the article (*emphasis mine*):

Is 4GB of RAM enough? 4GB of RAM is the bare minimum memory needed to run a base computer model. That said, the bare minimum may not provide a productive use of your time as your system will likely slow down every time you run two or more programs like internet browsing, email and some word processing simultaneously. So, unless you are running a legacy system, we generally recommend running your system with 8GB of RAM.

Is 8GB of RAM enough? 8GB of RAM is the amount of memory we

⁴³ I place students using screenreaders into this category since they are having to concurrently use a resource intensive screenreader/Screen Magnifier described in *Table 1.1* while performing all the tasks required of an "Intermediate User" in *Table 1.3*. Actual RAM use for just background tasks and running a screenreader/screen magnifier with Microsoft Word are available in *Figure 1.2* and *Figure 1.3*

recommend for casual computer users. If your usage includes internet browsing, email, lots of office programs, flash games, and multitasking – this level of memory should be sufficient.

Is 16GB of RAM enough? 16GB of RAM is the amount of memory we recommend for intermediate users looking for extra speed and smooth functioning. This may be especially beneficial if you tend to have several programs open and running, simultaneously. This is also a good level of RAM for casual gamers and standard business professionals.

Is 32GB of RAM too much? 32GB of RAM is the amount of memory we recommend for serious gamers, engineers, scientists, and entry-level multimedia users. ***This level of RAM allows for these memory-hungry programs to run smoothly, even as your computer ages.*** Therefore, It's not too much, it's just right.

Is 64GB of RAM too much? 64GB of RAM is typically recommended for top-end users. If you're a professional user of RAM-intensive programs, like games running at high refresh rate and resolution, 3D modelling applications, 4K or 8K photo or video editing software, you may want to future-proof your computer's memory by installing at least 64GB of RAM.

1.3: Current Student & Professional Laptops

Table 1.4 lists the laptops students I work with use in classrooms as of October 3, 2024. These laptops are fairly standard and represent off-the-shelf laptop options used in classrooms.

Vision Department Technology Needs

Company / Model	Cost	Keyboard	RAM	Screen	Processor
Students & Professionals Dell Latitude 3190	\$379	QWERTY	4GB ⁴⁴ 8GB ⁴⁵	11.6 <i>Touchscreen</i>	Intel® Celeron Silver (Intel® for Education)
Students ⁴⁶ Lenovo 500w Gen 3	\$358	QWERTY	4GB	11.6 <i>Touchscreen</i>	Intel® Pentium Silver (Intel® for Education)
Professionals Dell Precision 3530	\$1751	QWERTY	16GB	16.0	8th Gen Intel® Core™ i7
Professionals Dell Precision 7420	\$1349	QWERTY	16GB	16.0	8th Gen Intel® Core™ i7
2023 Personal Laptop Microsoft Surface Laptop 3	\$1500	QWERTY	32GB	15.0 <i>Touchscreen</i>	AMD Ryzen™ 7
2024 Personal Laptop Framework Laptop 16	\$2750	QWERTY	64GB	16.0	AMD Ryzen™ 9

caption Current Student
and Professional Laptops

⁴⁴ Student laptops have 4GB

⁴⁵ Some professional laptops have 4GB, the majority have 8GB

⁴⁶ Starting 2024-2025

1.4: Current Laptop Performance

Having a computer with sufficient RAM and an up-to-date processor is crucial for running a screenreader and screen magnifier smoothly as a student with visual impairments in order to receive a free and appropriate public education. Screenreaders and screen magnifiers are software applications that require a significant amount of processing power and memory to function properly. Insufficient RAM can cause the screenreader or screen magnifier to load slowly, which can lead to delays in the user's workflow. An up-to-date processor is also important because it can help ensure that the software runs smoothly and efficiently. By having a computer with sufficient RAM and an up-to-date processor, students with visual impairments can access the same educational materials as their sighted peers and participate fully in the curriculum. This can help improve their academic performance and ensure that they have the tools they need to succeed in their studies and beyond.

In addition to having sufficient RAM and an up-to-date processor, it is also important to ensure that the computer is running the latest version of the screenreader and screen magnifier software. Software updates often include bug fixes, performance improvements, and new features that can help improve the user experience. By keeping the software up-to-date, students with visual impairments can ensure that they are getting the most out of their assistive technology. It is also important to ensure that the computer is free of malware and other malicious software that can slow down the system and interfere with the operation of the screenreader and screen magnifier. By taking these steps, students with visual impairments can ensure that their computer is running optimally and that they have the tools they need to succeed in their studies and beyond.

1.5: Screenreader Loading

The latency of a screenreader is the time it takes for the software to load and start functioning. It is important to measure the latency of a screenreader to determine if the laptop has sufficient RAM to run the software properly. Insufficient RAM can cause the screenreader to load slowly, which can lead to delays in the user's workflow. Measuring the latency of a screenreader can help identify if the laptop has enough RAM to run the software smoothly. This can help users avoid frustration and improve their productivity. In addition to identifying insufficient RAM, measuring the latency of a screenreader can also help users identify if there are other issues with their laptop that may be causing the software to run slowly. For example, if the latency is still high even after upgrading the RAM, it could be an indication of a slow hard drive or outdated drivers. By measuring the latency of a screenreader, users can ensure that their laptop is running optimally and that they are getting the most out of their software. It is recommended to measure the latency of a screenreader periodically to ensure that the laptop is running smoothly and to identify any issues that may arise.

Figure 1.1 shows a boxplot of the latency to load JAWS measured across the various student and professional computers I had access to. The student laptop generally took >2 minutes for JAWS to load, a higher spec student laptop took about 1 minute, and the professional laptops took under a minute⁴⁷.

⁴⁷ Zipped Interactive HTML version of Figure 1.1

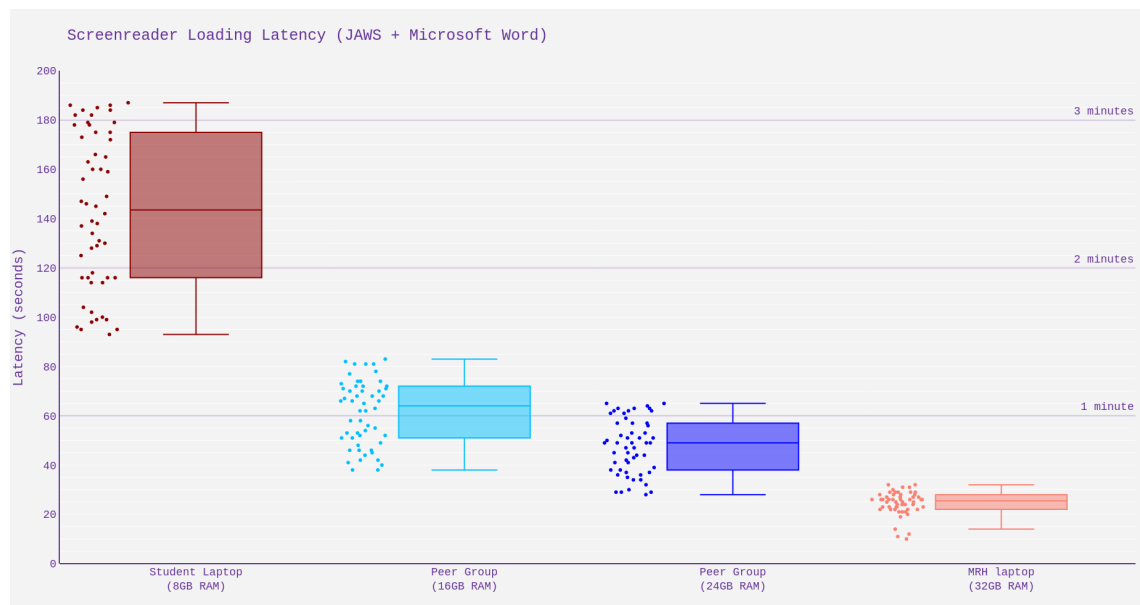


Figure 1.1: Plot showing Latency to Load JAWS while Microsoft Word is open across a typical student laptop (Dell Latitude 3190 with 8GB RAM), a high quality student laptop (Dell Precision 3530 with 16GB RAM), a professional laptop (Lenovo ThinkPad E16 with 24GB RAM), and a high power laptop (Microsoft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

1.6: Screenreader Responsiveness

Measuring the latency of a screenreader to respond to key presses is important to determine if the laptop has sufficient RAM to run the software properly. If the laptop has insufficient RAM, the screenreader may take longer to respond to key presses, which can lead to delays in the user's workflow. Measuring the latency of a screenreader can help identify if the laptop has enough RAM to run the software smoothly. This can help users avoid frustration and improve their productivity. Additionally, measuring the latency of a screenreader can help users identify if there are other issues with their laptop that may be causing the software to run slowly. By measuring the latency of a screenreader, users can ensure that their laptop is running optimally and that they are getting the most out of their software. *Table 1.5* provides these data for the same computers shown in *Figure 1.1*.

Computer

(Color as Labelled in Figure 1)





	Students Laptop ⁴⁸ 8GB RAM	143 [93-183] ⁴⁹	38 [27-91] ⁵⁰
	Student/Professional Laptop ⁵¹ 16GB RAM	64 [38-93]	9 [4-15]
	Professional Laptop ⁵² 24GB RAM	49 [26-65]	1 [0.05-2.5]
	Professional Laptop ⁵³ 32GB RAM	25 [10-32]	0.5 [0.01-1] ⁵⁴

Table 1.5: Lag in JAWS Reporting Readable Content

Professional Laptop ⁵⁵ 64GB RAM	XX [XX-XX]	XX.XX [XX-XX] ⁵⁶
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Table 1.5: Lag in JAWS Reporting Readable Content⁴⁸ Dell Latitude 3190⁴⁹ These are the data plotted in Figure 1.1 above. The responsiveness data are more clear when presented as a table here than as a plot⁵⁰ It is further important to note here that any lag in screenreader responsiveness of >1 sec means the student is behind their peers and their educational opportunity is limited by the technology not being sufficient (*i.e.*, not an adequate accommodation).⁵¹ Dell Precision 3530⁵² Lenovo ThinkPad E16 (TVI Personal Laptop)⁵³ Microsoft Surface 3 (My Personal Laptop)⁵⁴ 0.01 represents an immediate response that could not be measured⁵⁵ Framework 16.0 (My Personal Laptop)⁵⁶ 0.01 represents an immediate response that could not be measured

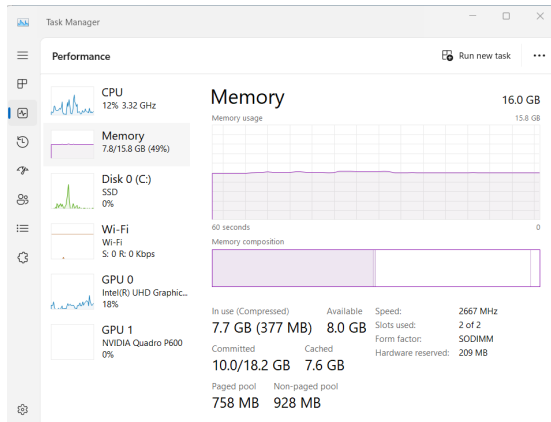
1.7: Measured Laptop RAM with Accessibility Tools

To demonstrate the actual RAM usage, I used a Dell Precision 3530 with 16GB RAM (second option in *Table 1.5* and *Figure 1.1*⁵⁷) and the built-in snipping tool to measure RAM and CPU usage shown in the Activity monitor. *Figure 1.2* shows the results of this evaluation.

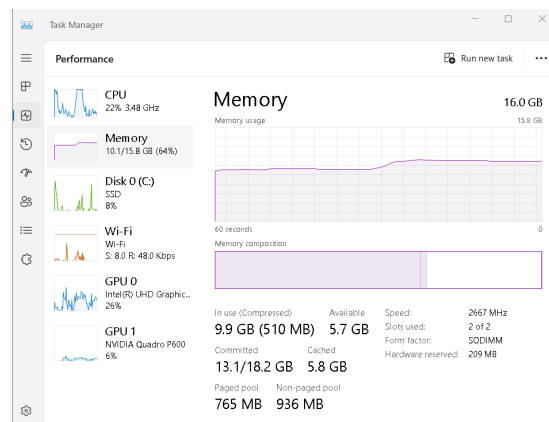
Figure 1.2a shows RAM values for just the Windows 11 background Processes, *Figure 1.2b* shows RAM usage with only JAWS screenreader added⁵⁸, *Figure 1.2c*, shows RAM usage with ZoomText magnification, and finally *Figure 1.2d*, shows RAM usage with Freedom Scientific Fusion (Integrated JAWS + ZoomText). I use these options as they are considered the gold standard and are industry standard.

⁵⁷ This laptop has an integrated NVIDIA Quadro P600 GPU

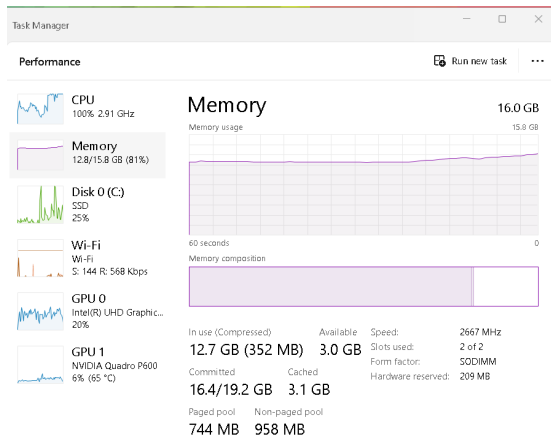
⁵⁸ The previous addition was turned off and the computer restarted prior to each test and the system allowed to reach equilibrium for 3 minutes prior to taking any screenshots



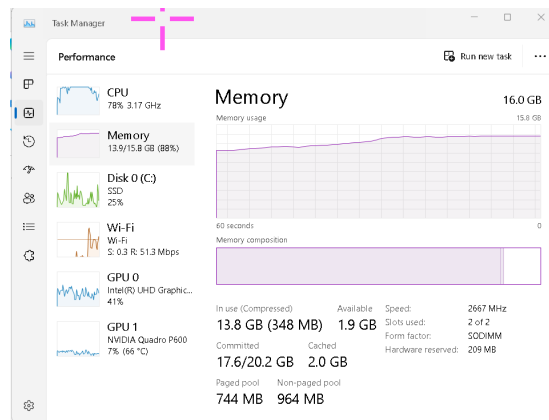
(a) Background RAM Usage - 7.7GB



(b) RAM Usage JAWS - 9.9GB



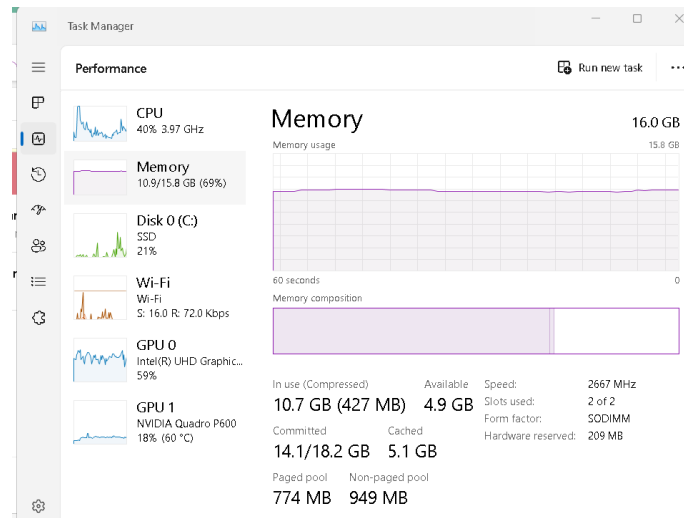
(c) RAM Usage ZoomText - 11.0GB



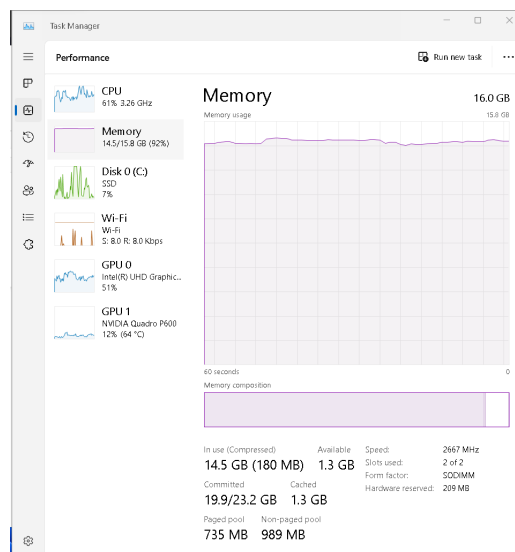
(d) RAM Usage Fusion - 13.8GB

Figure 1.2: Measured Laptop RAM with only Accessibility Tools Open. Note that this laptop has two GPU, GPU0 is the Intel® Videos card and GPU1 is an NVIDIA Quadro P600, both of which show much less activity in this test than the next one shown in Figure 1.3

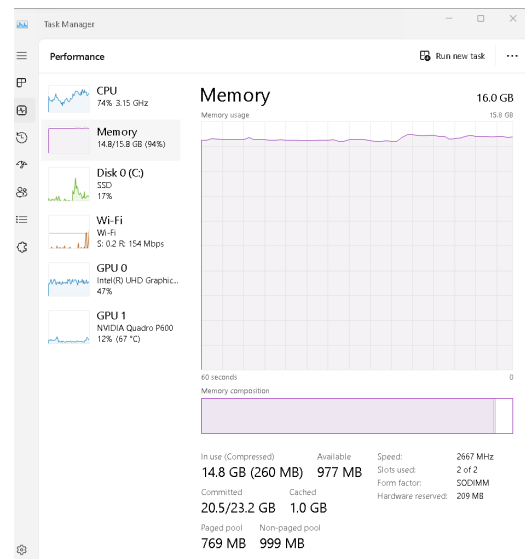
Figure 1.3 shows measures laptop RAM with the same laptop as used in Figure 1.2. Figure 1.3a shows RAM usage with JAWS and Word running, Figure 1.3b ZoomText + Word, and Figure 1.3c Fusion and Microsoft Word running in the background.



(a) RAM Usage JAWS + Word - 10.7GB



(b) RAM Usage ZoomText + Word - 14.5GB



(c) RAM Usage Fusion + Word - 14.8GB

Figure 1.3: Measured Laptop RAM with Accessibility Tools + Microsoft Word. Note that this laptop has two GPU, GPU0 is the Intel® Videos card and GPU1 is an NVIDIA Quadro P600, both of which show much higher activity in this test than the previous shown in Figure 1.2

1.8: Laptop Cost Factors

Students with visual impairments require laptops that are compatible with assistive technology to receive a free and accessible public education. When selecting a laptop, there are several cost factors that must be taken into account. Firstly, the laptop should have sufficient RAM to run the assistive technology software smoothly. Secondly, the laptop should have a high-quality screen that is large enough to display text and images clearly. Thirdly, the laptop should have a long battery life to ensure that students can use it for extended periods of time without needing to recharge. Fourthly, the laptop should have a durable build quality to withstand daily wear and tear. Finally, the laptop should be lightweight and portable to enable students to carry it around easily. These factors can help ensure that students with visual impairments have access to the technology they need to succeed in their studies.

1.8.1: Laptop Durability

I asked ChatGPT why we should consider future usage needs of a laptop into my purchasing plans and here is its response (emphasis mine):

Buying laptops with high-end RAM and processor specifications can be beneficial for several reasons, especially in terms of longevity and performance. Here are some key considerations:

1. Future-Proofing:

- Investing in higher-end components can help future-proof your laptop to some extent. As software and applications become more demanding over time, a laptop with better specifications is likely to remain relevant and capable of handling new software updates and requirements.

2. Multitasking and Performance:

- Higher RAM allows for better multitasking capabilities. If you use resource-intensive applications or run multiple programs simultaneously, having ample RAM prevents slowdowns and ensures smooth performance.
- A powerful processor can handle complex computations and tasks more efficiently, contributing to faster overall system performance.

3. Graphics Processing:

- For tasks such as video editing, gaming, or other graphics-intensive applications, a high-end GPU (Graphics Processing Unit) is crucial.

This is separate from RAM and the main processor but is equally important for certain tasks.

4. Long-Term Usability:

- Technology advances quickly, and what is considered high-end today might become standard or entry-level in a few years. However, starting with a high-end laptop gives you a more extended period before your system becomes outdated.

5. Smooth Upgrades:

- Some laptops allow users to upgrade certain components like RAM and storage. Starting with higher-end specifications provides more headroom for future upgrades, allowing you to extend the useful life of your laptop.

6. Resource-Intensive Applications:

- If you use applications that require a lot of processing power, like video editing software, 3D modeling tools, or virtualization software, a high-end laptop can handle these tasks more efficiently, providing a better user experience.

7. Responsiveness and Speed:

- A faster processor and more RAM contribute to a more responsive system. Applications load quicker, and the overall user experience is smoother, which can significantly impact productivity.

8. Enhanced Resale Value:

- High-end laptops generally retain their value better than lower-end models. If you decide to sell or upgrade your laptop in the future, having top-tier specifications can make it more attractive to potential buyers.

It's important to note that the specific requirements depend on your usage patterns and needs. Not everyone needs the highest specifications, and sometimes a mid-range laptop can be more than sufficient for everyday tasks. However, **for users with demanding workloads or those who want a longer usable life from their device, opting for higher-end specifications can be a wise investment.**

1.8.2: Role of GPU in Laptop Performance

A CPU or Central Processing Unit is the primary processor of a computer. It is responsible for executing instructions and performing calculations for all the programs running on the computer. A GPU or Graphics Processing Unit, on the other hand, is a specialized processor designed to handle complex calculations required for rendering graphics and images. While a CPU is designed to handle a wide range of tasks quickly, a GPU is designed to quickly render high-resolution images and video concurrently⁵⁹.

When it comes to improving laptop performance for graphics-intensive tasks or coding, a dedicated GPU can significantly improve performance. A dedicated GPU is a separate processor that is designed to handle the complex calculations required for rendering graphics and images. By offloading the processing of graphics data from the CPU, a dedicated GPU allows the CPU to focus on other tasks, resulting in faster and smoother performance for graphics-intensive applications. Additionally, a GPU can also be beneficial for processes involving AI. AI algorithms require a lot of processing power, and a GPU can help speed up the process. NVIDIA®, AMD®, and Intel® are some of the most popular GPU manufacturers, with models available for both desktop and laptop computers. Laptops with a dedicated GPU can handle AI tasks with ease, making them ideal for professionals who work with AI⁶⁰.

In summary, a CPU is responsible for executing instructions and performing calculations for all the programs running on the computer, while a GPU is a specialized processor designed to handle complex calculations required for rendering graphics and images⁵². A dedicated GPU can significantly improve laptop performance for graphics-intensive tasks such as gaming, video editing, and 3D modeling by offloading the processing of graphics data from the CPU. Screen magnification software can also benefit from a dedicated GPU. Screen magnification software enlarges the content on the screen, which can be taxing on the CPU. A dedicated GPU can help alleviate this burden by handling the graphics processing required for screen magnification. This results in a smoother and more responsive experience when using screen magnification software⁶¹.

I evaluated with my personal laptop⁶² the role for a CPU and GPU in using screenreader and magnification software. I also did the same with the mid-range professional laptop with 16GB of RAM. I found there was no increase in performance for JAWS, ZDSR, NVDA, or Dolphin Screenreader when an integrated GPU was present (AMD Vega® 10 or Intel® UHD Graphics 630 integrated GPU). However, when I assessed performance of ZoomText, Fusion (ZoomText + JAWS), and Dolphin SuperNova magnifier, as well as

⁵⁹ WekaIO. (n.d.). What is a GPU? WekaIO

⁶⁰ u/ChaosMotor: Outside of videogames, what is the point of a "framework"? (2012, December 12). Reddit

⁶¹ Run:AI. (n.d.). CPU vs GPU: Architecture, Pros and Cons, and Special Use Cases. Run:AI

⁶² My 4 year-old Surface Laptop 3 at the time of the evaluation

Dolphin Magnifier + ScreenReader, I saw a 30-45% increase in responsiveness for both speech and visual markers available on the screen. In this case I opened 10 tabs in Google Chrome, 10 tabs in Microsoft Edge, 10 tabs in Mozilla Firefox, and started typing in an online Microsoft Word document using office 365 online. Response time refers to the time it took the system to react when I typed beyond the field of view and the system had to move the screen and visual screen marker to a new location. *Table 1.6* shows these data. Importantly, both of the laptops were able to improve their performance for Magnification tasks by a similar percentage when the integrated GPU was used in concert with the CPU.

	Latency (s)		% Faster
	CPU	CPU+GPU	
Screenreader Only ⁶³			
JAWS Screenreader	0.5 [0.01 – 1]	0.5 [0.01 – 1]	0%
	9.0 [4 – 15]	9.0 [3 – 17]	0%
JAWS Screenreader	0.5 [0.01 – 1]	0.5 [0.01 – 1]	0%
	9.0 [4 – 15]	9.0 [3 – 17]	0%
NVDA Screenreader	0.2 [0.01 – 0.5]	0.2 [0.01 – 0.5]	0%
	4.0 [1.5 – 6]	4.0 [1.5 – 6]	0%
Dolphin Screenreader	0.5 [0.01 – 1]	0.5 [0.01 – 1]	0%
	9.0 [5 – 17]	8.8 [5 – 17]	2%
ZDSR Screenreader	0.2 [0.01 – 0.75]	0.2 [0.01 – 0.75]	0%
	5.0 [2 – 7]	5.0 [2 – 7]	0%
Screen Magnification Only ⁴⁸			
ZoomText	1.1 [0.5 – 1.25]]	.75 [0.3 – 1]]	32%
	15 [10 – 19]	5 [2.5 – 10]	33%
SuperNova	1.5 [0.75 – 1.45]	.77 [0.4 – 1]	48%
	11 [4 – 20]	7 [3 – 11]	36%
Screenreader + Magnification ⁴⁸			
SuperNova + Magnification	1.5 [1 – 25]]	.75 [0.25 – 1]]	48%
	16 [9 – 25]	6 [3 – 15]	37%
Fusion (ZoomText + JAWS)	1.5 [1 – 1.75]	.75 [0.25 – 1]	48%
	13 [3 – 19]	5 [2.5 – 13]	38%

Table 1.6: Screen Magnifiers Benefit from Use of an Integrated GPU. The top row in each table cell contains data for the laptop with 32GB RAM, an AMD Ryzen™ 7 processor and AMD Vega™ 10 integrated GPU. The lower row in each cell contains data for the laptop with 16GB RAM, an 8th Gen i7 processor, and Intel® UHD 630 integrated GPU. Integrated GPU were activated or inactivated by turning hardware acceleration ON or OFF for each laptop

⁶³ The visual marker outlining the current focus was used to measure response

1.8.3: Laptop Cost Optimization

There is an economic theory based on a Terry Pratchett novel that explains this phenomenon better than we can. It is called the Vimes Boots Index⁶⁴

Table 1.7 illustrates this theory in terms of student laptop computers (Assuming student has a laptop using a screenreader through 3rd-12th grade). *Table 1.7* also illustrates why we choose to err on the side of spending \$2000-3000 on a laptop computer that will last 3-5 years over spending \$1500-2000 on a laptop that will reach end-of-life within 1-2 years before becoming obsolete. By the end of 5 years we will have spent more on Low End and Mid Range Laptops than we would have otherwise spent had we purchased a High End Laptop. Importantly; however, we also would have been using laptops that always performed more poorly than a High End laptop would.

⁶⁴ Full Text (emphasis mine):

The reason that the rich were so rich, Vimes reasoned, was because they managed to spend less money.

Take boots, for example. He earned thirty-eight dollars a month plus allowances. A really good pair of leather boots cost fifty dollars. But an affordable pair of boots, which were sort of OK for a season or two and then leaked like hell when the cardboard gave out, cost about ten dollars. Those were the kind of boots Vimes always bought, and wore until the soles were so thin that he could tell where he was in Ankh-Morpork on a foggy night by the feel of the cobbles.

But the thing was that good boots lasted for years and years. **A man who could afford fifty dollars had a pair of boots that'd still be keeping his feet dry in ten years' time, while the poor man who could only afford cheap boots would have spent a hundred dollars on boots in the same time and would still have wet feet.**

Basically, **we are destined to be stuck in a cycle of perpetually spending more money for inferior products and will, in the end, spend more money than if we just paid for better product in the first place.**

– *Men At Arms*, page 38

Does School Have to Purchase a Replacement Laptop by Year											
RAM Cost	1	2	3	4	5	6	7	8	9	10	10-year Cost
4GB ^{65,66} \$525	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	\$1250
4GB ^{67,59} \$550	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	\$1500
8GB ⁶⁸ \$1184	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	\$11,840
16GB ⁶⁹ \$1751	✓	-	✓	-	✓	-	✓	-	✓	-	\$1755
32GB ⁷⁰ \$2824	✓	-	-	-	-	✓	-	-	-	-	\$1648
Best Case ⁷¹											
32GB ⁷² \$2824	✓	-	-	✓	-	-	✓	-	-	-	\$1472
Cautious ⁷³											

Table 1.7: Cost of Laptops Across Time. Notice that the final cost of the 32GB option is comparable to the 4GB options over 10 years. However, the 4GB laptops are not capable of running JAWS reliably in the classroom setting.

- For the **Best Case** Scenario, the 32GB laptop is between \$1107 and \$1192 **cheaper** over time compared to the 16GB and 8GB laptops, respectively.
- For the **Cautious** Scenario, the 32GB laptop is between \$283 and \$1386 **cheaper** over time compared to the 16GB and 8GB laptops, respectively

⁶⁵ Dell Latitude 3190 Education

⁶⁶ The 4GB Laptop *cannot* run JAWS and is included to show price comparison to the other options

⁶⁷ Lenovo 500w Gen 3 Education

⁶⁸ Dell Latitude 3190 Education

⁶⁹ Dell Precision 3530 given to TVIs teaching screenreaders

⁷⁰ Microsoft Surface Laptop 3

⁷¹ This is my personal experience

⁷² Microsoft Surface Laptop 3

⁷³ This is a conservative estimate to account for potential rough treatment of a computer

1.8.4: Replacement Timeline

Optimally, given the needs of students for use of technology in the classroom, the following timeline for laptop replacement is suggested⁷⁴. The idea behind this timeline is to minimize the number of times any single LEA has to purchase a laptop for a student.

The student be provided with a laptop capable of screenreader usage in 3rd/4th grade depending upon the needs of the student. A replacement laptop should be provided in 7th grade when the student moves to middle school. A final replacement should be provided in 10th grade when the student moves to high school. This means during the 10 years of a student's education, the district would only have to purchase 3 laptops for the student, and each school would only have to purchase one.

To implement this plan, it is imperative that the vision team be involved in the decision making process for the laptop purchase, primarily to describe the software and hardware specifications required to meet each individual student's needs. This will ensure that the laptop is capable of running the necessary software for the student's entire educational career. These discussions need to start in December of the year previous to the purchasing of the laptop, so that the cost of the technology can be included in the school's technology budget for the following year and the STS can have time to determine which of any agreed upon laptop options fit both the needs of the student as well as the budgetary constraints of the school. This means that discussions should happen in December of the student's 2nd/3rd grade year (this depends upon when the students in that school move from an iPad based setup to using laptop computers), December of their 6th grade year with the middle school, and December of their 9th grade year with the high school.

⁷⁴ this is based on the assumption of the school LEA and not the vision department being the first resource for purchasing technology

1.9: Recommended Laptop Specifications

Table 1.8 is a list of recommendations for laptop specifications by use case.

Use Case	Recommendation
Screenreader Only	
JAWS Screenreader	>16GB
NVDA Screenreader	>16GB
Dolphin Screenreader	>16GB
ZDSR Screenreader	>16GB
Screen Magnification Only⁷⁵	
ZoomText	>24-32GB
Windows Magnifier	>16GB
Dolphin SuperNova	>24-32GB
Screenreader + Magnification⁷⁵	
JAWS Screenreader + Windows Magnifier	>24-32GB
NVDA Screenreader + Windows Magnifier	>24-32GB
ZDSR Screenreader + Windows Magnifier	>24-32GB
Dolphin Screenreader + Windows Magnifier	>24-32GB
SuperNova Screenreader + Magnification	>32-64GB
Fusion Screenreader + Magnification	>32-64GB

Table 1.8: Recommended Laptop Specifications

⁷⁵ can also benefit from either an integrated or dedicated GPU

1.10: Laptops Meeting Specifications

Table 1.9 is an alphabetical list of laptop computers that meet the recommended specifications defined in *Table 1.8*.

Company / Model	Cost	RAM	Display	Processor
Screenreader Only⁷⁶				
<\$1000-\$2000				
Acer Aspire 5	\$1319	32GB	15.6	13th Gen Intel® Core™ i7
Acer Swift Go 16	\$999	32GB	14.0	13th Gen Intel® Core™ i7
ASUS Vivobook 17X	\$1149	32GB	17.3	AMD Ryzen™ 7
ASUS Vivobook 17X	\$1189	40GB	17.3	AMD Ryzen™ 7
ASUS Vivobook 17X	\$1249	40GB	17.3	13th Gen Intel® Core™ i9
BT Speak Pro ⁷⁷	\$1195	TBD	none	TBD
Dell G16 Gaming Laptop	\$1999	32GB	16.0	13th Gen Intel® Core™ i7
Dell Inspiron 16 Plus	\$1499	32GB	16.0 Touchscreen	13th Gen Intel® Core™ i7
Dell Inspiron 3530	\$1259	32GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
Dell Inspiron 3530	\$1339	48GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
Dell Inspiron 3530	\$1419	64GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
Dell XPS 9530	\$1829	32GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
Dell XPS 9530	\$1929	48GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
Framework 13	\$1102	32GB	13.5	13th Gen Intel® Core™ i7
Framework 13	\$1732	32GB	13.5	AMD Ryzen™ 7
Framework 13	\$1892	64GB	13.5	AMD Ryzen™ 7
HP 14	\$1189	32GB	14.0	13th Gen Intel® Core™ i7
HP 14	\$1269	48GB	14.0	13th Gen Intel® Core™ i7

Continued on Next Page

⁷⁶ Laptops without integrated/dedicated GPU units

⁷⁷ This is a Linux computer with Perkins-style input and auditory output

Company / Model	Cost	RAM	Display	Processor
HP 14	\$1349	64GB	14.0	13th Gen Intel® Core™ i7
HP 15	\$1879	64GB	15.6	13th Gen Intel® Core™ i7
HP 17	\$1019	32GB	17.3	AMD Ryzen™ 7
HP 17	\$1449	64GB	17.3	13th Gen Intel® Core™ i7
HP 17	\$1802	64GB	17.3	13th Gen Intel® Core™ i7
HP 17	\$1929	64GB	17.3	AMD Ryzen™ 7
HP Dragonfly Pro	\$1549	32GB	14.0 Touchscreen	AMD Ryzen™ 7
HP EliteBook 860 G10	\$1819	64GB	16.0 Touchscreen	13th Gen Intel® Core™ i7
HP Envy	\$1749	32GB	17.3 Touchscreen	13th Gen Intel® Core™ i7
HP ENVY x360 15	\$1059	64GB	15.6 Touchscreen	AMD Ryzen™ 7
HP ENVY x360 15	\$1519	32GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
HP ENVY x360 15	\$1599	48GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
HP ENVY x360 15	\$1679	64GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
HP Pavilion 15	\$1329	48GB	15.6	AMD Ryzen™ 7
HP Pavilion 15	\$1359	32GB	15.6	13th Gen Intel® Core™ i7
HP Pavilion 15	\$1409	64GB	15.6	AMD Ryzen™ 7
HP Pavilion 15	\$1439	48GB	15.6	13th Gen Intel® Core™ i7
HP ZBook Firefly 16 G10	\$1934	32GB	16.0 Touchscreen	13th Gen Intel® Core™ i7
Lenovo Slim Pro 9i	\$1899	32GB	14.0 Touchscreen	13th Gen Intel® Core™ i7

Continued on Next Page

Vision Department Technology Needs

Company / Model	Cost	RAM	Display	Processor
Lenovo ThinkPad E16 Gen 1	\$1049	24GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Lenovo ThinkPad E16 Gen 1	\$1309	32GB	16.0 <i>Touchscreen</i>	AMD Ryzen™ 7
Lenovo ThinkPad E16 Gen 1	\$1349	40GB	16.0 <i>Touchscreen</i>	AMD Ryzen™ 7
Lenovo ThinkPad E16 Gen 1	\$1459	32GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Lenovo ThinkPad E16 Gen 1	\$1599	40GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Lenovo ThinkPad T14 Gen 4	\$1286	24GB	14.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Lenovo ThinkPad T14 Gen 4	\$1286	24GB	14.0 <i>Touchscreen</i>	AMD Ryzen™
Lenovo ThinkPad T16 Gen 2	\$1994	32GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Lenovo ThinkPad X13 Gen 4	\$1309	32GB	13.3 <i>Touchscreen</i>	AMD Ryzen™ 7
Lenovo Thinkpad X1 Yoga Gen 8	\$1848	32GB	14.0 <i>Touchscreen</i>	AMD Ryzen™
Lenovo Yoga 7i 14	\$1399	32GB	14.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
LG Gram 14	\$1699	32GB	14.4	13th Gen Intel® Core™ i7
LG Gram 14	\$1799	64GB	14.4	13th Gen Intel® Core™ i7
LG Gram 16	\$1999	32GB	16.0	13th Gen Intel® Core™ i7
LG gram 17	\$1769	32GB	17.0	13th Gen Intel® Core™ i7
Malibal Aon L1	\$1589	32GB	16.0	13th Gen Intel® Core™ i7
Malibal Aon L1	\$1625	64GB	16.0	13th Gen Intel® Core™ i7
MSI Commercial 14	\$1279	32GB	14.0	13th Gen Intel® Core™ i7

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Company / Model	Cost	RAM	Display	Processor
MSI Commercial 14	\$1579	64GB	14.0	13th Gen Intel® Core™ i7
MSI Prestige 14	\$1529	32GB	14.0	13th Gen Intel® Core™ i7
MSI Prestige 16	\$1699	32GB	16.0	13th Gen Intel® Core™ i7
MSI Summit E14 Flip	\$1829	32GB	14.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
MSI Summit E14 Flip	\$1999	32GB	14.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Overpowered 17+	\$1699	32GB	17.3	13th Gen Intel® Core™ i7
\$2000-\$3000				
ASUS ProArt Studiobook	\$1999	32GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i9
ASUS Zenbook Pro 16X	\$1599	32GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i9
Dell XPS 13 Plus	\$1009	32GB	13.4 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Dell XPS 15	\$1999	32GB	15.6 <i>Touchscreen</i>	13th Gen Intel® Core™ i9
Dell XPS 9530	\$2029	64GB	15.6 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Framework 13	\$1222	64GB	13.5	13th Gen Intel® Core™ i7
Framework 16	\$1239 ⁷⁸	32GB	16.0	AMD Ryzen™ 9
Framework 16	\$1399 ⁶⁰	64GB	16.0	AMD Ryzen™ 9
HP ZBook Firefly 16 G10	\$2549	64GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Legion Pro 7i	\$1599	32GB	16.0	13th Gen Intel® Core™ i9
Lenovo ThinkPad P1 Gen 6	\$1489	32GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7

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⁷⁸ with NUMPAD

Vision Department Technology Needs

Company / Model	Cost	RAM	Display	Processor
Lenovo Thinkpad P14s	\$1199	32GB	14.0	AND Ryzen 7
Lenovo Thinkpad P14s	\$1509	64GB	14.0	AND Ryzen 7
Lenovo ThinkPad P16 Gen 2	\$1039	32GB	16.0 Touchscreen	AMD Ryzen™ 7
Lenovo ThinkPad P16 Gen 2	\$1829	64GB	16.0 Touchscreen	AMD Ryzen™ 7
Lenovo ThinkPad T16 Gen 2	\$2254	48GB	16.0 Touchscreen	13th Gen Intel® Core™ i7
LG gram 16 2-in-1	\$2119	32GB	16.0 Touchscreen	13th Gen Intel® Core™ i7
LG Gram 17	\$1099	32GB	17.3	13th Gen Intel® Core™ i7
\$3000-\$4000				
Dell Latitude 7440	\$1615	32GB	14.0	13th Gen Intel® Core™ i7
Dell Precision 3480	\$1205	32GB	14.0	13th Gen Intel® Core™ i7
Dell Precision 3581	\$1854	32GB	15.6	13th Gen Intel® Core™ i7
Dell XPS 17	\$1349	32GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
Dell XPS 17	\$1549	32GB	15.6 Touchscreen	13th Gen Intel® Core™ i9
Lenovo ThinkPad P16 Gen 2	\$1239	32GB	16.0 Touchscreen	13th Gen Intel® Core™ i7
Lenovo ThinkPad P16v	\$1339	32GB	16.0 Touchscreen	13th Gen Intel® Core™ i7
Lenovo Thinkpad X1 Yoga	\$1719	32GB	14.0 Touchscreen	13th Gen Intel® Core™ i7
>\$4000				
b.book ⁷⁹	\$1765	8GB-16GB	none	13th Gen Intel® Core™ i9
Dell Precision 5480	\$1354	32GB	14.0	13th Gen Intel® Core™ i7

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⁷⁹ This is a Windows Computer without a monitor, substituting a 40 cell braille display

Company / Model	Cost	RAM	Display	Processor
Dell Precision 5680	\$1597	32GB	16.0	13th Gen Intel® Core™ i9
Dell Precision 7680	\$1225	32GB	16.0	13th Gen Intel® Core™ i9
Lenovo ThinkPad P16 Gen 2	\$1189	64GB	16.0 Touchscreen	13th Gen Intel® Core™ i7
Lenovo ThinkPad P16v	\$1929	64GB	16.0 Touchscreen	13th Gen Intel® Core™ i7
Orbit Optima ⁷⁹	\$1500	32GB-64GB	none	13th Gen Intel® Core™ i7
Seika Studio ⁷⁹	\$1500	8GB-16GB ⁶²	none	12th Gen Intel® Core™ i7
Screenreader OR Magnification + Screenreader \$1000-\$2000				
Acer TravelMate P4 14 ⁸⁰	\$1499	32GB	14.0	13th Gen Intel® Core™ i7
Acer Nitro 16 AMD ⁸¹	\$1799	32GB	17.0	13th Gen Intel® Core™ i7
Acer Nitro 17 AMD ⁸¹	\$1799	32GB	17.0	13th Gen Intel® Core™ i7
Alienware x14 ⁸²	\$1999	32GB	14.0	13th Gen Intel® Core™ i7
ASUS ROG Zephyrus G14 ⁶⁵	\$1819	32GB	14.0	AMD Ryzen™ 7
ASUS ROG Zephyrus G14 ⁶⁵	\$1889	48GB	14.0	AMD Ryzen™ 7
ASUS ROG Zephyrus G14 ⁶⁵	\$1699	40GB	14.0	AMD Ryzen™ 9
ASUS ROG Zephyrus G16 ⁶⁵	\$1989	32GB	16.0	13th Gen Intel® Core™ i7
ASUS TUF Gaming A15 ⁶⁵	\$1549	32GB	15.6	AMD Ryzen™ 7
ASUS TUF Gaming A16 ⁸³	\$1445	32GB	16.0	AMD Ryzen™ 7
ASUS Vivobook 16X ⁸⁴	\$1739	40GB	16.0 Touchscreen	13th Gen Intel® Core™ i9

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⁸⁰ with NVIDIA® GeForce RTX™ 2050⁸¹ with NVIDIA® GeForce RTX™ 4070⁸² with NVIDIA® GeForce RTX™ 4080⁸³ AMD Radeon RX 7600S⁸⁴ with NVIDIA® GeForce RTX™ 3050

Company / Model	Cost	RAM	Display	Processor
ASUS Vivobook 16X ⁶⁵	\$1829	32GB	16.0 Touchscreen	13th Gen Intel® Core™ i9
ASUS Vivobook 16X ⁶⁵	\$1909	48GB	16.0 Touchscreen	13th Gen Intel® Core™ i9
Eluktronics RP-15 G2 ⁸⁵	\$1797	64GB	15.6	AMD Ryzen™ 7
HP Pavilion 15 ⁸⁶	\$1309	32GB	15.6	13th Gen Intel® Core™ i7
HP Pavilion 15 ⁶⁵	\$1389	48GB	15.6	13th Gen Intel® Core™ i7
HP Pavilion 15 ⁶⁵	\$1469	64GB	15.6	13th Gen Intel® Core™ i7
HP Victus 16 ⁶⁵	\$1599	32GB	16.1	AMD Ryzen™ 7
HP Victus 16 ⁶⁵	\$1699	64GB	16.1	AMD Ryzen™ 7
Lenovo IdeaPad Gaming 3 15 ⁶⁵	\$1079	64GB	15.6	AMD Ryzen™ 7
Lenovo IdeaPad Gaming 3 15 ⁶⁵	\$1149	32GB	15.6	AMD Ryzen™ 7
Malibal Aon L1 ⁶⁵	\$1589	32GB	16.0	13th Gen Intel® Core™ i7
Malibal Aon S1 ⁶⁷	\$1812	32GB	14.0	13th Gen Intel® Core™ i7
MSI Alpha 17 ⁸⁷	\$1849	32GB	17.3	AMD Ryzen™9
MSI Bravo 15 ⁶⁵	\$1189	32GB	15.6	AMD Ryzen™ 7
MSI Bravo 15 ⁶⁵	\$1279	64GB	15.6	AMD Ryzen™ 7
MSI Bravo 17 ⁶⁸	\$1499	32GB	17.3	AMD Ryzen™7
MSI Crosshair 16 ⁶⁵	\$1699	32GB	16.0	13th Gen Intel® Core™ i7
MSI Crosshair 16 ⁶⁵	\$1809	64GB	16.0	13th Gen Intel® Core™ i7
MSI Cyborg 15 ⁶⁵	\$1699	48GB	15.6	13th Gen Intel® Core™ i7
MSI Cyborg 15 ⁶⁵	\$1874	32GB	15.6	13th Gen Intel® Core™ i7
MSI Cyborg ⁶⁵	\$1240	32GB	15.6	AMD Ryzen™7

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⁸⁵ with NVIDIA® GeForce RTX™ 4060

⁸⁶ with NVIDIA GeForce e MX550

⁸⁷ with AMD Radeon RX5500M

Company / Model	Cost	RAM	Display	Processor
MSI Katana 15 ⁶⁵	\$1899	32GB	15.6	13th Gen Intel® Core™ i9
MSI Pulse 17 ⁷⁰	\$1899	32GB	17.3	13th Gen Intel® Core™ i9
MSI Pulse 15 ⁶⁵	\$1599	32GB	15.6	13th Gen Intel® Core™ i7
MSI Pulse 15 ⁸⁸	\$1699	32GB	15.6	13th Gen Intel® Core™ i7
MSI Raider 15 ⁸⁹	\$1999	32GB	15.6	13th Gen Intel® Core™ i9
MSI Stealth 14 Studio ⁶⁵	\$1949	64GB	14.0	13th Gen Intel® Core™ i7
MSI Vector ⁷¹	\$1999	32GB	17.3	13th Gen Intel® Core™ i9
Sager NP8855D ⁶⁵	\$1549	32GB	15.6	13th Gen Intel® Core™ i9
Sager NP8855D ⁶⁵	\$1704	64GB	15.6	13th Gen Intel® Core™ i9
Sager NP8875E ⁶⁶	\$1799	32GB	17.3	13th Gen Intel® Core™ i9
Sager NP8875E ⁶⁶	\$1954	64GB	17.3	13th Gen Intel® Core™ i9
XPG Xenia 15G ⁶⁶	\$1399	32GB	15.6	13th Gen Intel® Core™ i7
\$2000-\$4000				
Acer Nitro 5 Intel ⁹⁰	\$1299	32GB	15.6	13th Gen Intel® Core™ i7
Acer Nitro 5 AMD ⁹¹	\$1199	32GB	15.6	AMD Ryzen™ 7
Acer Predator Helios 16 ⁶⁵	\$1499	32GB	16.0	13th Gen Intel® Core™ i9
Acer Predator Triton ⁶⁵	\$1799	64GB	17.0	13th Gen Intel® Core™ i9
Alienware m16 ⁶⁵	\$1499	32GB	16.0	13th Gen 19

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⁸⁸ with NVIDIA® GeForce RTX™ 3060⁸⁹ with NVIDIA® GeForce RTX™ 3070⁹⁰ with NVIDIA® GeForce RTX™ 3070Ti⁹¹ with NVIDIA® GeForce RTX™ 3070Ti

Vision Department Technology Needs

Company / Model	Cost	RAM	Display	Processor
ASUS Creator Laptop Q ⁶⁷	\$2799	40GB	15.6	13th Gen Intel® Core™ i9
ASUS ROG Flow X16 ⁶⁵	\$2489	32GB	16.0	13th Gen Intel® Core™ i9
ASUS ROG Flow X16 ⁶⁵	\$3059	64GB	16.0	13th Gen Intel® Core™ i9
ASUS ROG Zephyrus G14 ⁶⁵	\$2359	48GB	14.0	AMD Ryzen™ 9
ASUS ROG Zephyrus G14 ⁶⁵	\$2419	32GB	14.0	AMD Ryzen™ 9
ASUS ROG Zephyrus G16 ⁶⁵	\$2039	48GB	16.0	13th Gen Intel® Core™ i7
ASUS ROG Zephyrus M16 ⁶⁵	\$2079	32GB	16.0	13th Gen Intel® Core™ i9
ASUS ROG Zephyrus M16 ⁶⁵	\$2369	64GB	16.0	13th Gen Intel® Core™ i9
ASUS ROG Zephyrus M16 ⁶⁴	\$3289	96GB	16.0	13th Gen Intel® Core™ i9
ASUS TUF Gaming A15 ⁶⁵	\$2069	64GB	15.6	AMD Ryzen™ 9
ASUS TUF Gaming A16 ⁹²	\$2119	64GB	16.0	AMD Ryzen™ 9
ASUS Vivobook Pro 16X ⁶⁵	\$2339	32GB	16.0 Touchscreen	13th Gen Intel® Core™ i9
ASUS Vivobook Pro 16X ⁶⁵	\$2349	64GB	16.0 Touchscreen	13th Gen Intel® Core™ i9
ASUS Zenbook Pro 14 ⁶⁵	\$2779	48GB	14.5 Touchscreen	13th Gen Intel® Core™ i9
ASUS Zenbook Pro 14 ⁶⁵	\$2199	32GB	14.5 Touchscreen	13th Gen Intel® Core™ i9
Corsair Voyager ⁹³	\$1350	32GB	16.0	AMD Ryzen™ 9
Dell XPS 9530 ⁶⁵	\$2399	32GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
Dell XPS 9530 ⁶⁵	\$2599	64GB	15.6 Touchscreen	13th Gen Intel® Core™ i7
Dell XPS 9730 ⁶⁴	\$3899	32GB	17.0 Touchscreen	13th Gen Intel® Core™ i9

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⁹² with AMD Radeon RX 7700S

⁹³ with AMD Radeon 6800M

Company / Model	Cost	RAM	Display	Processor
Dell XPS 9730 ⁶⁴	\$5299	64GB	17.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i9
DigitalStorm Nova ⁶⁶	\$1294	32GB	16.0	13th Gen Intel® Core™ i9
DigitalStorm Nova ⁶⁶	\$1428	64GB	16.0	13th Gen Intel® Core™ i9
Falcon NW TLX ⁶⁵	\$1423	32GB	16.0	13th Gen Intel® Core™ i9
Falcon NW TLX ⁶⁵	\$1567	64GB	16.0	13th Gen Intel® Core™ i9
Framework 16 ⁷³	\$1808	64GB	16.0	AMD Ryzen™ 9
Framework 16 ⁷⁴	\$1639	32GB	16.0	AMD Ryzen™ 9
HP ENVY 16 ⁶⁵	\$2069	40GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i9
HP ENVY 16 ⁶⁵	\$2119	48GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i9
HP ENVY 16 ⁶⁵	\$2589	32GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i9
HP ENVY 16 ⁶⁵	\$3264	64GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i9
HP ZBook Firefly 16 G10 ⁹⁴	\$2269	32GB	16.0 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
HP ZBook Power G10 ⁹⁵	\$2299	64GB	15.6 <i>Touchscreen</i>	13th Gen Intel® Core™ i7
Lenovo Legion Slim 7i 16 ⁶⁵	\$2169	32GB	16.0	13th Gen Intel® Core™ i9
Lenovo ThinkPad P1 Gen 6 ⁹⁶	\$2049	64GB	16.0	13th Gen Intel® Core™ i7
LG Gram 16 ⁶⁷	\$1199	32GB	16.0	13th Gen Intel® Core™ i7
LG Gram 17 ⁶⁷	\$1199	32GB	17.3	13th Gen Intel® Core™ i7

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⁹⁴ with NVIDIA® GeForce RTX™ A500⁹⁵ with NVIDIA® GeForce RTX™ 2000 Ada⁹⁶ with NVIDIA® GeForce RTX™ A1000

Vision Department Technology Needs

Company / Model	Cost	RAM	Display	Processor
Malibal Aon L1 ⁶⁶	\$1664	64GB	16.0	13th Gen Intel® Core™ i7
Malibal Aon S1 ⁶⁷	\$1779	64GB	14.0	13th Gen Intel® Core™ i7
Microsoft Surface Laptop Studio 2 ⁶⁵	\$1299	64GB	14.4 Touchscreen	13th Gen Intel® Core™ i7
Microsoft Surface Laptop Studio 2 ⁶⁵	\$3299	64GB	14.4 Touchscreen	13th Gen Intel® Core™ i7
Microsoft Surface Laptop Studio 2 ⁷⁶	\$1599	32GB	14.4 Touchscreen	13th Gen Intel® Core™ i7
Microsoft Surface Laptop Studio 2 ⁹⁷	\$1799	32GB	14.4 Touchscreen	13th Gen Intel® Core™ i7
MSI Creator M16 ⁶⁵	\$2169	32GB	16.0	13th Gen Intel® Core™ i7
MSI Creator M16 ⁶⁵	\$2269	48GB	16.0	13th Gen Intel® Core™ i7
MSI Creator M16 ⁶⁵	\$2389	64GB	16.0	13th Gen Intel® Core™ i7
MSI CreatorPro M16 ⁹⁸	\$2079	32GB	16.0	13th Gen Intel® Core™ i7
MSI Cyborg 15 ⁶⁵	\$2029	64GB	15.6	13th Gen Intel® Core™ i7
MSI Katana 15 ⁶⁵	\$2445	32GB	15.6	13th Gen Intel® Core™ i9
MSI Katana 15 ⁶⁵	\$2745	64GB	15.6	13th Gen Intel® Core™ i9
MSI Pulse 15 ⁶⁵	\$2049	64GB	15.6	13th Gen Intel® Core™ i7
MSI Stealth 14 Studio ⁶⁵	\$2019	32GB	14.0	13th Gen Intel® Core™ i7
MSI Stealth 15 ⁶⁵	\$2029	32GB	15.6	13th Gen Intel® Core™ i7
MSI Stealth 15 ⁶⁵	\$2179	64GB	15.6	13th Gen Intel® Core™ i7

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⁹⁷ with NVIDIA® GeForce RTX™ 4050

⁹⁸ with NVIDIA RTX A1000

Company / Model	Cost	RAM	Display	Processor
MSI Stealth 16 Studio ⁶⁵	\$2334	32GB	16.0	13th Gen Intel® Core™ i7
MSI Stealth 16 Studio ⁶⁵	\$2549	64GB	16.0	13th Gen Intel® Core™ i7
MSI Summit E16 Flip ⁶⁵	\$2129	32GB	16.0	13th Gen Intel® Core™ i7
Origin Eon16-SL ⁶⁶	\$1421	64GB	16.0	13th Gen Intel® Core™ i9
Origin Eon16-SL ⁶⁶	\$1201	32GB	16.0	13th Gen Intel® Core™ i9
Razer Blade 15 ⁶⁶	\$1999	32GB	15.6	13th Gen Intel® Core™ i7
VelocityMicro Raptor S77 ⁶⁶	\$1319	32GB	17.3	13th Gen Intel® Core™ i9
VelocityMicro Raptor S77 ⁶⁶	\$1449	64GB	16.0	13th Gen Intel® Core™ i9

Table 1.9: Laptop Options Meeting Minimum Recommended Specifications. Options are organized by use case and cost point.

Chapter 2:

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

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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 journeys¹. Within the realm of tablets, both iPad and Android devices stand as beacons of innovation, offering not only user-friendly interfaces but also a diverse array of applications specifically tailored to bridge the accessibility gap. This chapter embarks on a compelling exploration of how tablets, in tandem with purpose-built apps, are not just tools but catalysts for success in the educational odyssey of visually impaired students.

The tactile elegance of tablets goes beyond mere convenience; it represents a paradigm shift in the way students interact with information. For visually impaired learners, tablets serve as dynamic portals, offering a multi-sensory approach to engagement. Through the lens of this chapter, we will unravel the unique functionalities of both iPad and Android tablets, delving into their respective strengths and contributions to an inclusive educational experience.

Apps, the lifeblood of these devices, play an instrumental role in transforming tablets into personalized learning companions. From screen readers that convert text to speech with remarkable precision to magnification apps that enhance visual content, the ecosystem of applications available empowers visually impaired students to navigate the digital realm with confidence. Tablets, coupled with innovative apps, are not mere gadgets; they represent a dynamic force propelling visually impaired students toward success; underscoring the indispensable role these tools play in shaping an educational landscape where every student, regardless of visual abilities, can seize the opportunities that lie ahead.

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

2.1: Tablet Considerations

When selecting a tablet for students with visual impairments to access their schoolwork, careful consideration must be given to the device's accessibility features to ensure an inclusive and conducive learning environment. Essential considerations include the tablet's compatibility with screen readers and magnification tools, ensuring that these assistive technologies seamlessly integrate with the device's operating system. Additionally, evaluating the availability and effectiveness of built-in accessibility features such as VoiceOver for iOS or TalkBack for Android is crucial². The tablet's tactile features, size, and weight should also be taken into account to accommodate students' specific needs. High contrast and customizable color settings, as well as text-to-speech functionalities, are vital components that enhance readability. Furthermore, the tablet's compatibility with a variety of educational apps designed with accessibility in mind is paramount. By prioritizing these considerations, educators and administrators can empower students with visual impairments to engage with their schoolwork independently and efficiently, fostering a more inclusive learning experience.

One frequently overlooked challenge in using tablets for individuals with visual impairments is the potential for visual fatigue. Recent research, such as the study by Pakdee and Sengsoon (2021)³, reveals that opting for a slightly larger device can mitigate visual fatigue, particularly for those engaged in visually demanding tasks. This consideration becomes even more pertinent for individuals with visual impairments.

While the iPad Pro2 and Samsung Galaxy Tab 9 tablets are often lauded for their increased brightness, it's crucial not to prioritize brightness as a major factor. Research suggests that boosting brightness can exacerbate visual fatigue. Instead, emphasis should be placed on the larger screen's enhanced resolution and expanded visual area, facilitating efficient use of Zoom functions. This becomes especially significant when aiming to teach students to adeptly navigate assistive technology without relying solely on pinch zooming, a feature that may not consistently function within all applications.

Another critical consideration involves contrast ratios. For students with photophobia, adjusting luminance levels to lower settings can significantly enhance clarity of text and images. This nuanced approach to tablet selection is pivotal in creating an accessible and comfortable learning environment for students with visual impairments.

For individuals with visual impairments, the efficacy of these devices relies heavily on

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 *cf.*, Pakdee, S., & Sengsoon, P. (2021). Immediate Effects of Different Screen Sizes on Visual Fatigue in Video Display Terminal Users. *Iranian Rehabilitation Journal*, 19(2), 137-1461. DOI:10.32598/irj.19.2.1108.2

factors that go beyond mere functionality. One crucial aspect that significantly impacts the accessibility of tablets for visually impaired students is the contrast ratio. The contrast ratio, representing the difference in luminance between the brightest and darkest elements on a screen, plays a pivotal role in ensuring that individuals with visual impairments can effectively engage with educational content. In a school setting, where tablets are increasingly utilized for various learning activities, understanding and prioritizing contrast ratio becomes paramount in fostering an inclusive and enriching educational environment for all students, regardless of their visual abilities.

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 text⁴. On the other hand, Apple devices have an “Increase Contrast” feature that can be turned on to make text and other elements more visible⁵.

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 students with visual impairments⁶. 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^{7,8}. 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 call⁹. 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 2.1* describes current tablet computers that are available for students with visual impairments.

⁴ Google. (n.d.). Color contrast - Android Accessibility Help. Retrieved December 19, 2023

⁵ iMore. (n.d.). How to increase contrast for visual accessibility on iPhone and iPad. Retrieved December 19, 2023

⁶ American Foundation for the Blind. (n.d.). Smartphone or Tablet: Which is Best for You? Retrieved December 19, 2023

⁷ American Academy of Ophthalmology. (n.d.). 30 Apps, Devices and Technologies for People With Vision Impairments. Retrieved December 19, 2023

⁸ American Foundation for the Blind. (n.d.). Apple iOS for iPhone and iPad: Considerations for Users with Visual Impairments. Retrieved December 19, 2023

⁹ American Academy of Ophthalmology. (n.d.). Technology Tools for Children with Low Vision. Retrieved December 19, 2023

Tablet	Cost	Screen Size
AndroidOS 13+ Tablets		
Acer Iconia Tab P10	\$199	10.4
Alldocube iPlay 50 mini Pro NFE	\$209	8.4
Alldocube iPlay 60	\$319	10.9
Blackview OSCAL Pad 16	\$150	10.5
Doogee U10 Pro	\$139	10.1
Galaxy Tab A9	\$179	8.7
Galaxy Tab A9+	\$239	11.0
Google Pixel Tablet	\$499	10.9
Honor Tablet Pad 9	223	12.1
Hyundai HyTab 7	\$59	7.0
Lenovo Tab Extreme	\$949	14.5
Lenovo Tab M10 5G	\$441	10.6
Lenovo Tab M10 Plus (3rd Gen)	\$149	10.6
Lenovo Tab M7 (3rd gen.)	\$99	7.0
Lenovo Tab M8 (4th Gen)	\$109	8.0
Lenovo Tab M9	\$149	9.0
Lenovo Tab P11 (2nd gen)	\$269	11.5
Lenovo Tab P11 Plus	\$209	11.0
Lenovo Tab P11 Pro (2nd Gen)	\$339	11.2
Lenovo Tab P12	\$379	12.7
Lenovo Tab P12 Pro	\$629	12.6
Lenovo Xiaoxin Pad 2024	\$228	11.0
Lenovo Yoga Tab 11	\$269	11.0
Lenovo Yoga Tab 13	\$589	13.0
Nokia T10	\$169	8.0
Nokia T20	\$199	10.4
Nokia T21	\$279	10.4
OnePlus Pad	\$479	11.6
Oppo Pad Air 2	\$259	11.4
Oscal Pad 18	\$319	11.0
Razer Edge	\$399	6.8

Continued on Next Page

Tablet	Cost	Screen Size
Redmi Pad	\$219	10.61
Redmi Pad SE	\$225	11.0
Samsung Galaxy Tab A7 Lite	\$119	8.7
Samsung Galaxy Tab A8	\$179	10.5
Samsung Galaxy Tab Active3	\$439	8.0
Samsung Galaxy Tab S7 FE	\$529	12.4
Samsung Galaxy Tab S9	\$799	11.0
Samsung Galaxy Tab S9 FE	\$449	10.9
Samsung Galaxy Tab S9 FE+	\$599	12.4
Samsung Galaxy Tab S9 Ultra	\$1199	14.6
Samsung Galaxy Tab S9+	\$999	12.4
Teclast P30T	\$176	10.1
Teclast T60	\$225	12.0
UMIDIGI A15 Tab	\$999	11.0
Vivo Pad 2	\$349	12.1
Xiaomi Pad 6	\$399	11.0
Xiaomi Pad 6 Pro	\$589	11.0
ZTE Nubia Pad 3D	\$1099	12.4
iPadOS Tablets		
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
Window OS Tablets		
Alldocube	\$669	12.6
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

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Tablet	Cost	Screen Size
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
ChromeOS Tablets		
Acer Chromebook Tab 10	\$299	9.7
Asus Chromebook CM3	\$369	10.5
Asus Chromebook Tablet CT100	\$299	9.7
Fydetab Duo	\$630	12.4
Google Pixel Slate	\$499	12.3
HP Chromebook x2	\$799	12.3
HP Chromebook x2 11	\$599	11.0
Lenovo 10e Chromebook Tablet	\$259	10.1
Lenovo Chromebook Duet	\$229	10.1
Lenovo Chromebook Duet 3	\$349	11.0
Lenovo Chromebook Duet 5	\$379	13.3

Table 2.1: Tablet Options Organized by OS

2.3: Tablet Recommendations

Table 2.2 describes current tablet computers that are available for students with visual impairments.

Tablet	Cost	Screen Size
AndroidOS 13+ Tablets		
Google Pixel Tablet	\$499	10.9
Lenovo Tab P12 Pro	\$629	12.6
Samsung Galaxy Tab S9	\$799	11.0
Samsung Galaxy Tab S9 Ultra	\$1199	14.6
Samsung Galaxy Tab S9+	\$999	12.4
iPadOS Tablets		
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
Windows OS Tablets		
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
ChromeOS Tablets		
Google Pixel Slate	\$499	12.3
Lenovo IdeaPad Duet 3	\$349	11.0
Lenovo IdeaPad Duet 5	\$379	13.3

Table 2.2: Tablet Recommendations Organized by OS. Preferred option is highlighted in light red.

2.4: 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 2.3* gives a list of current apps available for use with students with visual impairments.

App	Cost	Function	OS
Accessibility Training/Auditory Games			
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 ¹⁰	Sonic Games	iOS/iPadOS
Blindfold Tap and Swipe	free	Train VoiceOver Gestures	iOS/iPadOS
ObjectiveEd Games	free ¹⁰	Sonic Games	iOS/iPadOS
VO Lab	\$4.99	Train VoiceOver Gestures	iOS/iPadOS
Screenreader	free	Train Accessibility Gestures	iOS/iPadOS Android 13+
Cortical Vision Impairment			
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 ¹¹	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

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¹⁰ Games purchased separately

¹¹ Annual Price Per Enrolled Student: 1-5=\$300 6-10=\$250 11-15=\$200 16-19=\$150

App	Cost	Function	OS
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
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
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
Audiobook/Reading			
Audible	free ¹²	Audiobook	iOS/iPadOS AndroidOS 13+
BARD Mobile	free ¹³	e-Book	iOS/iPadOS AndroidOS 13+
Bookshare Reader	free	DAISY Reader	iOS/iPadOS
Dolphin EasyReader	free	DAISY Reader	iOS/iPadOS AndroidOS 13+
KNFB Reader (rebranded OneStepReader)	\$99.99	OCR/Reading	iOS/iPadOS AndroidOS 13+

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¹² requires books to be purchased

¹³ requires account with local affiliate State Library for the Blind

App	Cost	Function	OS
Kindle	free ¹²	e-Book	iOS/iPadOS AndroidOS 13+
Libby	free ¹³	Audiobook	iOS/iPadOS AndroidOS 13+
VoiceDream Reader	free ¹⁴	DAISY Reader	iOS/iPadOS
Productivity/Schoolwork/Optical Character Recognition			
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 ¹⁵	Online learning platform ¹⁶	iOS/iPadOS
Clusive	free	Online learning platform ¹⁷	iOS/iPadOS
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 ¹⁸	Scan & Markup Documents	iOS/iPadOS AndroidOS 13+
KNFB Reader (rebranded OneStepReader)	\$99.99	OCR/Reading	iOS/iPadOS AndroidOS 13+
My Board Buddy	free	local view of class blackboard	iOS/iPadOS
Notability	free ¹⁶	Scan & Markup Documents	iOS/iPadOS AndroidOS 13+
QuickScanner	free ¹⁹	OCR	iOS/iPadOS AndroidOS 13+
SeeingAI	free	Talking Camera	iOS/iPadOS AndroidOS 13+

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¹⁴ requires \$79.99/yr subscription and additional \$4.99 for each premium voice¹⁵ Full access provided through Vocational Rehabilitation¹⁶ Clusiv is an online learning platform for the blind and visually impaired that teaches occupational training, technology skills, and educational courses to empower employment¹⁷ Clusive is an open-source online learning platform for the blind and visually impaired¹⁸ with in app purchases¹⁹ a paid subscription removes ads and allows saving of documents

App	Cost	Function	OS
TapTapSee	free	Talking Camera	iOS/iPadOS AndroidOS 13+
Voice Aloud Reader	free ²⁰	OCR/Reading	iOS/iPadOS Android 13+
Orientation & Mobility / Navigation			
Apple Maps	free	Turn by Turn Navigation	iOS/iPadOS
BlindBat	free	Echolocation for the blind ²¹	iOS/iPadOS
BlindSquare	\$39.99	GPS Navigation	iOS/iPadOS
Clew	free	Indoor navigation ²²	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
Oko	free	Smart Camera Traffic lights/traffic	iOS/iPadOS AndroidOS 13+
Seeing Eye GPS	free ²³	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+

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²⁰ Premium Voices=\$9.99/mo, Pro Version=\$8.99/mo, OCR 800=\$1.99/mo, OCR 100=\$0.99/mo

²¹ Echolocation requires specific training

²² Augmented Reality is used to identify turns and stairways

²³ Monthly subscription \$6

App	Cost	Function	OS
Independent Living Skills			
CashReader	free ²⁴	Scan and Identify Paper money	iOS/iPadOS Android13 +
Menus4All	free ²⁵	Accessible Restaurant Menus	iOS/iPadOS
Zuzanka	free ²⁶	Expiration Date Barcode Scanner	iOS/iPadOS

Table 2.3: Mobile/Tablet Apps²⁴ requires a subscription to remove limited scans/day, \$2/mo, \$12/yr, &30/lifetime²⁵ requires a subscription, \$3/mo or \$30/yr²⁶ requires a subscription to remove limited scans/day, \$5/mo, \$35/yr, &80/lifetime

Chapter 3:
Bridging Literacy: The Crucial Role of Refreshable
Braille Displays in Empowering Visually Impaired
Students

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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 embarks on a compelling exploration of how refreshable braille displays are not merely tools but keystones in the quest for literacy and educational achievement among visually impaired students.

At the heart of this exploration lies the transformative power of refreshable braille displays—a technological marvel that seamlessly integrates the tactile richness of braille with the dynamic capabilities of digital communication. This chapter delves into the ergonomic design and sophisticated functionalities of these devices, spotlighting their pivotal role in ensuring that visually impaired students not only read but actively participate in the discourse of knowledge acquisition.

Refreshable braille displays play a dual role in the educational narrative of visually impaired students. Firstly, they 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. Secondly, and perhaps more profoundly, these devices 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 emerge not just as tools but as instruments of empowerment, fostering a sense of agency and paving the way for academic success in the rich landscape of education.

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* gives the specs for currently available braille notetakers.

Display	Cost	Battery	Keyboard	Manufacturer	OS
BrailleNote Touch+ ¹	\$5,795	12h	Perkins	Humanware	Android 8 ²
BrailleSense 6	\$5,795	12h	Perkins	HIMS	Android 10 ^{3,4}
BTSpeak Pro ^{5,6}	\$1,195	15h	Perkins	Blazie Tech	Linux

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¹ For both the BrailleNote Touch+ and BrailleSense 6, there is an emerging issue with outdated operating systems, WiFi connectivity inconsistencies, and incompatibility with Google applications.

- Link to article from Perkins.org regarding the BrailleNote Touch Plus
- Continually Updated List for End of Life for all flavors of AndroidOS

² Android 8 'Oreo' Security Support Ended (i.e., End of Life) 2017-12-05

³ Android 10 'Queen Cake' Security Support Ended (i.e., End of Life) 2023-03-06

⁴ The Braille Sense has a firmware update v2.0 released 2023-11-28 which updates the operating system to Android 12, but this is currently buggy and causing system overheating. (*note*: Android 12 will only receive updates until ~October of 2024)

⁵ This is a Linux Computer without a monitor that runs on ORCA, but it has settings to function like a braille notetaker

⁶ This device has only auditory output

Display	Cost	Battery	Keyboard	Manufacturer	OS
Canute Console	\$6,890 ⁷	15h	QWERTY	Bristol Braille	Rasperian 12 ^{8,9}
ElBraille 40 ^{10,11}	\$6,000 ¹²	TBD	QWERTY	Elita	Windows 10 ¹³
InsideONE+	\$5,499	6h	Perkins	InsideVision	Windows 11
Nattiq Note	\$5,200	12h	QWERTY	Nattiq	Windows 11
Notey the Notetaker	~\$750+ ¹⁴		QWERTY Perkins	Miscs	Windows 11
Orbit Optima ¹⁵	\$6,000 \$9,000	TBD	QWERTY	Orbit Research	Windows 11
Seika Studio ¹⁶	\$6,500	TBD	QWERTY	Nippon Telesoft	Windows 10
b.note	\$4,360	15h	Perkins	Eurobraille	Windows 10
b.book	\$5,765	15h	Perkins	Eurobraille	Windows 10 ¹⁷

Table 3.1: Braille NoteTakers and Laptops

⁷ \$3,995 for the Canute Console+\$2,895 for the Canute Display

⁸ Debian 12 Linux for Raspberry Pi

⁹ This is a console/terminal driven operating system that requires knowledge of Linux (or desire to learn) and a certain level of comfort using bash commands as a primary method of controlling the system

¹⁰ This is a Windows Computer without a monitor that runs on JAWS, but it has settings to function like a braille notetaker

¹¹ This is not included above as a laptop option since it has only 4GB of RAM

¹² This price is for the ElBraille unit itself as well as a Focus 40 that docks into the unit as a display

¹³ Windows 11 is not yet officially supported, but users are updating to Windows 11 without issue

¹⁴ Self build Specs for Notey the NoteTaker

¹⁵ This is a Windows Computer without a monitor that runs on any screenreader, but it has settings to function like a braille notetaker

¹⁶ This is a Windows Computer without a monitor, but it has settings to function like a braille notetaker

¹⁷ Windows 11 version coming Q1 2024

3.2: Braille Notetaker/Laptop Recommendations

The BrailleNote Touch Plus runs on Android 8.1 Oreo, while the BrailleSense 6 runs on Android 10¹⁸. Both operating systems are outdated, with Android 14 being the current version of the Android operating system as of October 3, 2024¹⁹.

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 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 system 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.

Display	Cost	Battery	Keyboard	Manufacturer	OS
Orbit Optima	\$6,000 \$9,000	TBD	QWERTY	Orbit Research	Windows 11
Seika Studio	\$6,500	TBD	QWERTY	Nippon Telesoft	Windows 10
b.book	\$5,765	15h	Perkins	Eurobraille	Windows 10

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¹⁸ 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

¹⁹ Android 15 will be released in Beta in February 2024 and as a stable version in October 2024

Display	Cost	Battery	Keyboard	Manufacturer	OS
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Table 3.2: Braille Notetaker and Laptop Recommendations. Overall recommendation highlighted in light red.

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* lists current available display options.

Display	Cost	Battery	Keyboard	Manufacturer
Actilino	\$2,795	16	Perkins	Help Tech
Basic Braille 20	\$2,295	16	none	Help Tech
Brailliant BI20x	\$2,199	14	Perkins	Humanware
Chameleon 20	\$1,715	14	Perkins	APH
Focus 14 Blue	\$1,545	18	Perkins	Vispero
Orbit Reader 20+	\$799	20	Perkins	Orbit Research
Orbit Speak ²⁰	TBD	20	Perkins	Orbit Research
BTSpeak ²⁰	\$1,195	15	Perkins	Blazie Tech
Seika 24	\$2,395	20	none	Nippon Telesoft
Seika Mini Plus	\$2,795	20	none	Nippon Telesoft
VarioUltra 20	\$4,340	12	Perkins	VisioBraille
b.note 20	\$2,695	15	Perkins	Eurobraille

Table 3.3: 14-20 cell Single Line Refreshable Braille Displays

²⁰ This device has no braille output, but uses braille input and returns auditory output

3.3.2: 32-40 cell 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. *Table 3.4* lists current available display options.

Display	Cost	Battery	Keyboard	Manufacturer
Activator	\$6,495	40	Perkins	Help Tech
Active Braille	\$6,495	20	Perkins	Help Tech
Active Star	\$6,795	40	Perkins	Help Tech
Alva 640 Comfort	\$3,046	10	Perkins	Optelec
Alva 640 USB	\$3837	n/a	none	Optelec
Alva BC 640	\$2,087	10	none	Alva
Basic Braille Plus	\$3,295	12	Perkins	Help Tech
Brailiant BI40x	\$3,195	14	Perkins	Humanware
Focus 40 Blue	\$3,145	18	Perkins	Vispero
Mantis Q40	\$2,495	14	QWERTY	APH
Orbit Reader 40	\$1,399	20	Perkins	Orbit Research
QBraille XL	\$3,195	16	Perkins	HIMS
Seika V5	\$2,495	20	none	Nippon Telesoft
Vario 340	\$5,138	20	none	VisioBraille
Vario 440	\$4,550	20	none	VisioBraille
Vario Ultra 40	\$7,643	12	Perkins	VisioBraille
b.note 40	\$3,565	15	Perkins	Eurobraille

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Display	Cost	Battery	Keyboard	Manufacturer
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Table 3.4: 32-40 cell Single Line Refreshable Braille Displays

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* lists current available display options.

Display	Cost	Battery	Braille Lines	Keyboard	Manufacturer
APH Monarch	~\$15,000	11 hr	10 row x 32 cell +32 cell line	Perkins	Humanware APH
Blitab	\$500	TBD	14 row x 23 cell	Touch Interface	Blitab
BraillePad	\$4,390	TBD	50 row x 40 cells	none	4Blind
Cadence	TBD	TBD	6 row x 8 cells stack to 24 x 16	Perkins	Tactile Engineering
Canute 360	\$2,895	Req AC	9 row x 40 cell	none	Bristol Braille
DotPad	~\$15,000	11 hr	10 row x 32 cell + 20 cell line	Touch interface	Dot Inc.
Graphiti	~\$15,000	20-22	60 row x 40 cell	Perkins	Orbit Research
Graphiti Plus	~\$15,000	20-22	60 row x 40 cell + 40 cell line	Perkins	Orbit Research
Orbit Slate 340	\$3,995	20-22	5 row x 20 cell	Perkins	Orbit Research
Orbit Slate 520	\$3,495	20-22	5 row x 20 cell	Perkins	Orbit Research
TACTIS 100	~\$5,000	Req AC	4 row x 25 cell	none	Tactisplay
TACTIS Table	~\$15,000	Req AC	25 row x 40 cell	none	Tactisplay
TACTIS Walk	~\$7,000	Req AC	10 row x 25 cell	none	Tactisplay
Tactile Pro	TBD	TBD	TBD	Perkins	PCT
Tactonom Pro	~\$15,000	Req AC	89 row x 119 cell	N/A	Tactonom

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Display	Cost	Battery	Braille Lines	Keyboard	Manufacturer
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Table 3.5: Multiple Line Refreshable Braille Devices

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 effectively²¹. 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 effectively²².

In addition to providing a more engaging learning experience, specialized tools like 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* lists current available options for braille instructional devices.

Equipment	Cost	Manufacturer
Braille Doodle	\$85	Touchpad Pro Foundation
Braille Teach	\$150	Braille Teach
BrailleBlox	\$85 ²³	BrailleBot

Continued on next page

²¹ Taptilo. (n.d.). Taptilo. Retrieved December 19, 2023 <https://www.taptilo.com/>

²² Thinkerbell Labs. (n.d.). Polly. Retrieved December 19, 2023 <https://www.thinkerbelllabs.com/>

²³ Requires purchase of a LeapFrog Fridge Phonics base, ~\$20

Equipment	Cost	Manufacturer
BrailleBuzz	\$99	APH
BrailleCoach	\$1,095	Logan Tech
Feelif Creator	\$2,200	Feelif Technology
Feelif Pro	\$3,595	Feelif Technology
Mountbatten Braille Tutor	\$5,495	Harpo
Polly ²⁴	\$999	APH Thinkerbell Labs
Read Read	\$645	EdVar Tech
SMART Brailler	\$2,195	Perkins
Taptilo	\$1,349	HIMS OHFA Tech

Table 3.6: Braille Education Device

²⁴ Called “Annie” outside the Unites States

Chapter 4:

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

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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 embarks on a profound exploration of 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 sophisticated devices, with their ability to translate complex symbols and notations into tangible braille and tactile graphics, stand as pioneers in fostering 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 emerge as transformative tools that 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. Assessing the landscape of inclusive STEM education, it becomes evident that high-quality braille embossers are not merely tools but enablers of success. 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 the exciting and dynamic world of 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 embossers¹.

Machine	Cost	Capability	Company
APH PageBlaster (old Model Index-D V4)	\$4,295 ²	Simple Graphics, Interpoint Braille	APH Index Braille
Basic-D V5	\$3,695 ³	Simple Graphics, Interpoint Braille	Index Braille
BrailleTrac 120	\$3,595	Simple Graphics, Interpoint Braille	Irie-AT
Juliet 120	\$4,195 ²	Simple Graphics, Interpoint Braille	ETS Humanware
ViewPlus Columbia ⁴	\$3,495	Complex Graphics, Interpoint Braille	ViewPlus
ViewPlus Rogue (old ViewPlus Max) ⁴	\$5,995	Complex Graphics, Interpoint Braille	ViewPlus

Table 4.1: Braille Embossers focusing on Text

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

² Requires free Firebird Tactile Graphics Software for graphics functionality

³ Requires TactileView license for full graphics functionality (\$484 for 1 year license)

⁴ Requires Tiger Software Suite for full functionality (\$195 for 1 year license)

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.”⁵
- 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

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.

⁵ Adkins, A., Sewell, D., & Cleveland, J. (2016). The Development of Tactile Skills. *TX SenseAbilities, Fall/Winter*.

Machine	Cost	Company
APH PixBlaster (old Model ViewPlus Columbia)	\$4,295 ⁶	APH ViewPlus
Basic-D V5	\$3,695 ⁷	Index Braille
EZ-Form Brailon Duplicator	\$3,899	American thermoform
PIAF tactile embosser	\$1,745	Humanware
Swell Form Machine	\$1,400.00	American Thermoform
ViewPlus Columbia	\$3,495 ⁶	ViewPlus
ViewPlus Delta	\$4,195 ⁶	ViewPlus
ViewPlus Elite	\$14,995 ⁶	ViewPlus
ViewPlus Premier	\$9,995 ⁶	ViewPlus
ViewPlus Rogue (old ViewPlus Max)	\$5,995 ⁶	ViewPlus

Table 4.2: Equipment for Tactile Graphics Generation⁶ Requires Tiger Software Suite for full functionality (\$195 for 1 year license)⁷ Requires TactileView license for full graphics functionality (\$484 for 1 year license)

4.3: Tactile Graphic Supplies

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

Paper / Medium	Cost	Company
Brailon Thermoform Paper (for EZ-Form Duplicator)	\$42.99 (100 sheets heavy), \$75.99 (500 sheets regular)	American Thermoform
Swell Touch Paper (for Swell Form Machine)	\$165 for 100 pages	American Thermoform
Tangible Magic capsule Paper (for PIAF tactile embosser)	\$220 for 100 pages	Humanware
Tractor-Feed Braille Paper (for embossers)	\$79.47 for 1000 pages	APH

Table 4.3: Paper supplies for Tactile Graphics Generation

Chapter 5:

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

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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 embarks on a captivating exploration of the indispensable role that 3D printed materials play in providing a tangible, tactile bridge to knowledge. These innovative creations not only facilitate hands-on engagement with concepts but stand 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. Enter 3D printed materials—a technological marvel that transcends the limitations of traditional teaching tools. This chapter delves into the transformative impact of these creations, spotlighting their role in enhancing literacy by providing a multisensory gateway to understanding.

From intricate historical artifacts to complex mathematical models, 3D printed materials have the power to transform abstract concepts into tangible, touchable entities. Through this chapter, we will explore how these creations transcend the boundaries of traditional education, offering visually impaired students the opportunity to feel, explore, and internalize knowledge in a manner that aligns with their unique learning styles.

The immersive nature of hands-on learning with 3D printed materials not only fosters comprehension but also instills a sense of empowerment and curiosity. Given the diverse applications of these innovative tools, it is clear that they are not merely educational aids but agents of transformation, democratizing access to knowledge and enhancing the educational journey for visually impaired students. This chapter seeks to underscore the necessity of 3D printed materials in shaping the hands-on literacy experience, ensuring that visually impaired students can grasp the intricacies of the world around them with confidence, curiosity, and a sense of empowerment.

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 be capable of producing 3D models that are tactile and can be easily understood by students with visual impairments. The models should have a clear texture and be easy to touch and feel.

High resolution: The printer should be able to produce high-resolution models with fine details. This is important for creating models that are accurate and easy to understand.

Ease of use: The printer should be easy to use and operate. It should have a simple interface and be easy to set up and maintain.

Compatibility: The printer should be compatible with a wide range of software and file formats. This is important for creating and printing models from a variety of sources.

Cost: The printer should be affordable and within the budget of the school or institution. This is important for ensuring that all students have access to the technology they need to access a free and appropriate public education.

According to a study by Kietzmann et al., 3D printing can help visually impaired students learn a variety of disciplines such as engineering, manufacturing, food, art, and health. Additionally, 3D printed models can be beneficial for students who are blind and sighted, which allows for students of various levels of vision to use the same tactile learning tools¹. Neal McKenzie, an Assistive Technology Specialist for the Visually Impaired Department at the Sonoma County Office of Education, uses 3D printing technology to make education more accessible and comfortable for his students. He recommends using 3D printing to create tactile math graphing systems, Braille learning tactile games, and other functional tools that help visually impaired students be more independent and access specific concepts or assignments².

Table 5.1 lists current available 3D printers.

Model	Cost	PPrint Bed Size	Filament Size	Manufacturer
Ender 3 Max Neo	\$359	300x300x320mm	1.75mm	Crealiti
Ender 5 Plus	\$579	350x350x400mm	1.75mm	Crealiti

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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

Model	Cost	Print Bed Size	Filament Size	Manufacturer
K1	\$599	220x220x256mm	1.75mm	Creality
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
P1P 3D Printer	\$699	256x256x256mm	1.75mm	Bambu
P1S 3D Printer	\$949	256x256x256mm	1.75mm	Bambu
A1 3D Printer	\$559	256x256x256mm	1.75mm	Bambu
Sidewinder X2	\$399	300x300x396mm	1.75mm	Artillery

Table 5.1: 3D Printers

5.2: 3D Printer Materials

3D printing is a production technique that creates a three-dimensional object from a computer-aided design (CAD) file. The process involves depositing one or more materials, typically plastic, metal, wax or composite, layer by layer to build a shape³. To use a 3D printer in an educational environment, you would need the following materials:

- **3D printer:** 3D printers come in various sizes, from small enough to fit on a benchtop to large-format industrial machines. Large printers can produce bigger objects, but the machines take up more space and cost significantly more than benchtop printers³.
- **Filament:** Filament is the material used to create the 3D object. The most common filament materials are PLA, TPU, ABS, CPE, PETG, nGen, INOVA-1800, HIPS, HT, t-glase, Alloy 910, Polyamide, Nylon 645, Polycarbonate, PC-Max, PC+PBT, PC-ABS Alloy, PCTPE, and more⁴.
- **Computer:** A computer is required to create the 3D model using CAD software. The computer sends the model to the 3D printer to create the object.
- **CAD software:** CAD software is used to create the 3D model. There are many free and paid CAD software options available.
- **Slicing software:** Slicing software is used to convert the 3D model into a format that the 3D printer can understand. The software slices the model into layers and generates the G-code that the printer uses to create the object⁵.

Table 5.2 lists materials needed in order to use the 3d printers shown in Table 5.1.

Item	Cost	Vendor
1.75mm filament	\$12.00/kg	Elegoo
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

Table 5.2: 3D Printer Materials

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

5.3: 3D Printer Software

3D printing has revolutionized the manufacturing industry by enabling the creation of complex and intricate designs that were previously impossible to produce. Programs that create, edit, and slice 3D STL models are essential for 3D printing. These programs allow users to create 3D models from scratch or modify existing ones. They also enable users to slice the 3D model into layers and generate G-code, which is a machine-readable code that instructs the 3D printer on how to print the object. Some popular 3D printing software programs include TinkerCAD, FreeCAD, and Blender⁶. These programs offer a wide range of tools for designing and editing 3D models, including the ability to sculpt, combine/merge multiple STL files, delete sections, repair errors, resize, scale, and convert a model to a solid and export-ready for slicing⁷. The importance of these programs lies in their ability to make 3D printing accessible to everyone, from hobbyists to professionals, by providing a user-friendly interface and a wide range of features that cater to different skill levels *Table 5.3* lists materials needed in order to use the 3d printers shown in *Table 5.1*.

Program	Cost	Function
Fusion 360	\$free ⁸	Generate 3D file
FreeCAD	\$0	Generate 3D file
SolidWorks	\$4,000/yr	Generate 3D file
TinkerCAD	\$0	Generate 3D file
SketchUp Free	\$0	Generate 3D file
Blender	\$0	Generate 3D file
Rhino 6	\$995/\$195 student	Generate 3D file
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

Table 5.3: 3D Printer Materials

⁶ 3D Insider. (2021, June 16). Best Free 3D Printing Software for Beginners and Pros

⁷ All3DP. (2022, January 4). 2022 Best 3D Printing Software (CAD/Free/Paid)

⁸ for advanced features \$60/month

Chapter 6:

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

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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 education¹:

- **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: 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: The magnifier should be compatible with the student's other assistive technology devices, such as screen readers and braille displays.
- **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 6.1* lists current available video magnification devices for students with visual impairments.

Model	Cost	Deployment	Company
AceSight VR	\$2,695	VR Headset	Zoomax
Acesight	\$4,295	E-Glasses	Zoomax
Acesight 8	\$2,995	E-Glasses	Zoomax
Acuity 22	\$2,695	Desktop	Irie AT
Acuity 22 Speech	\$3,695	Desktop	Irie AT
Amigo	\$1,400	Portable	Enhanced Vision
Cloverbook Plus	\$2,295	Mobile	Irie-AT
Cloverbook Pro	\$2,995	Mobile	Irie-AT
Connect 12	\$2,695	Desktop Mobile	Humanware

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

Vision Department Technology Needs

Model	Cost	Deployment	Company
Connect 12 (10x)	\$2,845	Desktop Mobile	Humanware
Connect 12 (25x)	\$2,895	Desktop Mobile	Humanware
Distance Camera	TBD	Hand-Held	Zoomax
explore 12	\$1,895	Desktop	Humanware
explore 5	\$845	Hand-Held (5" screen)	Humanware
explore 8	\$1,275	Hand-Held (8" screen)	Humanware
I-See 22"	\$2,095	Desktop	Irie AT
Juno	\$1,392	Hand-Held (7" screen)	APH
Jupiter Portable Magnifier	\$3,599.00	Desktop Mobile, but heavy	APH
Luna 6	\$795	Hand-Held (6" screen)	Zoomax
Luna 8	\$895	Hand-Held (8" screen)	Zoomax
Luna Eye	TBD	Hand-Held	Zoomax
Luna HD Pro	\$2,995	Desktop	Zoomax
Luna S	\$385	Hand-Held (4.3" screen)	Zoomax
MAGNA 3	\$149	Hand-Held (3.5" screen)	Orbit Research
MAGNA 4	\$199	Hand-Held (4.3" screen)	Orbit Research
MAGNA 5	\$249	Hand-Held (5" screen)	Orbit Research
MATT Connect v2	\$3,895	Desktop Mobile, but heavy	APH
Magnibot	\$2,995	Desktop Mobile	Trysight
Magnilink Air	\$5,995	Desktop	Low Vision International
MagniLink Tab	\$5,895	Desktop	Low Vision International
MagniLink One	\$2,395	Desktop	Low Vision International
MagniLink S Premium	\$4,295	Mobile	Low Vision International
MagniLink Vision	\$3,190 - \$4,250	Desktop	Low Vision International
MagniLink WifiCam	\$3,695	Mobile	Low Vision International
MagniLink Zip	\$3,625	Desktop	Low Vision International
Merlin Mini	\$3,570	Mobile	Enhanced Vision
ONYX Desk set HD	\$3,330	Desktop	Freedom Scientific

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Model	Cost	Deployment	Company
ONYX OCR	\$4,520	Desktop	Freedom Scientific
Panda HD	\$2,098	Desktop	Zoomax
Pebble HD	\$656	Handheld	Enhanced Vision
RUBY	\$600.60	Hand-Held (4.3" screen)	Freedom Scientific
RUBY 10	\$1,640	Hand-Held (10" Screen)	Freedom Scientific
RUBY 7 HD	\$1,317.75	Hand-Held (7" Screen)	Freedom Scientific
RUBY HD	\$710.85	Hand-Held (4.3" screen)	Freedom Scientific
RUBY XL HD	\$987.00	Hand-Held (5" screen)	Freedom Scientific
Reveal 16	\$3,295	Desktop	Humanware
Reveal 16 (XY table)	\$3,995	Desktop	Humanware
Reveal 16i	\$4,295	Desktop	Humanware
Reveal 16i (XY table)	\$4,995	Desktop	Humanware
Snow 12	\$1,395	Desktop Mobile	Zoomax
Snow Pad	TBD	Hand-Held	Zoomax
TOPAZ EZ HD	\$3,081.75	Desktop	Freedom Scientific
TOPAZ OCR	\$4,640.00	Desktop	Freedom Scientific
TOPAZ XL HD	\$4,045.00	Desktop	Freedom Scientific
Tactonum Pro	£10,000	Desktop Not Readily Mobile	Tactonum
Tactonum Reader	£3,795.00	Desktop Not Readily Mobile	Tactonum
Transformer HD	\$3,565	Mobile	Enhanced Vision
Traveller HD	\$656	Mobile	Optelec

Table 6.1: Video Magnification Devices

Chapter 7:

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

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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 schools¹. 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 features².

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 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 (Digital Accessible Information System) readers. This chapter embarks on a profound exploration of the indispensable role that these tools play in breaking down barriers to literacy, ensuring access to a rich tapestry of knowledge, and propelling visually impaired students towards academic success.

The quest for literacy is deeply entwined with the ability to access and engage with textual content. Audiobook and DAISY readers emerge as champions in this narrative, providing a dynamic bridge that transcends the limitations posed by traditional print materials. As we delve into this chapter, we will unravel the nuanced functionalities of these tools, showcasing how they offer not just access to literature but a pathway to immersive and engaging learning experiences.

In subjects ranging from literature to science, where the written word is the gateway to understanding, Audiobook and DAISY readers become indispensable companions for visually impaired students. This chapter will explore how these technologies facilitate not only independent reading but also active participation in classroom discussions and

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

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

assignments. By providing a platform that transforms written content into spoken words or navigable digital formats, these tools empower students to explore the vast realms of knowledge with autonomy and confidence.

The significance of Audiobook and DAISY readers extends beyond mere accessibility; they are key enablers of success. It is evident that these tools are not just aids for the visually impaired; they are essential components of an inclusive education landscape. Audiobook and DAISY readers ensure that every student, regardless of their visual abilities, can embark on a literary journey that is both enriching and empowering.

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 Digital Accessible Information System (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 (Digital Accessible Information System) 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* lists current available DAISY readers.

Model	Cost	Function	Company
Milestone 212 Ace Book Reader	\$380	DAISY Reader Digital Audio Player	Bones
PlexTalk PTN2	\$375	DAISY Reader CD Player	PlexTalk
PlexTalk Pocket	\$275	DAISY Reader Digital Audio Player	PlexTalk
Reizen DAISY Digital Recorder	\$219	DAISY Reader Digital Audio Player	Reizen
Victor Reader Stratus	\$495	DAISY Reader Digital Audio Player Not very portable	Humanware
Victor Reader Stream	\$550	Digital Audio Player	Humanware

Continued on Next Page

Model	Cost	Function	Company
Victor Reader Trek	\$975	GPS Digital Audio Player	Humanware

Table 7.1: DAISY/Audiobook/Podcast Devices

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. It is important to note that the use of assistive technology helps prepare students for independent living, vocational pursuits, or higher education following graduation from high school.

Text-to-Speech technology is a powerful tool that can help students with visual impairments or blindness receive a free and appropriate public education. These students face unique challenges in the educational environment, as they must be able to access text information across all curricular areas and participate fully in instruction that is often rich with visual content. Assistive technology is one way of supporting them in that process. Text-to-Speech software allows the computer to “read” digital text to the student in a digitized voice, which can be a game-changer for students who struggle with text in written form. Some programs will highlight words as they are read, allowing students to follow along. Refreshable braille displays can be connected to the digital text source, providing students with the option to read the text tactually Text-to-speech technology offers an alternative way for students of all ages and learning abilities to access a variety of texts with ease. Using it correctly, the text-to-speech benefits students who struggle with text in written form By providing students with visual impairments access to text-to-speech software, we can help ensure that they have the tools they need to succeed in their studies and beyond. *Table 7.2* lists current available text-to-speech devices.

Model	Cost	Function	Company
c-Pen2	\$399	Pen Scanner Text-to-Speech Reader	c-Pen
MyEye Pro	\$4,250	Glasses Mounted Text to Speech	OrCam
LyriQ	\$1,960	Text to Speech	Zyrlo
Read 3	\$2,490	Hand-held Text to Speech	OrCam
Scanmarker Air	\$150	Hand-held Text to Speech	Scanmarker
Smart Reader HD	\$2,495	Portable Text to Speech	Enhanced Vision

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³ 20 U.S.C. § 1400, et.

Model	Cost	Function	Company
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Table 7.2: Text-to-Speech Devices

Chapter 8:

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

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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 embarks on a compelling exploration of 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 unravel 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. This chapter will explore how 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 crossing¹.
- **Compatibility:** The GPS unit should be compatible with other assistive technology devices, such as screen readers and braille displays².
- **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.
- **Cost:** The cost of the GPS unit should be reasonable and within the user's budget.

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.

Model	Cost	Function	Company
Stellar Trek	\$1,595	GPS	Humanware
Victor Reader Trek	\$975	GPS + Digital Audio Player	Humanware
Wayband	\$250	GPS (Haptic Output)	WearWorks

Table 8.1: Accessible GPS Mapping / Navigation

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

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 way³. 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 way³. 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 feedback⁴. 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 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 Braille⁵. 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.

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

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

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 living⁶:

- **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 living⁷.

Model	Cost
Infrared Talking thermometer	\$45
Liquid Level Indicator	\$10
PenFriend Voice Labelling System	\$170 ⁸
Talking First Aid Guide	\$35
Talking Indoor/Outdoor Thermometer	\$15
Talking Kitchen Scale	\$35
Talking Measuring Tape	\$145
Talking Meat Thermometer	\$40

Continued on Next Page

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

⁸ An extra 418 labels are available for \$30

Model	Cost
Talking Timer Clock	\$15
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 ⁹

Table 8.2: Accessible Independent Living Technology

⁹ An extra 25 magnets are available for \$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 curriculum¹. 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. Screen magnification is one such assistive technology that can help students with visual impairments access their free public education. 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 others¹. This can help improve their self-esteem and confidence, which can have a positive impact on their academic performance and overall well-being.

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

¹ 20 U.S.C. § 1400, et.

impairments to receive a free and appropriate public education. The technology needs of these students must be addressed within the framework of IDEIA¹, 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.

APPENDICES

Appendix A

Troubleshooting Screenreader & Magnifier Performance

Contents

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Appendix A.1: Clearing System Cache

One thing that is 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.

Appendix 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.

Appendix 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.

Appendix A.4: Community Support via ListServ

Sometimes asking a listserv that talks about screen readers may give faster responses than contacting official customer support. This is because 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 listserv 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

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Appendix 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 mode¹. 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 defaults². 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 defaults². This may help to resolve 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.

¹ Humanware. (n.d.). BrailleNote Touch - Frequently Asked Questions. Retrieved December 18, 2023

² BrailleSense 6 User Manual, Chapter 3.9, page 68

Appendix 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.

Appendix 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

Appendix 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. This is because 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
 - Brailiant-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

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Appendix C.1:

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 studies¹. Additionally, a valid assessment can help ensure that the student receives the appropriate accommodations and modifications to their educational program².

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 studies³. 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. 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 others⁴.

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.

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

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

Appendix C.2: 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 in⁷.

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}.

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.

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

Appendix C.3: 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

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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 possible¹. 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 display². Magnification software enlarges the text and images on the screen for low vision users³. 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 them⁴.

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

Appendix 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.

- Typio⁵

⁵ This product was specifically developed for use with the blind

- Ballyland Keyboarding⁵
- TypeAbility⁵
- Sao Mai Typing Tutor⁵
- Keystroke⁵
- APH Typer Online^{5,6}
- Typing Club
- Touch-Type Read and Spell (TTRS)⁷

⁶ Formerly known as Talking Typer

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

Appendix 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 effectively¹⁰. 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 App¹²
- Ballyland Apps
- The Screen Reader Training Website¹³
- Listen with TalkBack Series from Hadley
- Listen with VoiceOver Series from Hadley

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

Appendix 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 paragraph¹⁴. 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 fields¹⁷. 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 Up¹⁸
- The Screen Reader Training Website¹⁹
- Windows Narrator Series from Hadley
- NVDA Series from Hadley
- Windows Screen Reader Primer^{20,21}
- Access Technology Institute, LLC. Courses²²
- NVDA Training Materials²³
- JAWS Basic Training

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 October 3, 2024

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

- Working with Text from eyeTvision²⁴
- Basic Internet Navigation from eyeTvision²⁴

²⁴ Covers NVDA, JAWS, and ChromeVox Screenreaders

Appendix 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 needs²⁵. Specialized software can provide features such as color filtering, cursor enhancements, and text-to-speech capabilities²⁶. 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 jobs²⁷. 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

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.

Appendix 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 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 writing²⁹. 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

²⁹ Perkins School for the Blind. (n.d.). Benefits of Using a Braille Display with Emerging Readers. Retrieved January 8, 2024

Appendix 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 coders³⁰. 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 youth³¹. 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 code³². It's worth noting that blind people can be successful software developers, with 1 out of every 200 software developers being blind³³. With the right resources and support, blind students can learn computer programming and pursue a career in software development.^{34,35}

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.

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.

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 Beijers³⁶
- CodeHS
- Code Academy
- APH CodeJumper^{37,38}
- Code Quest³⁸
- APH Code & Go Mouse³⁸
- EarSketch³⁹

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

Contents

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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 APFont 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 Standards¹ and other regulations require sans-serif fonts in certain places, and typography choices have a huge impact on accessibility². 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 readability⁵

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

Appendix E.1: Atkinson Hyperlegible Font⁶

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%

1'1'2'2'3'3'4'4'5'5'6'6'7'7'8'8'9'9'

{ } () [] # * : ; ! ? ° < > person_name@email.com © ® ™

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?

⁶ Developed by the Braille Institute

Appendix E.2:

APHont⁷

Sample text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Facilis 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%

1¹1²2¹2²3¹3²4¹4²5¹5²6¹6²7¹7²8¹8²9¹9²

{ } () [] # * : ; ! ? ° < > person_name@email.com © ® ™

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?

⁷ Developed by the American Printing House for the Blind, font download [here](#)

Appendix E.3: 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.

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

1¹¹²²³³⁴⁴⁵⁵⁶⁶⁷⁷⁸⁸⁹⁹

{ } () [] # * : ; ! ? ° < > person_name@email.com © ® ™

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?

Appendix E.4:

JetBrains Mono⁸

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%

1¹2²3³4⁴5⁵6⁶7⁷8⁸9⁹

{ } () [] # * : ; ! ? ° < person_name@email.com © ® ™

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?

⁸ Font created for monospace/coding needs

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