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The weak link in assistive technology – the internet

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ABSTRACT

Assistive Technology (AT) allows individuals with disabilities to circumvent areas of weakness. Many AT tools have been developed for server-side environments with the assumption that students will have access to sufficiently fast internet when they need it in order to use the tools effectively. However, this is not always the case. In the current study, the impacts of client-side versus server-side applications, internet speed, and the cache on the loading time of four popular AT tools were examined. Client-side applications were expected to result in the fastest loading time, and a preloaded cache was expected to eliminate much of the disparity between high- and low-speed internet. These hypotheses were largely confirmed. There were significant differences in the time to open client-side programs compared to server-side programs with low-speed internet. Several classroom implementation strategies for server-side AT are discussed.

1. Introduction

Assistive technology (AT) is any technology that allows an individual with a disability to increase, maintain, or improve their functional capabilities [1]. AT has been deemed a critical component of the successful classroom inclusion and academic success of students with learning disabilities [1] as it can help them circumvent areas of challenge and complete tasks more efficiently and independently [2]. Some common AT tools that are used in classrooms include programs that can convert printed text to voice (text-to-speech; e.g., Kurzweil 3000, Natural Reader), that can help students organize their writing (graphic organizers; e.g., Inspiration, Mindomo), that provide students with spelling suggestions as they type (word prediction; e.g., WordQ, Read & Write), and that can convert information spoken by students into text on their screen (voice recognition; e.g., Dragon Naturally Speaking, TalkTyper).

AT has been thoroughly investigated and has been found to be beneficial for students with learning disabilities. While AT has been shown to improve reading comprehension and vocabulary, writing fluency, and motivation to write, it is often abandoned or inconsistently implemented [3]. While there are many reasons for abandonment of AT, a proposed barrier to AT use is the internet. For example, a recent survey of teachers in Ontario focusing on the barriers to AT integration in their classroom identified the internet as a significant challenge when it comes to using technology in the classroom, with teachers noting that their students' AT do not always reliably connect to the internet [4].

In recent years many AT programs have moved from client-side to server-side applications [5]. Client-side applications run on a user's local computer and, therefore, do not require an internet connection to run. They may be preferable when users want to ensure the security of their data. They also allow users to use computer applications when internet is unavailable or slow [6]. Server-side applications run through a remote server and, therefore, require a reliable internet connection to operate appropriately [7]. In other words, the user's computer must connect to a program that is hosted on a server computer that is not local to the user. Server-side

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applications are often referred to as "cloud-based" tools.

It would seem that server-side applications would be preferable to client-side applications because they allow students and school boards to access a wider variety of AT products at lower cost both in the home and school environments, but with reliable internet access being a critical component of the student's ability to access these server-side applications, this is not always the case. With more students working or attending school from home than ever before, access to server-side AT would be a barrier to learning for the 11.0% of Canadian households who do not have any internet access (with this statistic being an even more pronounced 31.0% in lower income households) [8]. It is important, therefore, to consider the internet as part of a student's learning environment when selecting AT tools and products for students.

1.1. Selection of AT

When selecting appropriate AT tools for students, there are many variables that must be considered. The SETT [Student, Environment, Task, Tool] framework encourages teachers to examine ecological variables in a systematic way [9]. It is important to understand and gather data about the **Student** (e.g., What are the student's cognitive strengths and weaknesses?), the **Environment(s)** in which the student works (e.g., What are the instructional and physical arrangements?), the **Task(s)** the student has to accomplish (e.g., What are the curriculum objectives?), and then which AT **Tool** would best suit the student's needs (e.g., Is a system of AT tools and strategies required for a student with these needs and abilities to do these tasks in these environments?). As many AT tools and products are being developed as server-side applications, the internet has increasingly become a critical component to consider as part of a student's work environment.

In Ontario, there is a massive variety in access to internet speeds. Despite the Canadian Radio-television and Telecommunications Commission (CRTC) recommendations that Canadians should be able to access 50Mbps download and 10Mbps upload speeds, many rural and remote environments lack the infrastructure that is necessary to meet minimum speed recommendations [10]. The CRTC recently has estimated that 85.7% of Canadian households were meeting their broadband speed recommendations [8]. School boards and governments have devoted significant funding toward improving internet infrastructure so that their students are able to access reliably fast internet. For example, in 2017 Ontario devoted $50 million dollars to improve internet access for students through the Broadband Access for All Students initiative [11]. Despite this progress, principals were recently reporting that high speed internet connectivity is an ongoing challenge in their schools [12]. This combined with the move by many AT developers toward a focus on server-side applications, has led to many problems with using AT in the classroom and while working from home.

1.2. Computer response time and user satisfaction

The push for greater funding for technology, specifically internet, infrastructure in schools illustrates the importance of well-functioning, fast internet to students and teachers. School boards have devoted many resources to improving internet bandwidth within their schools, but with more and more students and teachers connecting to the school internet daily there reportedly never seems to be enough. It has become important to investigate the impacts of low bandwidth on the user experience of websites and applications given that lower bandwidth results in slower loading times for webpages, which is experienced by users as slower computer response time (RT) [13].

Hoxmeier and DiCesare examined the effect of manipulating computer RT (from less than one second to twelve seconds) on adult user satisfaction of a webpage and the likelihood that users would use the webpage again [14]. The authors found that longer computer system RT led to lower satisfaction among users of a webpage [14]. This lower satisfaction may ultimately lead to the discontinued use of an application. Specifically, in Hoxmeier and DiCesare's study participants rated webpage satisfaction the highest for RTs that were less than one second but reported that they would use the system again for RTs of up to nine seconds. Further, a twelve second RT resulted in the lowest participant satisfaction. With the twelve second delay participants reported that they would not use the application again. Overall, Hoxmeier and DiCesare found that response times were the most influential variable when it comes to user satisfaction.

Many other authors examined user experiences for the RTs of internet-based applications and found varying estimates for the optimal delay [15,16]. For example, Nah found that two seconds was as long as most users were willing to wait for web-based information retrieval tasks [17]. Chen and Li investigated other factors (e.g., cartoon indicator, perceived RT) and found that participants preferred shorter perceived wait times, but that external factors could impact the perception of wait times [15]. Despite the variability of findings for optimal RT, it is important to examine the current RT for client-side and server-side AT programs, as it is expected that the majority of internet-based, server-side applications are well beyond the thresholds found by previous authors.

In addition to bandwidth, drops in connectivity can impact user experience [18]. Drops are caused by too many individuals attempting to access the same internet port with limited bandwidth, interference from other devices, or a number of other factors. These drops can lead to even greater lags in information access and RT on the internet, as users are required to resubmit their requests to the internet server after each drop [18].

1.3. The cache

With the propensity of server-side and cloud-based applications, internet caching was developed to ensure data availability and sufficiently fast data delivery speed despite internet bandwidth or speed [8]. When a user downloads a file from a server-side application a copy of the file is automatically stored in the cache (locally on the user's computer). This allows the user to subsequently access the file from their local computer, which greatly enhances the data delivery speed [8]. This enhanced delivery speed can improve a user's satisfaction with the website or application as they should be unaware that the cache is even being utilized [19]. Using the cache could mitigate the potential impacts of slower internet speeds for users of AT.

1.4. Objectives and hypotheses

When AT tools are developed exclusively for server-side or internet environments, there is an assumption that students will have access to sufficiently fast internet when they need it in order to use the tools effectively, but as was previously explained this is not always the case. The purpose of the current study was to examine the impacts of client-side versus server-side applications, internet speed, and the cache on the loading time of four popular AT tools: graphic organizer (GO), word prediction (WP), text-to-speech (TTS), and voice recognition (VR). It was hypothesized that the client-side applications would result in the fastest loading time, and further that a preloaded cache would eliminate much of the disparity between high-speed and low-speed internet. This study is not intended to replace or combat the paucity of literature focused on the benefits of cloud-based computing, but rather to investigate one factor than impacts AT use in the classroom – the internet. Additionally, it is hoped that this study may be useful to AT decision-makers in making appropriate and effective recommendations for students that increase their access to curriculum, and to teachers in facilitating the implementation of AT into their classrooms.

1.5. Manuscript organization

This manuscript includes a thorough description of the methods, including materials, design and procedure. This is followed by the statistical results which describe the performance of each AT tool in four different internet environments. The discussion includes a summary of the statistical results, implications for teachers and schools, and a description of the limitations of the present study and future directions.

2. Method

2.1. Materials

In all conditions both client-side and server-side applications were compared. Four of the most common AT tools that are used in classrooms were selected: graphic organizers, word prediction, text-to-speech, and voice recognition software. The programs that were selected were well-known to the authors and determined to be popular AT tools in Ontario classrooms at the time of writing based on the authors' professional experience in the field.

2.1.1. Graphic organizer

A GO allows for the visual representation of a student's knowledge or their ideas. GOs help with learning, planning, and organizing information. Features of the software support brainstorming, planning, organizing, outlining, pre-writing, diagramming, concept mapping, webbing, and more [20]. *Inspiration* by Inspiration Software, Inc. was selected as the client-side GO application, and was compared with *Mindomo* by Expert Software Applications, a popular server-side application.

2.1.2. Word prediction

When using WP software, as the user types each letter the software predicts the intended word (offering a list of adjustable length). If the intended word is in the list, the user can type the number of the word or point and click with the mouse to insert the word in the sentence. If the intended word is not present, the student can keep typing and different options will appear [21]. *WordQ* by Quillsoft was selected as both the client- and server-side application. The client-side application is typically used as an overlay of a standard word processor [22], whereas the server-side application is a Google Chrome extension that uses a separate word processing window.

2.1.3. Text-to-speech

TTS circumvents the need for students to decode words by presenting them auditorily. *Natural Readers* by NaturalSoft Ltd. was selected as the client-side application. It allows students to copy and paste, or upload documents and then reads the content to them. *Read & Write for Google Chrome* by TextHelp, was selected as the server-side application, and is a Google Chrome extension that allows students to work from a Google Document. It also features a screenshot reader so that students can read PDF documents.

2.1.4. Voice recognition

VR software enables the user to talk naturally to the computer, which will record exactly what they said as text. *Dragon Professional 15* by Nuance Communications, Inc. was selected as the client-side application. *Dragon* allows individuals to not only dictate writing, but to control their computer using their voice. It works as an overlay over all computer programs (including Google Documents). For the server-side application *Google Talk and Type*, which is built into the *Read & Write for Google Chrome* toolbar by TextHelp, was selected. *Google Talk and Type* works within Google Documents. For all VR tasks a *Samson Go Mic* microphone was used. The Rainbow Passage, one of the most common standard reading passages that contains almost all of the English phonemes [23] was recorded below and above 3.8 syllables per second (which is the average talking speed of adult English speakers [24]) and was used for all VR experimental conditions.

2.2. Design and procedure

2.2.1. Experimental conditions

There were five experimental conditions for each AT tool. These included: the client-side application condition, and four server-side application conditions (high-speed internet with a cleared cache [HS-Cleared], high-speed internet with a preloaded cache [HS-Preloaded], low-speed internet with a cleared cache [LS-Cleared], and low-speed internet with a preloaded cache [LS-Preloaded]). Internet speed was throttled to high speed urban and low speed rural bandwidths. The high-speed internet was connected to the University of Toronto network using Ethernet, therefore providing an average speed higher than most Ontario schools (55 Mbps download and 77 Mbps upload on average). The low-speed rural internet was throttled to 231 Kbps download and upload, which was an estimate of the average rural bandwidth in schools at the time this study was completed based on one published source [25]. In both the high- and low-speed conditions, the internet environment was controlled to eliminate drops in connectivity.

2.2.2. Data collection

Three trials were completed by the second author for each condition of each AT tool. Each trial included opening the tool and recording the length of time it took to complete each step of the program opening (until the AT tool started working). For example, to open Mindomo, first the internet browser had to be opened, next the Mindomo website had to be opened, the login needed to be completed, and finally a mind map had to be opened. For the VR trials, transcription errors were also counted as number of deviations from the Rainbow Passage. For each experimental condition internet speeds were confirmed, and the cache was cleared where appropriate (for the high-speed and low-speed cleared cache conditions).

3. Results

For each AT tool an analysis was conducted to examine if internet speed affected the total time (in seconds) taken to run the AT tool (i.e., GO, WP, TTS, VR).

3.1. Graphic organizer

The ANOVA revealed that GO software had significantly different total time to open depending on the internet speed (Table 1), $F(4, 10) = 62.46$, $p < .001$. The strength of relationship between internet speed and total time as assessed by η^2, was strong, with the internet speed accounting for 96% of the variance of the dependent variable. Follow-up tests were conducted to evaluate pairwise differences among the means. Levene's Test of Equality of Error Variances indicated that the variances among the internet speeds are significantly different, $F(4, 10) = 4.55$, $p = .024$, therefore we chose to use the Games-Howell test. Post hoc comparisons revealed no significant difference between the client-side application and HS-Clear, HS-Preloaded, or LS-Preloaded, however there were significant differences for client-side application and LS-Clear, $p < .01$, 95% CI [-184.02, -134.18]. In fact, LS-Clear total time was significantly different than all other conditions, except for LS-Preloaded, $p = .065$, 95% CI [126.29, 185.57].

3.2. Word prediction

The ANOVA revealed that WP software had significantly different total time to open depending on the internet speed (Table 2), $F(4, 10) = 28.92$, $p < .001$. The strength of relationship between internet speed and total time as assessed by η^2, was strong, with the internet speed accounting for 92% of the variance of the dependent variable. Follow-up tests were conducted to evaluate pairwise differences among the means. Levene's Test of Equality of Error Variances indicated that the variances among the internet speeds are significantly different, $F(4, 10) = 2.46$, $p = .113$. Post hoc comparisons revealed significant differences between the client-side application and HS-Clear, $p < .001$, and LS-Clear, $p < .001$, whereas the client-side application did not differ significantly from the HS-Preloaded, $p = .336$, or LS-Preloaded conditions, $p = .092$.

3.3. Text-to-Speech

The Kruskal–Wallis one-way analysis of variance was used due to violation of both assumptions of normality and homogeneity of variances, $F(4, 10) = 11.53$, $p = .001$, and revealed that TTS software had significantly differently total time to open depending on the internet speed (Table 3), $\chi^2(4) = 12.83$, $p = .012$. Post hoc tests of pairwise comparisons showed that total time for the client-side

Table 1
Means and Standard Deviations of the Total Time Taken to Operate Graphic Organizer Software.

Condition	Number of Trials	Total time (seconds) *M*	*SD*
Client-Side	3	13.00	3.67
HS-Clear	3	20.10	3.24
HS-Preloaded	3	16.17	1.58
LS-Clear	3	172.10	7.20
LS-Preloaded	3	57.09	31.85

Table 2
Means and Standard Deviations of the Total Time Taken to Operate Word Prediction Software.

Condition	Number of Trials	Total time (seconds) *M*	*SD*
Client-Side	3	6.52	1.62
HS-Clear	3	20.25	1.91
HS-Preloaded	3	10.05	.54
LS-Clear	3	22.13	1.45
LS-Preloaded	3	11.67	3.86

application was significantly different to the total time for the LS-Clear internet speed ($p = .010$). No other pairwise comparisons showed significant differences between samples.

3.4. Voice recognition

3.4.1. Time

The ANOVA revealed that VR software had significantly different total time to open depending on the internet speed (Table 4), $F(4, 10) = 260.84$, $p < .001$. The strength of relationship between internet speed and total time as assessed by η^2, was strong, with the internet speed accounting for 99% of the variance of the dependent variable. Follow-up tests were conducted to evaluate pairwise differences among the means. Levene's Test of Equality of Error Variances indicated that the variances among the internet speeds are not significantly different, $F(4, 10) = 2.76$, $p = .088$. Post hoc comparisons revealed significant differences between the client-side application and LS-Clear conditions only, $p < .001$, 95% CI [-182.68, -140.68].

3.4.2. Errors

Levene's Test of Equality of Error Variances was significant, $F(9, 20) = 6.41$, $p < .001$ and the assumption of normality was violated, therefore we conducted the Scheirer-Ray-Hare Extension of the Kruskal-Wallis Test to examine whether the number of errors in a passage dictated to VR software differs based on either speed of dictation (under 180wpm vs. over 180wpm; see Table 5), internet speed (client side application, HS-Clear, HS-Preloaded, LS-Clear, LS-Preloaded), or an interaction between both WPM and internet speed. The analysis revealed significant main effects for both WPM, $H(1, 20) = 7.05$, $p = .008$, and internet speed, $H(4, 20) = 15.87$, $p = .003$, but no significant interaction, $H(4, 20) = 3.59$, $p = .465$. Post hoc comparisons for internet speed revealed significant differences between the client-side application and all other internet speeds, including HS-Clear, $p = .033$, 95% CI [-196.20, -127.80], HS-Preloaded, $p < .001$, 95% CI [-319.20, -250.80], LS-Clear, $p = .002$, 95% CI [-324.20, -255.80], and LS-Preloaded, $p = .001$, 95% CI [-340.20, -271.80].

4. Discussion

Server-side applications allow for greater universal accessibility of AT tools [6] and with this comes the assumption that sufficient internet is already in place to guarantee ease of access. Many schools and students' home environments do not have enough bandwidth to support server-side applications at a reasonable speed [8,12], and yet students are expected to use these applications on an ongoing basis to support their learning.

Internet speed plays a significant role in the utility of server-side applications in the classroom [8] but has been widely ignored in the AT decision-making process. The current study demonstrated that there are significant differences in the time to open client-side programs compared to server-side programs with low-speed internet. This difference was largely overcome by using internet caching and preloading of programs, indicating that several strategies need to be implemented in the classroom environment before assigning server-side AT to students.

It is important to note that the present study examined a very small subset of the AT products that are available on the market. There will be individual variations in the impact of internet speed, but regardless of the selected product there is more to take into consideration when using server-side applications than when using client-side applications. For example, WordQ was unique in the current study in that the load-up time for high-speed internet with a cleared cache was significantly longer than the client-side application, and statistically similar to the load-up time for low-speed internet with a cleared cache. This illustrates that WordQ's

Table 3
Means and Standard Deviations of the Total Time Taken to Operate Text-to-Speech Software.

Condition	Number of Trials	Total time (seconds) *M*	*SD*
Client-Side	3	8.19	.52
HS-Clear	3	15.07	2.91
HS-Preloaded	3	13.88	1.56
LS-Clear	3	157.21	60.38
LS-Preloaded	3	42.54	15.46

Table 4
Means and Standard Deviations of the Total Time Taken to Operate Voice Recognition Software.

Condition	Number of Trials	Total time (seconds) *M*	*SD*
Client-Side	3	24.54	4.40
HS-Clear	3	15.1433	2.61
HS-Preloaded	3	21.23	.80
LS-Clear	3	186.18	12.67
LS-Preloaded	3	34.03	10.90

Table 5
Means and Standard Deviations of the Number of Errors for Voice Recognition.

Syllables per second	Condition	Number of Trials	Total errors *(n)* *M*	*SD*
Over 4	Client-Side	3	4.33	1.15
	HS-Clear	3	166.33	25.74
	HS-Preloaded	3	289.33	15.50
	LS-Clear	3	294.33	19.30
	LS-Preloaded	3	310.33	22.14
Under 4	Client-Side	3	12.00	13.08
	HS-Clear	3	88.67	17.56
	HS-Preloaded	3	165.67	54.17
	LS-Clear	3	103.33	17.21
	LS-Preloaded	3	106.00	85.71

programming requires a longer load-up time, but once the program is loaded the functionality and RT do not depend on internet speed.

4.1. Implications

Faster seems to be better when it comes to RT for internet- or server-based applications [14,15]. Therefore, teachers and schools should consider internet speed when working with the limited AT options that are available within their school boards. Several suggestions for implementation at all levels of the school environment are summarized in Table 6. It should also be noted that increasing student internet access in their home environment is an important area of further investigation and investment. These investments would help to overcome some of the current challenges with server-side programs. The recommendations provided are specific to the school context.

It will be important for school boards to carefully consider internet infrastructure such as network speed and the consistency of the internet in the various schools when selecting AT programs (Table 7). Consistency is of the utmost importance because as drops in connectivity occur the functionality of server-based AT tools is lost [18]. If internet access is consistent, bandwidth is the next most important consideration. Then, if bandwidth is sufficient and consistent, policy makers need to consider the speed of computer load-up and log-in.

School boards will need to continue to push to increase bandwidth, while also monitoring the ongoing capacity of their infrastructure to support AT software. Because technology develops at such a fast rate, ongoing monitoring and infrastructure development are critical. This consideration needs to be implemented as a key component of the decision-making process.

At the system level, hybrid programs (such as *Snap&Read Universal* or *Co:Writer*) may be considered. These programs are client-side executed, but still have a cloud-, or server-side platform. This allows students to enjoy the speed-based benefits of client-side

Table 6
Implementation Recommendations for Server-Side AT.

Level of Implementation	Recommendation	Purpose
School Board/ System	Carefully consider internet infrastructure when selecting AT programs (Table 7). Continue to push to increase bandwidth, while also monitoring the ongoing capacity of infrastructure to support software.	To ensure that the bandwidth and infrastructure continue to support the AT recommended to students.
	Hybrid programs may be considered. These programs are client-side executed, but still have a cloud-, or server-side platform.	This allows students to enjoy the speed-based benefits of client-side applications while still enabling them to access data from any device.
	Consider programs more similar in load-up style to WordQ.	This program was unaffected by internet environment when the cache was used.
School	Prioritize available bandwidth to AT devices.	Will ensure that students who require internet access are receiving sufficient speed.
Classroom	Implement classroom routines in which teachers preload AT programs that are required for their students upon entering the classroom.	Will ensure that the programs are loaded into the cache and increase speed of operating the programs.

Table 7
Internet Decision-Making Considerations.

Consideration	Purpose	Consultation Questions for IT Department	Preferred Answers for Server-Side Programs
Bandwidth	Slow bandwidth leads to extensive wait times, which may lead to decreased satisfaction with the product and likelihood that they will use the product again [14,17].	What is the bandwidth of the school? What is the average bandwidth per student in the school?	At least 50 Mbps download and 10 Mbps upload speeds [8].
Speed of computer load-up and log-in	Computers may need to be booted up and logged in prior to when they are needed if the load-up and log-in times are too slow, or an alternative client-side technology may need to be considered.	How long does the student's computer take to load? How long does the student have to wait for the computer to be ready to use once they have entered their password?	The load up and login times should be as close to 12 seconds as possible [14]. Student frustration with load up times may also be monitored to determine if the computer should be booted up and logged in prior to when the student needs it.
Consistency of internet	Drops in connectivity result in loss of functionality of server-based AT tools [18], which can result in loss of work or long wait times for students.	Does the school board IT department have network management protocols that allow students' computers to communicate with network devices and share information for diagnosing connectivity problems [18]? How quickly are connectivity problems typically resolved?	The IT department should be able to outline the protocol and provide suggestions for who to contact in the case of connectivity drops. If there is no protocol for diagnosing and fixing connectivity problems quickly, the student may be waiting too long to use their AT when they need it. Consider client-side programs.

applications while still enabling them to access data from any device. Specifically, the programs will operate without internet, but when they are connected to internet their data are uploaded. In the current study, *WordQ* worked very efficiently in both low- and high-speed environments once it was preloaded in the cache.

A system-level analysis can inform the school routines. The current study demonstrated that preloading of the cache can significantly decrease the speed required to load and use server-side programs in low-speed internet environments. Therefore, teachers can use internet caching to their advantage to overcome the internet as a weak link in AT. Preloading common AT programs as part of a procedural routine upon entering the classroom will result in shorter program loading time and potentially greater satisfaction with the programs among students.

4.2. Limitations and future directions

Due to the experimental nature of the current study there are limitations with respect to the generalizability of the results to actual classroom environments. The findings have not been field tested in actual classrooms, rather the data was based on published reports. The study was also conducted in an environment with ideal internet conditions (for the high-speed conditions) and with continuous speed. While this is critical to confirm the impact of internet speed in isolation, future studies should seek to replicate the current study in school environments within both urban and rural centers, where internet drops and limited access to bandwidth are more common and more variable. As was previously discussed, the current study controlled for internet service drops, but these would be much more common in a school environment.

In addition to RT, user satisfaction with and likelihood to use server-side, or web-based, products may be influenced by the type of feedback provided to students about wait-times [15], the urgency of the task that they are attempting to perform [16] and familiarity with the product. These results were found using samples of university students in a controlled environment, so may not apply to younger students using AT products in classrooms, but the extent to which these factors influence use of AT should be examined in future research.

4.3. Conclusion

Despite the positive impacts of cloud-based computing for many individuals with disabilities, the move to more server-side AT applications has not been without difficulties. The results of the present study demonstrated that the internet can, clearly, be considered a weak link when it comes to using classroom-based AT. AT decision-makers need to consider the impact of internet speed, and the internet landscape of the environment, as a key component of the decision-making process when selecting AT tools for students. If client-side applications, which do not rely on internet resources, are unavailable or inappropriate then the cache can be used to help overcome some of the difficulties with server-side applications. Overall, teachers, schools, and system-level decision makers need to carefully consider the environment, including the internet, in which students will be using AT tools and use strategies to help overcome the potential challenges embedded in internet use.

CRediT authorship contribution statement

Todd Cunningham: Conceptualization, Methodology, Writing – review & editing. **Bronwyn Lamond:** Formal analysis, Investigation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

To the best of our knowledge, the named authors have no conflict of interest, financial or otherwise.

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