How Post-Secondary Students with Mathematics Learning Disabilities Use Their Personal Electronic Devices to Support Their Academic Studies

General Report

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Executive summary

Context
In recent years, there has been an increase in the number of students with learning disabilities enrolling in post-secondary studies. There has also been an increase in the number of post-secondary students with learning disabilities who are using personal electronic devices. In the meantime, there has been a growing interest amongst researchers about mathematics learning disabilities and how to support students who have them. This study fits in this nexus, investigating how students with mathematics learning disabilities use their electronic devices in their academic studies.

Approach
This is an exploratory study conducted on two post-secondary campuses in western Canada. We interviewed nine students who self-identified both as having a mathematics learning disability and as being confident in their use of technology.

Implications
This study has implications for researchers, post-secondary campus accessibility centres, post-secondary educators and administrators, K-12 educators and administrators, and those who design and build technology. The foundational implication that informs all others is that technology can help to even the playing field for people with a variety of abilities, supporting them so they can be more successful in their academic studies. We hope our findings may offer students with learning disabilities some new strategies for using technology more effectively, and provide educators and parents/guardians with suggestions about possible technological supports for their students or children. Finally, we hope our study will encourage other researchers and hardware/software designers to seek the input and participation of those with learning disabilities in the development of further technological features and practices that improve accessibility.

Results
Our participants tended to use technology they had experience with, whether it be the traditional assistive technology they had been trained to use earlier in their education (for those who had been diagnosed with their learning disabilities in elementary school), the specialized technology they were required to use in order to do statistical analysis in their courses, or the mainstream technology they used in their everyday lives.

However, our participants also had been making an effort not only to improve how they used their current technology, but to explore other technologies through a process of trial-and-error to find more helpful and efficient supports for their academics. To do this, they sought advice from counsellors and psychologists, computer store staff, online technology support people, their family and peers, and they kept an eye out for what other people were using and which technology was recommended in online reviews.
Our participants used technology to improve their access to mathematics course content, to learn more about the “why” behind the content, and to find alternate methods and procedures for doing the mathematics that made more sense to them, engaging with alternate presentations of mathematical concepts to enhance their level of understanding. Websites, on-line videos, quizzes and forums were all mentioned as being helpful. Technology helped our participants to monitor the accuracy of their work, both the numbers they typed in and the solutions themselves, and allowed them to perform frequently used formulas automatically so that they could focus instead on the mathematical data and patterns. Participants were able to access worked-out solutions to text-book questions online that helped them to review their own work. Some used games to help strengthen their arithmetic skills.

Technology helped our participants to access information delivered by their instructors during class time, allowing them to capture it through audio-recordings and Smartpens, and review these recordings on their own time and at their own pace. Settings that changed the speed of the audio, and allowed them to pause and repeat, were particularly helpful. Text-to-speech electronic narrators enabled participants to more easily access course readings and mathematics word problems, helping them to focus on the content and also to save time and energy. Word processing software settings helped them to adapt texts physically in order to improve readability and highlight key information.

Our participants generally found that technology reduced their workload and improved their level of organization. They found it helpful to be able to access their files and resources over a variety of devices. They appreciated electronic devices that were intuitive to use, had enough storage for their class recordings and other files, and were durable and affordable.

Participants noted that it took time and effort to find suitable online resources, as online materials rarely matched their specific course content, and that they had to use a variety of websites to address their needs fully. Participants found that they had to have at least some grasp of a mathematical concept in order to phrase a suitable search question that would allow them to locate suitable online resources. They were aware that the reliability of websites varied and they had to find ways to check the accuracy of the content and procedures being offered. Many participants hoped that something more interactive might be developed in the future: for example, an on-line tutor who could give them specific feedback about their work and answer particular questions. Finally, some of our participants mentioned having a sense that there was technology out there that could help them, they just hadn’t heard about it yet. Having access to information about what is both possible and available would be very much appreciated.

Conclusions
Students with learning disabilities who have been able to successfully navigate the educational system to reach post-secondary studies show a resilience that deserves recognition. To improve their level of support, our recommendations include registering with their campus accessibility centre (if they haven’t already done so) and making use of social media to build a support
community and find out about new resources. We suggest that post-secondary instructors continue to offer tutoring resources, make sure documents are in a format that students using text-to-speech applications can access, and consider using alternate forms of instruction to reach a wider range of students. Finally, we encourage post-secondary institutions to fully fund their campus accessibility centres so that they can continue to support students and educate instructors about making lessons and resources more accessible.
**Context**

More students than ever before have grown up with regular access to electronic technology. Through this frequent exposure many have become fluent and confident in its use (Trouche & Drijvers, 2010) including post-secondary students with learning disabilities (Garcia, 2013) who have the same patterns of mobile technology usage as their peers (Chmiliar & Anton, 2018). This report investigates how students who have mathematics learning disabilities, and who are currently enrolled in post-secondary institutions, use and adapt their use of personal electronic devices to support their learning.

According to a recent report about learning disabilities conducted by the Government of Canada (Bizier, Till, & Nicholls, 2014) 2% of the population aged 15 – 24 has a learning disability\(^1\), and 98% of adults aged 15 and older who were currently, or recently, in school, reported that their learning disability had a direct impact on their experiences in school.

The Learning Disabilities Association of Canada has recently defined learning disabilities as resulting “from impairments in one or more processes related to perceiving, thinking, remembering or learning. These include, but are not limited to: language processing; phonological processing; visual spatial processing; processing speed; memory and attention; and executive functions (e.g. planning and decision-making)” (2017). The definition of mathematics learning disability itself has been contentious, and there is currently no set definition in the literature (Lewis & Fisher, 2016). Many researchers, including ourselves, believe that the disability encompasses a range of issues as a number of brain processes feed into doing mathematics, including language processing, visual/spatial awareness, and working memory (Furlong, McLoughlin, McGilloway, Geary, & Butterworth, 2015; Willcut et al., 2013). As we once heard during a conference presentation about inclusivity, if you’ve met one person with a learning disability, you’ve met one person with a learning disability.

In recent years, students with learning disabilities have been enrolling in post-secondary studies at the same rate as the general population in the United States (Cortelia & Horowitz, 2014) but their graduation rate is lower. Of Canadian adults aged 15 to 64, only 35.6% have completed their post-secondary qualifications (Bizier et al., 2014), and only 38% of adults with learning disabilities in the United States complete their bachelor’s degrees (Cortelia & Horowitz, 2014). Yet, once students with learning disabilities have completed their post-secondary studies, they are just as successful in their rate of employment, their level of income and benefits, as their peers in the general population (Madaus, 2006).

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\(^1\) We note that the overall rate of reporting of learning disabilities is likely low. Not all countries, and not all regions in Canada, have adequate screenings to determine if children have learning disabilities. As well, because of the possible stigma (Parette & Scherer, 2004) associated with having a learning disability, people may feel a reluctance to be tested, or have their child tested, and risk being officially labelled.
What can be done to help support students with learning disabilities in completing their post-secondary education? There are challenges for all students beginning their post-secondary studies, but for those with learning disabilities these challenges have a greater level of complexity (Kreider, Bendixen, & Lutz, 2015). While over half of students with a learning disability aged 15 and over required educational support (Bizier, 2015), campus supports “are not typically provided in a coordinated fashion” (Kreider et al., 2018, p. 2) as they may have been in earlier levels of education. Students need to seek out supports on their own, but unfortunately, many may be reluctant to do so. In the National Longitudinal Study (National Longitudinal Transition Study-2, 2011) conducted in the United States of young adults with learning disabilities who were enrolled in a post-secondary institution, only 24% considered themselves to have a disability and informed their school. Of the rest, 64% did not consider themselves to have a disability, and thus did not inform their school, and 7% considered themselves to have a disability but did not inform their school (Cortelia & Horowitz, 2014). As a result, while 94% of young adults with learning disabilities received academic accommodations in high school, only 17% did in their postsecondary studies (Cortelia & Horowitz, 2014), a significant decrease in the level of academic support.

College students with learning disabilities who demonstrated strong help-seeking behaviours in supporting their academic needs have been found to perform as well in their studies as the general population does (Trainin & Swanson, 2005). In the Canadian study, the most common supports used by those aged 15 and older with a learning disability were extended times for tests (40.8%) and teacher aids or tutors (32.7%) (Bizer, 2015). Unfortunately, 44% of those who required needing technology-based support (e.g. an audio book) and 74.5% of those who required at least one kind of specialized learning disability-specific aid or device (e.g. computer with voice recognition) did not receive it. Cost was cited as the primary reason (71.6%) for this lack of access.

In recent years, the definition of assistive technology has been broadened to include “any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of a child with a disability” (Individuals with Disabilities Education Act, 2004, Section 300.5). Mainstream technology, computer hardware and software that has been designed for everyday use by the general public (e.g. Microsoft Word) has the potential to meet some access needs, and it appears that some students with learning disabilities are taking advantage of it when they use technology for their personal interests. For instance, in a survey commissioned by PopCap (CISON PR Newswire, 2008), a multi-platform provider of casual games, 20% of its users identified themselves as being “disabled,” and of these 11% described themselves as having a learning disability. It is not surprising that students with learning disabilities would use the same kinds of technology as their peers do (Edyburn, 2013). For one, it helps them blend into the crowd. As Ayres et al note, “no one standing in the middle of a store or on the street looks out of place staring at the screen of a smartphone, thus illustrating the social acceptability and validity of the
technology” (2016). As well, mainstream technology itself is increasingly designed to offer its users flexibility. For instance, customization enables users to adapt the navigation facilities, the layout of the format and the way the content is presented (Treiblmaier, Madlberger, Knotzer, & Pollach, 2004) in order to suit their preferences. They can usually do this through a menu of choices that allows them to activate or deactivate certain functionalities (Frias-Martinez, Chen, & Liu, 2009). For those with disabilities, this kind of flexibility can be helpful. For example, Kelly, et al (2009) concluded that being able to customize an adaptable Web framework provided users with more individualized accessibility. Users with disabilities can also choose functionalities that enable them to develop routines of using the technology that may go beyond what the designers of that technology may have originally intended. For instance, the developers of the video game The Last Door reported that 12.33% of the first 150,000 gameplays had the closed captioning activated, while 13.78% used a font specially designed for dyslexics (CISION PR Newswire, 2008). Recognizing the potential for this kind of use, mainstream technology has been adding features that might have once only been found in traditional assistive technology, such as the “read aloud” and “dictate” features now included in Microsoft and Google offerings. The introduction of these kind of assistive features to mainstream technologies may help users to avoid the issues associated with older forms of traditional assistive technology such as the training time to learn to use it, cost and lack of portability (Ochola, Stachowiak, Achrazoglou, & Bills, 2013).

Our work responds to a need for more research to determine the effectiveness of new assistive technologies in supporting academic difficulties (Bryant, Bryant, & Ok, 2014). While there are multiple technological platforms available for student use, for this study we have focused on the electronic devices which students use in their personal lives and increasingly in their educational ones.

**Methods**

Our study took place from September 2017 to March 2018 on two post-secondary campuses in western Canada. Individual participants took part in semi-structured interviews designed to elicit information about their experiences in different levels of school with their learning disability; how they learned to use technology to support their learning needs including personal electronic devices (electronic devices designed for personal use such as cell phones, smartphones, personal digital assistants, tablet devices, and laptop computers) and traditional assistive technology (computer hardware and software that has been specifically designed for the use of those with disabilities, such as Kurzweil 3000); their current uses of electronic technologies; and their opinions about what was effective about their current technology and what features they would like to see in the future. We received permission from the Research Boards of Ethics at both of our own post-secondary institutions for this study, and pseudonyms for all of our participants was used throughout our data collection and analysis.
We interviewed nine participants from the two campuses, ranging in age from early 20s to early 40s. All of them were on-campus students, and their areas of study included computer technology, sciences, business, and social sciences – all programs that either required at least one mathematics course or a course from another subject area that used mathematics regularly. Our participants were at a variety of stages of their respective programs, ranging from their first to their final year. All participants self-identified as having a learning disability that affected their performance of mathematics. One mentioned dyscalculia specifically, while others described their mathematics learning disability more generally. Most mentioned having additional diagnoses as well, including: dyslexia, non-specified reading disabilities, issues with working memory, attention deficit hyperactivity disorder (ADHD), attention deficit disorder (ADD) and obsessive-compulsive disorder (OCD).

Post-secondary students with learning disabilities can be a challenging population for researchers to reach. As they often require more time to process course material, and to complete their assignments, they do not have a lot of extra time for participating in interviews. As well, there is the stigma of having a learning disability which they may be reluctant to disclose to strangers. Thus, we very much appreciated the assistance of the managers and counsellors at the campus accessibility centres who helped us to recruit participants by distributing our flyers to students registered with the centres and by posting our notices physically in the centre offices and electronically through their e-mail distribution lists. As well, we advertised our study by placing posters in our institutions’ student centres, presenting to student groups, and posting notices on campus electronic listservs. Some of our academic colleagues also assisted by distributing information about the study to their undergraduate classes.

Seven of our participants had received their K-12 education in Canada, while two had studied outside of North America. Three participants had been formally diagnosed with having a mathematics learning disability while in elementary school, and four had been formally diagnosed after they enrolled at their post-secondary institution. Two students had not been formally diagnosed – one noted she was almost done her schooling so there did not seem to be any point in being tested now. However, both their descriptions of the type of issues they experienced (e.g. difficulties reading, mixing up symbols and numbers, having to take math courses multiple times to pass them) and the ways they were using technology to support themselves were very similar to the rest of our participants, so we have chosen to include their data in this report.

We used an interview protocol that was developed and refined during the previous summer through a pilot study with two other post-secondary participants. The interviews featured open-ended questions about how students used their devices and their opinions about them (Swan, van’t Hooft, Kratcoski, & Unger, 2005), and these questions were e-mailed to participants a few days ahead of the interview to give them time to think about the topic. Students with learning disabilities sometimes struggle with language processing, which may include verbal expression, so we employed an interview style that privileged doing/demonstrating/gesturing as well as
speaking. Participants were asked to bring their own personal electronic devices to the interviews so that they would be able to show us the technology they most frequently and comfortably used. And finally, the interviews were conducted by two of our research assistants, personable post-secondary students who were roughly the same age as most of the participants, and who had been trained in conducting interviews. All of this helped to prompt participant narratives about their experiences with their disability and their use of personal electronic devices, encourage participants to demonstrate their uses of technology and promote a more “natural” conversational style to the interview discussion that may have helped our participants to feel more at ease.

As this was an exploratory study, we used grounded theory (Glaser, 1978) to develop categories of the characteristics of the uses and adaptations of technology through recursive data analysis of the video recordings, interview transcripts and field notes. We then used open coding (Corbin & Strauss, 1990) that was grounded in the participants’ own words (Li, 2013) and actions. The data was categorized through an iterative process, first involving an independent examination by members of our research team to help foreground different interpretations (Li, 2013), and then a comparison of these interpretations to help us notice features about our participants’ technological practices (Demouy, Jones, Kan, Kukulksa-Hulme, & Eardley, 2016; Kukulksa-Hulme & de los Arcos, 2011). In this report, we will describe some trends in our participants’ use of technology, including quotes (in italics) from our participants describing what they do.

Findings

Overall, our participants all found technology to be a useful academic support.

I don’t think [the technology is] actually teaching me anything but it’s making it possible for me to do this stuff. Otherwise I wouldn’t be able to. So, you know, more like a crutch but not with negative [connotations]. I think crutch sounds so negative. People are like “You’re just using it.” It’s that you need it to walk, so how is that negative? So, it’s not teaching me anything but it is supporting me so I can keep moving forward.

Two of our participants mentioned using traditional assistive technology (Kurzweil 3000 and Natural Reader), and three of them mentioned what we’ll call “specialized technology” – technology that had been designed for a particular purpose (in this case, related to mathematics) that they had been trained to use in their academic courses (e.g. True Value Math, GraphPad Prism, Desmos). Most notably, all of our participants used mainstream technology on a regular basis. As mentioned earlier, there are many brain issues that feed into a mathematics learning disability, and we wanted to hear from our participants about any technology or strategies for using technology that they used to support them in their math courses, or performing math in other courses, that enhanced their ability to access information in their classes/lectures, textbooks and other assigned readings, etc. In this section, we will describe the different methods participants used to support their academic needs in their post-secondary studies.
Why participants used technical support

Our participants mentioned two main reasons for using technological support with mathematics: to find alternative sources of information about the mathematical topics they were studying in class, and to improve their ability to perform correct calculations. While all participants described practices that helped them with their general academic needs, they noted that courses that involved doing mathematics often had an extra layer of challenge:

[With] the math class you would pretty much need it to be [video] recorded so you can see what [the instructor is] writing at the same time. If you’re following [an audio recording] you tend to have the completed equation and you don’t know what point he is… talking about because you need to physically see the writing. And then in the [introductory math] classes [the instructor] kind of thinks you have a basic understanding that I don’t [have]. He’ll skip some simplification steps: so he’ll get one line – and I’ll be fine – [and go] to the next line, [and] he’ll have skipped a couple of steps that he thinks everyone should know. And I’m just like, “How did that just happen?” Wave the magic wand and now there’s a number on the bottom. That’s what it feels like!

Understanding procedures and content

Many of the participants noted that they required more information than they received in lecture-style mathematics classes. They wanted to know the “why” behind what they were doing, and they sought alternate ways to approach the mathematics that made more sense to them.

*Mostly time I just go to YouTube and search on the math question… I want to see how they do it in a video. Because just seeing it in formulas, like if I just see what they did on a page, there’s no animation, there’s no step by step process that I can see, and no one’s explaining to me. It’s just “This is how you do it, the end.”… I want to be able to explain why we do it this way, and why you should do it this way and not whatever.*

Some also sought a more thorough explanation, noting that instructors in class often skipped steps or worked through the steps too quickly for students to follow, leaving students wondering “what the numbers meant” in certain steps. Sometimes students wanted background information about mathematics topics that their instructors assumed that the class would already be familiar with, as well as about the topics they just didn’t remember, or understand, from their previous math courses. This information ranged from a reminder of the meaning of certain mathematical terms, to explanations about the meaning of certain symbols in formulas, to instruction about the concepts underlying the topic, perhaps filling in “gaps” in previous mathematical learning. Participants appreciated websites that had links enabling them to access further information about subtopics.

*Basically, I usually just research or search in it what I want to learn about, and then it plays videos. And then it goes [through] like a couple videos and questions from the videos. Then it is like, okay, you don’t get the concept, and it will go “View this video based on this concept.” There is a smaller concept you don’t understand. And then you answer the questions. The
questions usually have videos linked to them, so that if you don’t quite get it or need to review it, you can watch the video again. And then if you still don’t get it, it will actually show you how to work it out.

Some participants sought alternate ways to do the mathematics that made more sense to them than the strategies offered to them by their own instructors.

I find that YouTube videos, like tutorials, [can show you] how to do the problems or you can Google a set of problem sheets, and then they also have an answer attached. You can’t always find them, but I find those type of things, are really helpful, just because it can give you an extra practice that your teacher might not or teaches you in a way that your teacher might not. I had some high school teachers that used a lot of videos, and those classes I did well in, because they taught in one way and then they showed us a lot of videos that taught it like this way, this way, and this way. One of those teaching ways worked for me.

Participants appreciated when their instructors had websites that offered course notes, but they also would use search engines to seek out the websites of instructors from other institutions and use those resources, even when they did not match the curriculum their own instructors were following. One participant noted that she particularly liked video demonstrations that used music and visuals that helped to keep her engaged.

Finally, technology offered an opportunity for more guided practice, including additional questions to try, and fully worked-out solutions. A couple of participants had used apps such as Photomath with which users can photograph an equation and the app will solve it. Participants also described websites such as chegg.com and slader.com as being helpful.

[Slader.com] has it solved-out for you…. Your textbook usually just has the answer. This [website] actually has it worked out. It’s like a specific problem you have worked out so you can go over the steps. Usually it explains them too. So, it’s just each step explained and the specific question you have problems with.

However, participants noted the drawback of how online resources did not necessarily match up well with what they were learning in class. Often a lot of searching was required to find resources that would work for them.

But the thing with YouTube videos, like Khan Academy for example, is that it’s almost like websites like that have their own learning plan, and their own pace. Sometimes what that video is talking about is not completely applicable to what you’re learning in class. It might have too much context or not enough. So sometimes, I don’t find that YouTube videos very helpful….

Conducting an effective search of a website’s contents meant being able to pinpoint the specific concept they were having trouble with in order to phrase an appropriate question about it.

There is YouTube, and there are almost too many resources and again It’s hard to find [ones] with the context of what your teachers are teaching you…. Let’s say for Stats “normal
distribution.” I literally type in “normal distribution” because it’s, I don’t know exactly where the problem was for me, so that I cannot type in a really specific question, like “How do you find the mean for normal distribution.” It will just be “normal distribution.” And then I hope that I find the YouTube video that is less than five minutes [long], that’s really clear, that’s information packed. That’s usually not always the case though.

As well, some participants found that using one website was not enough.

And I also always look up videos, just in case the way the teachers did it isn’t kind of working for me. Sometimes it doesn’t explain things and I just don’t know. So then going over to things like Khan Academy where sometimes they can teach me more of the basics of a more complicated question, or just another way of doing it, or visualizing it, can suddenly make things kind of sort of click, so you get it.....Sometimes the Khan Academy only actually has one way to do the equation and stuff. So sometimes then I also look at YouTube. Sometimes YouTube will have other ways of doing the questions

Finally, there was the issue of judging the reliability of online resources, and the extra time it took to do so.

And usually you can compare what you are doing to other YouTubers too. So, you can figure out if somebody is doing something wrong [laughs]. You can go to the comments and see somebody say, “Oh no, you did it wrong, that’s not how it’s supposed to be.” So usually, that’s what happens.

While the use of online resources was helpful, it was by no means a panacea. Participants had to think critically about what to use, how to use it, and to judge the quality of possible resources.

Accuracy and Ease of Calculations

Depending on the nature of their disability, when performing mathematical calculations many of our participants had issues both with entering information correctly and noticing any errors they made while performing this input. For instance, participants might neglect to type in a number, insert an extra number, or inadvertently switch the order of numbers or symbols. Although participants did use regular electronic calculating devices (the traditional hand-held solar or battery-powered calculator with no programming ability), some particularly appreciated calculating devices (scientific calculators, Google calculator, computer system calculators) that displayed each step of what the participant had typed in. This enabled participants to double-check what they had entered. This visual record of these steps had the added benefit of prompting their memory by reminding them what they had already typed.

[With Google calculator] after I’ve hit equal [button] I still have that [display that shows what I’ve input] there so I can look and make sure that I’ve tapped in my numbers correctly. Because that’s something else I sometimes do, reverse my numbers or I’ll miss zeroes. Zeroes are the worst. When you’ve got a thousand, how many zeroes is that? And they all look the same, so there’s nothing breaking it up. My mind kind of jumbles over that. Here I can physically put my
paper up [beside the screen] and make sure that I’ve typed in all those numbers correctly. It just gives me that extra reassurance that I’ve done it correctly, but also that ability to see what’s happened…. Google is my go-to guy! [laughs]

Participants also appreciated the affordances that software such as Excel or GraphPad Prism offered in allowing them to plug in frequently used formulae and to do complicated calculations in a single step – again, helping to reduce the possibility of input error. This kind of software enabled participants to bypass frequently used calculations so they could focus instead on actually analyzing the meaning of the data they were working with.

[Demonstrating GraphPad Prism]: This is calculating the standard deviation so you just type in “stdv” and then the entire thing. It tells me right here how off something… like you can see there’s a very small error bar – it means the data points are very close together. That’s a high point so this one has a fair range but there’s no way I could have created a chart like this without this program. I can’t calculate standard deviation. Even with the formula I get mixed up, I get confused, and here all I just have to type in “stdv” and what numbers I need to do and it’s done. Yeah. So, this has got all my equations…. This is actually a full change in growth. There’s no way I could calculate that without this program.

In terms of practicing skills and building fluency with number facts and logic, some participants had used games, in particular those offered by the Khan Academy website.

I go through other apps that kind of go through more basic math procedures, like re-going over times tables and…. your division, addition, subtraction, and sometimes they test your speed, do it in sort of different ways. You can get that trained to know those things better, which helps…. Like I said [before], I have trouble like using, like figuring out math in my head, and this sort of like forces you to do that…. I guess it makes those connections and stuff, which helps.

How they made use of the technology

In class

All of the mathematics courses that our participants referred to had a lecture style format, where the instructor stood at the front of the room and delivered mathematical content. The main challenge for participants was keeping up with the flow of information that the instructor was providing. Although some students had accommodations to have human note-takers, they noted that it was sometimes difficult for instructors to get other students to volunteer to do this as there was no compensation for these volunteers. Most participants used their phones to audio-record the instructors, with or without their permission. Some recorded all lectures all the time.

I don’t think a lot of people record their lectures like I do. I know there are a few, but I don’t think it’s to the extent that I do. They’ll record the important [parts] – the prof says, “This is important” and they’ll pull out the record[er] and record it – where I record all of them all the time. No matter what.
A few participants used Smartpens that recorded what the instructor was saying while the student was taking notes in a specialized “notebook”. This allowed the student to later “touch” parts of the notes with the pen and have the recording of the lecture that had taken place to that point in the notes played back to them. One participant had been using the pen for a year or so and was quite fluent with it. Another had only been using the pen for a short while, and the third was anticipating receiving a pen shortly and was looking forward to trying it out. These three participants had all received grant funding, the application process facilitated by accessibility centres at their institutions, to purchase this technology. The use of the Smartpen allowed some flexibility in how students took their own notes:

So what I’ll do lots of times, if I am in class, and it’s a long lecture, not a lot of notes but a lot of speaking, I will just kind of [take] the first sentence that they say, I’ll write it down, and then I’ll listen. And so when I want to go back, I can go back. Okay this is the sentence they were talking about, here’s what they were talking about, just press on it, and then [the Smartpen] start talking back to me. And then I don’t have to write everything down, and I can just go back and listen.

Regardless of how the audio recording was made, by Smartpen or by the recording app on a mobile phone, participants were able to use the recording on their own time, and to repeat, pause, and skip through the recording to get at the particular information they needed to hear:

Sitting in front [of the classroom] helps me get a better recording [with the Smartpen]. And then after each class, I go back to my dorm room, I close the door, and I sit and I take notes over the recording, and I can pause, play, pause, and play....If I were to press on this, it pulls up my recording, and now if I’m sick of this part of my recording, and I want to go to this, I’ll press here, and it jumps. So that’s how that works, which actually I use a lot.

One student noted that video recording the mathematics class would be more helpful, because then there would be a visual record of what the instructor was writing on the board or displaying with an lcd projector, but that she understood why instructors would be reluctant to be recorded.

I have had teachers, professors, who have video tape, and then [this] allows me to go back and look at them. But I find a lot of professors are hesitant to do that just because of personal embarrassment.

Another student noted that she was not able to take photos of what the lecturer was writing on the board because it would mean turning off the audio recording app on her phone in order to take the picture which would result in her losing part of the lecture. Others noted that they sometimes took photos of what was on the board/screen but it could be challenging when instructors erased the board immediately after they had finished writing on it.

Some participants mentioned that their instructors provided notes on-line in the form of PowerPoint slides, class notes, and other documents. One student noted that the template that her instructor provided students for notetaking did not physically offer her enough room to write in it, so it was not helpful.
Outside of class
A few participants mentioned having developed a process in order to access and understand the information covered in their classes, including extensive review and seeking out more problems to practice.

If I am going to my statistics class, well that’s an hour, twice a week. So, it’s two hours in class, but they are expecting you to do five hours of homework, reading your textbook, everything like that. For me, not all of this [material] is going to make sense off the bat. So, I need to be going online and looking up examples from someone else who is able to explain it a little bit easier for me. Like I said, they will explain it, and they will have an example, and I’ll write all of that down too. So, hopefully, just by repeating, I know [from] psychology you learn if you do something over and over and over again, and you embed it into your identity, then you memorize it.

I have to do more examples to get... the topic [the instructor] explained. And then usually if I don’t try to do it as often I would be lost, and I will have to go on YouTube to watch people write it on a board and doing it... [U]sually on the YouTube channels they have a bunch of questions that he answered. So, I will try to answer his questions first. And then I’ll watch what they do and see what I did wrong, so that way I can see what they do.

Accessing and understanding assigned texts is also an issue for participants, and some had turned to software with narration features.

I try to write, read it by myself, if I read and if I didn’t understand [anything], I try to find out on YouTube. Maybe there are videos. If it doesn’t work, [I use] Natural Reader….Natural Reader definitely can force you, even though you are tired... to go over all the text. So, I can [sometimes get] myself to [start reading] the text [on my own], but instead I just stop, because I am tired, and I cannot continue. [With] the Natural Reader, first of all, I am not as tired as [when] I read it by myself; secondly, it just reads itself. It doesn’t stop. It would take me to read this article around four hours [by myself], for example. [But with Natural Reader] it would take me 1 hour and 30 mins, because I have somebody who reads it for me.

Another participant noted the benefit of electronic readers for math:

I think that programs that read to you are really great. With math, because lots of problems are so word-based, having something reading it for you is great]. Like I said, you’ve got two problems when you have a learning disability. One is reading, one is trying to figure out the numbers. When you take away one of them, then you can focus a lot more. That makes it so much easier.

Technology is also helpful for finding the meaning of specific words…

If there is a specific word from the question that I don’t understand, that my professor asks me, I just type it into Google and read more about it.

Not all texts that professors distribute can be electronically accessed, however.
If I [could] really take a picture of this document, and then have it transferred into a text document, one that I could alter and have read to me like what I do with my computer that would be wonderful. Because there are a lot of readings that my profs gave me, [some are] just a picture of the document, and then I actually have to read it myself [because it won’t work with an electronic reader], which takes twice as long as having my computer read it.

What participants liked about their current use of technology
Participants appreciated how technology enabled them to practice rehearsing their skills and knowledge and to monitor their progress, particularly those websites that offered videos and quizzes.

Every time, when I try to read that specific assignment or that specific activity, I look at the same video, and I go through [the information] with the person [doing the video]. So, it helps me to understand what they do and how they do that... [it goes] more smoothly into my brain. All the videos are organized, so I [can] go from one to [the] other, then I [can do] the exercises, and my target is not 90, it is 100 [percent]. So, it’s sort of like... “Okay, I know that, I don’t have to go through all the videos because I got 100 [percent], so I know what that’s about and how to solve that.”

Participants noted how technology allowed them to watch, listen, think and learn at their own pace.

So I guess when I am watching those videos to help myself outside of class, I always have a pen and paper, but [the video window is] always maximized, so it’s like I’m in the classroom watching, and then I will pause it too. So, lots of time, I don’t know if you notice this, but like I will be writing something, but the teacher is talking so fast, I am focusing on writing and not on what is he saying. So at least with these videos, I can like pause it, write my own examples, write my own words out, zoom in to what’s he’s saying.... Instead of only getting 50% of the lecture, I am getting 100% of what I’m watching. I am doing more work with my time. I’m learning more, because I’m actively understanding it and going at my own pace instead of just showing up physically, but mentally I am not there.

Other participants mentioned reformatting text documents to make them easier to read.

I’ll change the text, I’ll make it bigger. I’ll change the spacing between, so I’ll usually make it 1.5 at least. But there are some profs who put all their slide notes in PDF and I can’t alter those ones. And I found those are the classes that I actually do worse in, just because I can’t study for very long, because it’s too hard on my eyes.

Two participants had adopted the low-tech practice of using a coloured filter, such as a plastic transparent duotang cover, to layer over paper documents to improve readability for their electronic documents. They did so by changing the background colour of their documents in order to increase the contrast with the text (which remained black), with one participant preferring a green background and the other preferring orange. The process of converting the
documents was fairly time consuming, and both were hoping to find technology that would automate this.

Technology appeared to reduce the effort it took participants to keep organized. They found the folder system offered by most desktop systems to be very helpful. Technology also offered other conveniences.

[I use Samsung] Notes. That’s something on your tablet that you just can write on with your stylus, and it saves your work, like, your working pages. [If] you want to write down your formulas or whatever, you will just have it on your tablet then all the time. You don’t have to have a bunch of sheets of paper. It can kind of help you organize things.... I usually use Word because that’s the easiest to use. I have all my documents there. It uses One Drive. You can have it on your tablet, your phone, and your computer, so that’s helpful just to keep organized.

Students with learning disabilities are aware of how they are different from their peers, and some participants mentioned how their use of technology during class also signaled this.

I don’t think a lot of people turn all their text green [laughs]. Actually I am sitting in the front of lot of my classes, and I do, every once in a while, hear stuff from my classmates behind me, like “What is she doing?” Which I understand, because I’d I probably do the same thing if I were them. “What, what is she doing? Why is she turning it all green?”.... I am pretty much the only one [in my classes] that talks to my computer, and then has their computer talk to them.

However, another participant, who had been diagnosed with a learning disability in elementary school, appreciated how technology was becoming more discrete over time.

Well, the thing about it, it’s the embarrassment and shame of it. You know, I have a learning disability, and you can always tell the kid with learning disability by [them] having a computer that’s always out. With a tablet, it’s small, you don’t have to open it, you can just quickly check back to it. With my [practicum in an elementary school classroom] that I just did, we had students who were new to English, who were just learning. We gave them an iPad to just sit next to their desk. And they would be able to go over and quickly put something in and you wouldn’t even notice. But they gain so much from it. I think that would have helped me a lot as well.... like I have said before, when you have a learning disability there is lots of shame goes with it. It’s an embarrassment. You can’t read, you can’t write, you can’t do math. And you’re at this age, you should be doing it. You don’t want to be labelled as [that] kid all the time: that means they need to be pulled out of class, it means all of this and that. So just like things that are small and little that you can work on that doesn’t draw attention. With my laptop, it’s big. With an iPad, it’s right there. Or a tablet, it’s right there. So, just like, when I say “easy” it’s meaning like small things.... It’s not bringing attention.
How participants learned to support themselves with technology

Most of our participants learned about the technology they now used by experimenting with different things, particularly those participants who had not been diagnosed with a learning disability until they began their post-secondary studies.

Along with those YouTube Videos for self-help, how Excel works, that kind of thing, it has been trial-and-error for my whole life. These are the things that I have adapted, that have worked the best for me that I still use today.

Many participants mentioned how the counsellors and psychologists at their respective campus accessibility centres had been key in offering suggestions about the types of technology they might try and in helping them to get funding for specific assistive technologies (e.g. Smartpen). From there, participants pursued a variety of sources for information.

I just went to [the campus computer store]. You can go to computer stores and just get them to order it. And there is a free trial online to see if you like it or not. I believe you can also look through their website. I assume now with how technology is [now] you can just go order it online and download it. So, what had happened is I bought this program from [computer store]. The lady who runs it just kind of gave me a quick little “This is how you do it.” And then the Accommodation Center also gave me a quick “how to do it” and then they just said “Go home, play with it, and see what you can do.” YouTube videos, I watched a lot of YouTube videos. The call-support guys, I probably called them six times while I was trying to figure it out. They are great. They help out a lot. But yeah, it’s just kind of a learn-by-yourself kind of thing.

Another participant described how family members with a technology background, who did not have learning disabilities themselves, had shown her some of the benefits that mainstream software could offer.

With my computer, I have the setting on there that if you highlight the text, you press, I think it’s command-exit, it speaks what you’ve highlighted. I have an uncle, he is very good at technology, and he told me that one. And I also have a setting on there where, you could speak to the computer and it writes it out in text. My uncle also showed me that one. That one I would not have figured out without him. I am thankful for him…. My older brother is very good at technologies and phones, and so I learned how to change the size of the text when he was showing my dad, because my dad can’t read the text that’s small. And I can just sit in the back, and was like, “Hmmm that will be helpful for me too.” I pick up a lot of stuff just from eavesdropping on other people’s conversations about technologies.

Another participant mentioned how she kept track of what her peers were doing.
And I also think about what is going to be easiest for me. So, with this iPad – I really want this iPad, I’m telling you – I think about how I am going to use it in my everyday life, as well… Having an iPad there is just, it’s easy. Even Apple watches, I’ve heard lots about people using Apple watches to help them. Because it’s something people aren’t going to notice and you can just look down [looks down at wrist], use a calculator on it or whatever.

The flow of information worked both ways. One participant mentioned used what she had learned over the years to help her parents to use their family computer. Another participant mentioned how a strategy she used may have been taken up by a roommate who did not have a learning disability.

I have roommates who are all in [the] Education [program], which I think living with them is really good for them because they’re all future teachers [and] they all have to live with all my accommodations. And I showed this [turning a text document’s background to green to improve the contrast and make the text more readable] to one of them, and she said, “Wow, that’s really helpful. I bet that’s way easier to study.” And I think she is actually using it now. So, I don’t think it’s something that most [people] do, because they don’t realize that’s helpful. I think it’s helpful because I’m dyslexic, and that’s where I got the idea. But I think it will help everyday people as well.

Interestingly, none of the participants mentioned having peers with learning disabilities although one had found support on Facebook.

I am part of a Facebook group that is for people with learning disabilities. They all post different websites and articles, and things like that. I really enjoy that because I can just go back and see what they have to say…. What I did was I just kind of searched “learning disability group.” Yeah, it’s neat because... on this, [there are] a whole bunch of parents, teachers, and students and so they all tell their stories. They all upload articles and stuff. They’ve all helped me so much. It’s just like a little family, we all kind of help each other with different things.

Some participants purposely did research to find new technology, conducting online searches to find technology that might better suit their needs and reading online reviews. Sometimes, the discovery of supportive technology was mere happenstance. One participant described how she would see a product mentioned in passing on a website, this would pique her interest and she would look it up. Others discovered videos in a similar fashion.

Sometimes Google brings out videos in just regular Google and I clicked it mistakenly and I was like, “Wait, there’s videos of this?” [Laughs] So, then I started watching videos and then I was just hooked. Every single video I can see. And the thing about YouTube too is that... on the side it has like “next” kind of. Like [the] next video that would show, if it’s like related, related to that [one you’re watching]. And then you can scroll and go, “Oh that looks good”, and then just click the next one.
Participants’ recommendations for improvements to current technology

Although mathematics is sometimes portrayed as being all about right and wrong answers, our participants were well aware of the importance of understanding the mathematics concepts themselves. Having access to correct answers through apps or online resources was not enough.

If you are having trouble all you have to do is take a picture of [the question], and [the photo app will] solve it instantly. Which is good, of course. It’s good, it tells you the answer. But personally, for me, I don’t use it very often, because it’s just telling you the answer. It’s like looking in the answer book. It’s not telling me how I solve that. What’s helpful to me is going to the tutoring, having someone explain to me why A causes B.

It’s only just textbooks that are figured [out online]. If you want [solutions to other questions], the only thing I’ve found is you can sometimes look it up on Google. It will have certain questions figured out, but I don’t actually know anything that you can just type in the question and have it figure it out for you…. I wish you could just type in the question and then it would have the video to go over the question, like you do with a tutor [laughs]. That would be amazing….

As mentioned earlier, many of our participants used videos to try to supplement their classes, but some noted the lack of variety in approaches to solutions.

Usually you have to go between Khan Academy and YouTube to find different ways to solve a question. Even like slader.com, or whatever, only goes over one way to do that question. But I need multiple ways to do the questions. There [needs to be a] real grouping of ways that shows you, oh you could do it this way, or you can do it this way. You really have to go searching for that instead of it being altogether in one place.

I know there is a website like Khan Academy, for example. But I would like it if there were more websites like Khan Academy. Because, like what I said earlier, I think the reason why I have to fail math the first time [I take the course] and then be successful the second time is because I need to hear, not different people’s perspectives, but how they perform the information. So, Khan Academy is great, but I don’t always get what he’s saying, and [when] that’s the only resource then you’re kind of stuck. But if there is an Amira Academy, a Chau Academy, or whatever, you know, different people explaining the same concept, that would be nice. So, just more variety. And I know you can get that on YouTube more or less, but sometimes, YouTube is, like, even I can upload a video on YouTube about math. So, the sources are not always very good quality sources.

Participants were interested in finding something that was more interactive, a kind of on-line tutoring, and had ideas about how it might work.
More maybe like a forum structure, where let’s say someone has a question that would be a part of the forum. When I was in high school, we actually used it for my art class. So that if you had problems with a painting, you could type to the forum. You could ask the teacher about it on this forum, and other students could comment too then. Like “Oh, I have this problem”, and the teacher could be like “Oh, this could be a solution.” Your classmates could be, “This would be a good idea.” So, you’re getting multiple ideas.

I think if there is a Skype-Ask system or you could connect with a tutor online that would be neat, because it’s convenient when we are at home. But for someone like me even then I would still feel, “Oh, I am taking up your time and you could be helping someone else. Or you could be doing your own homework, but instead, you have to, you know, talk to me online.” And even with the Skype system that would be really difficult, because you do need a piece of paper in front of you. It would be nice if it could transfer the piece of paper between two, you can draw together.

Some wondered if technology might be able to take the place of a person as a tutor.

Technology-wise, if a tutor wasn’t available, [it would be nice] to have a program, software, application essentially online, that would be very similar to a tutor that is actually helping you with math. You know, like, telling you, okay, that’s the chapter you need to work on, this is the extra help you require. Or, this is another way to explain this. It would kind of be more self-directing instead of having to go to the same building, at the same time, this person…. That’s how it’s innovative, you could take it with you. You could take your laptop, technology with you anywhere. If you are still struggling with that, and it’s 1 o’clock in the morning, there is no tutor available, you can go on your technology, and have someone explain it to you before an exam or something. I think that would help.

Participants found that some of the symbols used in mathematics could be an issue in using online resources for help:

[Just to write in the question [is a problem]. Sometimes like typing up, putting “to the power of two,” you can’t [do that with] the keyboard.

Math has got a lot of symbols. Okay calculus, calculus has got limits and derivations and all that stuff. There’s no way to enter it into a computer that I’m aware of in order to help you to figure it out….. Computers don’t think, they just follow a path. Why can’t I enter the limit symbol into Google and get the answer? [Technology] is good for what it’s got but it needs to go to the next level in math.
Perhaps, for this reason, participants who had received training in software designed for more sophisticated mathematical applications, such as GraphPad Prism and Desmos, tended to stick with that software.

Participants’ preferences for different types of hardware seemed to be related to the kind of devices they already had knowledge of or experience with, for example, whether they preferred Apple or PC products. Participants also had different preferences for how they interacted with technology. One participant preferred using a keyboard rather than touching the device screen, whereas for another it depended on what they were doing.

*I prefer a keyboard for words. Yep. Numbers I like the touchscreen. If it had a number keypad over here I might like that better. I like the set-up of the number pad. I don’t like the strip across the top.*

Yet another participant preferred hardware/software that allowed them to be more hands-on.

*Because math was the biggest thing that I struggled with in high school, middle school, and elementary school, I think just having something to be able to take something, isolate it, and change it the way that I want to, that I can use my hands. Because being dyslexic and everything like I am so hands-on. Being able to touch on my iPad or actually physically being able to hold something is going to be a lot better than having words all on a piece of paper.*

A few participants mentioned preferring larger device screens for doing their schoolwork.

*It would be good to have something like almost like a double screen from a tablet. I find the fact you can write on your tablet good but maybe having something you could write on here, write on here. [Laughs] I guess they do make big long ones, really big tablets so maybe that would help. You can like, okay, here is your question, and then you have how to do it, and then you can like work on it. Also, at the same time, it’s going over it, like a video, or YouTube instructions and stuff.*

In general, technology which saved time and effort was much appreciated by all of our participants.

*If you just have to be focusing on all the extra details of your technology instead of just focusing on math, it makes that math just that more hard. Like I said, you’re doing double the work. I should just be just focusing on math, not focusing on my laptop…. Now that I am in class, I should be focusing on the class, not updating software and figuring out how to read it. No way.*

For this reason, good battery life, durability were all mentioned as desirable features – the less time students had to spend worrying about repairing and updating technology, the better.
Participants also preferred software that worked across devices, and had adequate storage, particularly for those who needed to keep recordings of lectures from all of their classes.

*I probably have about 300 hours of recording on there and those are most likely not going away until I am done university. It’s really important for me to have a lot of storage, so I can go back, even when I am not in that class anymore, and listen to that.*

Participants preferred technology that was intuitive or user-friendly, so that they didn’t have to teach/reteach themselves how to use it, that was easily adaptable, and that saved their personalized settings. As one explained, technology “shouldn’t be so complicated where you have to have a degree to figure it out.”

Finally, participants just wanted to have a better idea of what technological resources were available.

*I need to hear about it. I need to be told about it. That’s big. So getting the word out that there is stuff out there, it could help…. Most people go online for their things nowadays, so actually, advertising there [would be helpful] for those struggling with this and that, [knowing] that there are programs for us. That would be nice. Getting [so] more people are aware that [technology is] not just for the people who do well in math, but there are programs out there for people who struggle with it.*

**Our recommendations**

Our study explored how post-secondary students with mathematics learning disabilities used, and adapted the use of, their personal electronic devices to support their academic needs. Based on our findings, we propose the following general recommendations.

**Students**

We encourage students who have been diagnosed with learning disabilities to register with their campus accessibility centre in order to receive assistance with getting accommodations from instructors, suggestions for learning strategies, and access to resources (including funding). We also encourage students who have struggled with academics, but whose psycho-educational testing in elementary school was inconclusive, to seek retesting.

Students with learning disabilities often feel isolated in their struggles, so we suggest that they make use of social media to access on-line support. Organizations, including provincial learning disabilities associations, often have facebook pages and twitter accounts. As well, there are several support and advocacy groups with pages on facebook for those with learning disabilities where members can share ideas and resources and develop a sense of community.

**Post-secondary instructors**

We encourage instructors to:
• Post documents in formats such as Microsoft Word that students can both easily adapt for their own needs and use in their electronic narrators;
• Continue to offer opportunities for tutoring, and also consider ways that tutoring might be made available on-line;
• Move beyond the more traditional stand-and-deliver lecture format and make use of videos and technological applets that “show” mathematics in different ways;
• Suggest further on-line resources that students might access to review or learn more about a specific topic;
• When possible (and we realize that class sizes are often large), observe your students as they work. We note that one of our participants did not realize she had a learning disability until her instructor, who had been noticing the pattern of her struggles as she worked on in-class assignments, suggested that she go to the campus accessibility centre for testing.

Post-secondary institutions
• Ensure that your campus accessibility centre is adequately funded so the staff there can offer students adequate supports.
• Inform your faculty and instructors about ways they can make lessons and materials more accessible to a wider variety of students, and encourage them to do so.
References


## Appendix A: What participants mentioned using

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Appendix B: Summary of participants’ strategies and suggestions

Capturing class content
- Audio-recording (cellphone)
- Smart-pens
- Photos (cellphone)

Accessing class texts
- Electronic readers (text-speech) – Word, Natural Reader, Kurzweil 3000

Accessing textbook information
- Websites with detailed answers (slader.com; chegg.com)

Accessing additional information (text, quizzes, videos) for additional practice, for alternate methods, to answer specific queries
- Search engines (Google, YouTube)
- Websites
  - Khan Academy
  - Wolfram Alpha
  - Other instructor websites
  - Discussion forums

Accessing videos
- Using controls for speed, pausing, repeating, rewinding/fast-forwarding, zooming-in

Accessing text
- Adjusting font size, font style
- Coloured background (improve contrast with text)
- Highlighting
- Summarizing (creating own compilation through screenshots, cut-and-paste)
- Zoom view of document

Calculations
- Calculator apps or online calculators (handy, shows input)
- Excel
- Desmos
- TMV (Time Value of Money)
- GraphPad Prism
Social Media

- facebook
- Instagram
- Discussion forum on YouTube

Organization

- E-mailing reminders to self
- E-mails as to-do list
- Folders/files – naming conventions
- Map apps (determining the time it takes to travel somewhere)

What they want from technology

- Sufficient storage/memory for recordings
- “Intuitive” software so don’t need to relearn it
- Durable
- Lower cost

What they would like

- More information about what technology is possible and available
- Photo-to-text
- Interactive online tutoring, online office hours
- Ways to type in math symbols
- Source that offers a variety of ways to approach a math concept in one place
- Better ways to capture instruction content during class time