EVALUATING INTERSECTIONS OF VISION IMPAIRMENT WITH STEM RESEARCH IN CANADA

by

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Abstract

A quarter of a million Canadians have some sort of vision loss. To inform programs and policy about persons with visual impairments, I focused on research questions in the current Canadian literature: Looking at accommodations and barriers that persons with visual impairments confront when pursuing STEM learning; to identify deeper themes and gaps that present themselves; and use the gathered data as information that will lay the foundation for further research inquiries, improvements, and pedagogical change in educators for persons with visual impairment (PVI). A comprehensive search of databases (PubMed, Google Scholar, ERIC) was performed. Due to the minor criteria, the focus was on Canadian literature or the best available research on the keywords used. The findings highlighted themes that emerged in three different areas of accessibility, behaviour, and social settings for PVI.

Furthermore, relationships were highlighted between the main themes and broken down further. This MRP discusses accommodation and the social and behavioural context in STEM education and identifies barriers faced by PVI and educators. While there is ample research on accessibility for PVI, more research needs to take place on lived experiences of PVI and to understand the behaviour and social aspects of engagement to ensure services of accommodations are met.

Keywords: visual impairment, stem, Canada, accessibility, science, social, teacher, training, behaviour

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Luke Pereira

The Language of Disability

Persons with Visual impairment (PVI) – How to call a disability.

The way we speak to or about other individuals with a disability is essential because it shows our opinions and preconceptions about that person. In an ideal world, we would refer to people using the language that they are most comfortable with. Language does change, though, because some words and phrases have come to be associated with negative connotations in recent years. I appreciated that different countries focus on several terms to describe disabilities. I focused on “persons with visual impairment” (PVI) for my MRP, taken from the Australian context. In Australia, persons with disabilities want to be recognized as individuals (ACE Disability Network, n.d.). They avoided using words such as Blind and visually impaired and provided acceptable alternatives such as "person who is blind" and "person with vision impairment or low vision”. Because of this, I decided to incorporate “persons with visual impairment (PVI)” into my MRP when referring to the blind or visually impaired.

Introduction

The experiences of PVI in higher education are vastly underrepresented in the literature, with most studies concentrating on disabled students in general or on specific occurrences and situations within the student learning experience. According to current research, PVI struggles to integrate into post-secondary environments because of academic and social barriers. They take longer to graduate because of their difficulties navigating the physical campus space and the technological barriers they face when studying online (Reed & Curtis, 2012). This MRP aims to identify and aggregate outcomes from a selection of Canadian literature to provide an inclusive portrayal of the inaccessible access to learning by PVI in the pursuit of science, technology, engineering, and mathematics (STEM) from K-12 to post-secondary level education.

Additionally, in Roberts et al. (2011), it was noted that there is an unfavourable impression of many students with disabilities that prevent them from achieving success in an online degree program.

Blindness is described as a state in which a person simultaneously loses all vision in both eyes. Visually impaired individuals have more developmental challenges and substantial distinctions than sighted peers, affecting the way they perceive their own identities (Zahoor, 2021). Because of the low prevalence of visual impairment or blindness in the general community, a child with vision loss is frequently the only child with this disability in their school or neighbourhood (Canadian National Standards).

According to Gold et al. (2010), PVI or those with low impaired vision are more likely than their peers to participate in passive and moderately socially engaging activities rather than highly socially interactive activities. The findings were in line with the expectation that greater levels of visual impairment would be associated with more significant barriers to participation in activities that are more socially engaged in nature. Low levels of vision loss, on the other hand, may make it impossible to participate in a variety of social activities such as sports.

In Canada, according to the Canadian Council on Learning Disabilities, most students who are PVI, as well as those with additional disabilities, get their education through an inclusive curriculum in a school in their home community rather than a particular school (Zuvela, 2009). When a person's vision is impaired, they cannot interact with the environment, significantly influencing growth and development in many cases (Warren & Hatton, 2003).

The repercussions are incredibly complicated for a student's ability to participate in formal and informal educational opportunities at school, at home, and in the community. Because of the lower incidence of blindness and low visual impairment among children and adolescents, there should be assistance from families, educators, and administrators who are organizing an early intervention and educational initiatives that need to be provided from the beginning of the journey to ensure that the process is successful (Bell & Silverman, 2018). Intervention for persons with PVI must depend on their ability to receive, analyze, and respond to the vast amount of sensory information exposed daily, which is especially true for children and adolescents (Ferrell, 2011). It is possible for a child who has restricted access to visual information due to an impairment in ocular functioning or their brain's optical system to struggle to cope with a wide range of routine chores (Lueck, Chen, Kekelis, & Hartmann, 2010).

Students develop a more in-depth grasp of their natural environment through science education. As part of their overall topic understanding, the BC K-12 Science Curriculum motivates students to ask questions and cooperate with others to test ideas and apply data analysis and critical thinking skills to lead essential decision-making processes that impact their lives. Researchers discovered that students with PVI may have typical misconceptions about scientific topics compared to their counterparts who have normal eyesight by comparing their beliefs with those of their colleagues who have normal vision (Koehler & Wild, 2017). This inaccuracy may be due to fewer opportunities for incidental learning because of total or partial visual impairment, which is probably the case. When necessary, the teacher collaborates with classroom and subject-area educators to ensure that essential improvements are implemented to materials, modeling, and equipment before school begins. In addition, the teacher collaborates with students to pre-teach any knowledge of science that will be required for successful participation in courses and laboratories in the future. In most cases, people with visual impairments need longer to preview and complete inquiry tasks such as experiments than their counterparts who can usually see (Supalo, Isaacson, & Lombardi, 2014).

The qualifications that education professionals must possess to become teachers of visually impaired students (TSVIs) vary from province to province. A Master's degree from a university program that is expressly created for the education of PVI and the completion of a series of university-level endorsement courses are required in some jurisdictions. In others, a bachelor's degree is sufficient. A TSVI must have knowledge and abilities that at the very least meet the Council for Exceptional Children's (CEC) Initial Specialty Set: Blind and Visual Impairments requirements to be certified (CEC, 2015). Several jurisdictions have established additional standards for TSVI knowledge and abilities that must be proven to ensure that blind or visually impaired children receive the specialized support they require (e.g., Standards of Practice for Educators of Children and Youth who are Blind or Partially Sighted; APSEA, 2014). Know-how includes things like understanding visual conditions and their consequences, knowing how to teach braille literacy, knowing how to conduct specialized assessments, and being qualified to teach students disability-specific content that is required for them to access the curriculum and learn essential life skills that cannot be learned incidentally through vision.

Every Canadian has the right to continue their education beyond high school. Fair and inclusive education, a vital component of a student's educational experience, must consider the unique problems of being a PVI. Service providers, educators, and parents/caregivers should be aware of the consequences of vision impairment on learning and development to offer them the best possible assistance.

This MRP hopes to extrapolate and aggregate qualitative data from the current literature to provide an understanding of the realities of inaccessibility for persons with visual impairments for those looking to get into STEM in post-secondary. The outcome would provide educators insights into how to pivot their teaching pedagogies and improve accommodations for persons with visual impairments in STEM.

The research objectives proposed look: 1) to identify the breath of recent Canadian literature that focuses on their research outcomes on accommodations, challenges, and barriers persons with visual impairments face when navigating STEM learning; 2) to identify deeper themes and gaps that present themselves and use the gathered data as information that will lay the foundation for further research inquiries, improvements, and pedagogical change in educators for PVI.

This secondary research and their outcomes would hope to collectively add insights to improvements in education, allowing educators new ways to enhance accessible learning of science in Canada, more so towards PVI. Additionally, the support and use of better accessible technologies, understanding behaviour, and social skills, will help foster improved collaboration for students, sighted and non-sighted, and other disabilities to work towards an inclusive future in their careers.

Human Rights and Disabilities

The Human Rights Code of Ontario (Code) states that a person's ability to participate in the labour market, realize their full potential, live independently and make a meaningful contribution to society. It influences their ability to achieve their educational objectives and reach their full potential. Having positive experiences in elementary and secondary school increases a person's likelihood of seeking post-secondary education after graduating from high school. The ability of an individual to sustain an acceptable standard of living is becoming increasingly reliant on their having finished post-secondary educational requirements (OHRC, 2018).

Students with disabilities who are adversely affected by an established requirement, regulation, or standard, according to the Code, have a legal obligation to have their needs met by educational providers. The provision of reasonable accommodations is necessary to overcome academic hurdles that would otherwise prevent students with disabilities from enjoying the same opportunities, access, and advantages as their peers.

Rather than being a blanketed concept, the Code defines accommodation as a technique that can be thought of as a scale of intensity rather than an all-or-nothing proposition. This range includes everything from a full-service facility that prioritizes the student's dignity while fostering privacy to a solitary confinement facility that offers little to no services. The use of additional accommodations (which would be less than "perfect") as a further step on the scale may be considered when the most desirable lodging is not attainable.

In contrast, under the Code, neither "perfect" lodging nor the right to a specific form of accommodation is guaranteed. When left with a dilemma between two comparable accommodations in their ability to meet a student's needs in a dignified manner, the educational institution has the right to choose the less expensive or less disruptive option. It has been highlighted in the OHRC (2018) that determining the "most appropriate" accommodation is distinct from deciding whether or not the capacity will result in an undue burden for the employee. Whenever a given accommodation measure results in undue hardship, it must be substituted with the next-best available alternative.

STEM Barriers: Motivation and Self-efficacy when visually impaired

The beliefs a student has about their abilities, and academic learning and achievement are the elements that determine a student's motivation, goals, and academic performance (Bandura, 1993). As described by Vansteenkiste et al. (2009), the self-determination approach is based on a multidimensional understanding of the meaning of motivation that distinguishes between the quantities of motivation, the volume of motivation, the intensity of motivation, and the quality or type of motivation. According to the outcomes of their research, students were highly driven and exhibited an increased interest in topics when professors were independently supporting their learning activities. When there is a lack of high-quality motivation, the absence of this support, on the other hand, generates vulnerability. In their daily lives, PVI must contend with varying levels of self-efficacy, whereas teachers are more concerned with the motives of sighted students. Self-efficacy is defined as a person's belief in their ability to carry out the behaviours necessary to attain specific performance goals in each situation, regardless of the circumstances (Bandura, 1977). As highlighted in Vansteenkiste et al. (2009), a task is more likely to be completed successfully by individuals who believe in their abilities to exercise control over their motivation, conduct, and social environment than by individuals who think they cannot complete the task successfully. Reed et al. (2009) showed that among undergraduate PVI, self-efficacy had been proven to be positively associated with academic success and increased use of scholarly approaches that help them attain academic success.

Social isolation of persons with visual impairments

According to Reed & Curtis (2012), young adults with visual impairments are more at risk of being socially isolated the longer they are out of school, particularly among their peers, as time goes on. Their disability may harm their social position, causing them to feel ostracised and unaccepted by their peers because of their condition (MacCuspie, 1996). Developing social skills in PVI, particularly in their early years of development, cannot be overstated (Sacks et al. 2006). According to Young-il (2003), unfavourable attitudes and a lack of contextual cues in society provide a considerable challenge for the visually impaired. They can result in severe obstructions in their everyday life.

Demographics of disabled groups

According to the Canadian Survey on Disability (2016) done in 2012, 14% of the Canadian population aged 15 years or older—3.8 million individuals—reported having a disability that limited their daily activities. Women (15%) were generally more likely than men (13%) to report disabilities. Pain-related disabilities were higher for women (11.2) compared to men (8.2), whereby for those with visual disabilities, women (3.1) were slightly higher than men (2.4). Due to the large age groups, the prevalence of vision disabilities also increased with age, from fewer than 1% of 15- to 24- year-olds to 10% of people aged 75 years or older. The difference between the percentages that had at least a university certificate, diploma, or degree at a bachelor's level was significant: 14% of persons with disabilities versus 27% of persons without disabilities.

Physically accessible spaces

When students are in K-12 or post-secondary, physical spaces make it difficult for them to become acclimated to a new setting, experience emotional distress in large groups, avoid harm, and navigate classrooms (Lourens & Swartz, 2016, p. 245). According to the National Academies of Sciences, spatial ability is a crucial talent that children need to develop to succeed in STEM subjects in the classroom setting. It is a cognitive capacity that requires an individual to be aware of the space surrounding them and to cognitively manipulate 3-D objects and environments to imagine a thing, its geographical location, or a property of a particular object (National Research Council et al., 2005).

The situated learning theory suggests that learning occurs in each location and environment. When students enter a STEM classroom (the setting), they apply what they have learned and convert it to a specific application (the context) (Lave & Wenger, 1991).

Adapt and Modify: Accommodations

The study of current literature revealed a lack of studies in Canada addressing accommodations and challenges for students with disabilities, mainly when it came to those with visual impairments and STEM fields. Most of the research has been conducted in the United States where the Americans with Disabilities Act and the National Science Foundation, overseen by the Science and Equal Opportunities Act, assure financing for research and initiatives in accommodation (Sukhai et al., 2014). Accommodations must be made in a timely way to be considered. Student access and participation in the curriculum can be severely hampered when accommodations are not provided on time or are inadequate. Delayed accommodations also could contribute to the development of disability-related behavioural problems and the difficulties that front-line educators have in dealing with these problems. A violation of the procedural obligation to accommodate and a violation of the Code of Federal Regulations may be determined in the case of unreasonable delays (Neads, 2018).

It is common for post-secondary institutions to have a department that oversees access to disability services, which is sometimes combined with equity services or human rights departments. These departments' goal is to make impaired students feel welcome while also providing specific services to meet their needs. One of the services available is disability awareness training. As a result, instructors and staff are better informed about what constitutes a disability and how to manage them strategically in the classroom.

Disabled students frequently qualify for bursaries and scholarships specifically designed for them. Some are geared toward people with physical disabilities. In contrast, others are primarily focused on people with learning difficulties, such as The Bursary for Students with Disabilities (BSWD) and the Canada Student Grant for Services and Equipment for Students with Permanent Disabilities (CSG-PDSE) help full and part-time post-secondary students with the costs of their disability-related educational services and equipment (OSAP, n.d.). These awards are made available to students who have registered with the disability offices; nevertheless, many scholarships go unclaimed since students are unaware of their availability due to a lack of awareness of their presence.

Disabled students may be eligible for financial assistance at the provincial or federal levels. Typically, the school's disability services department handles any documentation that arises. Amounts of funding are available to help with disability-related expenses. These include alternative formats for printed materials, adapted technology evaluations and training, interpreting and transcribing services, and psycho-educational examinations. Academic accommodations include providing material in an alternate format (Braille), private exam space for students with attention deficit disorder, and notetakers for students who have sustained a hand or wrist injury. The student's responsibility is to notify the administration if they require academic accommodations to make staff and space available. Many departments recruit student assistants who work with impaired students in various capacities, including exam assistants, exam invigilators, library access assistants, mobility aides, notetaking, scribing, and serving as a peer tutors for disabled students (Hill, 1996).

Only when accommodations are of excellent quality and readily available can they be considered successful. For students, obtaining access to these supports can be difficult due to high expenses, time-consuming administrative processes, and misinformation. As a result, access to these supports can be detrimental to students' academic progress (Byrne, 2014; Reed & Curtis, 2012). Disabilityawards.ca, for example, hosts many scholarships available for people with a variety of disabilities, organized by province and government funding levels. PVI or those with vision loss can apply for awards from one of the 17 organizations. Student financial services at universities and colleges assist students in completing the necessary paperwork and applying for these prizes, which are available to all disability groups.

Even though many post-secondary institutions provide accommodations, students with visual impairments take longer to complete their programs and do not have the same opportunities as their sighted peers. This is because accommodations are difficult to obtain and are of inconsistent quality (Reed & Curtis, 2012). Several studies, including a report by the National Educational Association of Disabled Students (NEADS, 2018), have found that there is variation across institutions in accommodation support, with the most notable being the barriers and gatekeeping by faculty, admissions committees, and service providers who negatively perceive competencies of the discipline or program and the student's disabilities. This can result in barriers to admission and effective participation of students with disabilities in graduate or professional programs.

According to Hill (1996), the findings of her study showed that students at small universities were more satisfied than students at larger institutions, graduate students were more confident than undergraduate students, diploma students were more confident than degree students, males were more satisfied than females, and students with chronic health problems were more satisfied than all other groups.

The most critical points from the literature sources are summarised in the next section. The common themes and discoveries are defined because of this process. Based on the themes and findings found, the paper will then look at overall recommendations for services and outcomes relating to this demographic. According to the authors, the demographics collected across the literature indicate 48 children aged 4-17, 205 students, 90 teachers, and 178 adults with total ages ranging from 18-56 years old.

Literature Review

Educators' experiences

The literature evaluation done for this MRP identified four relevant themes in the Canadian setting. Lindsay et al. (2019) presented their findings on the theme of educators' experiences, in which they illustrated how a group-based robotics program influenced the STEM activation of students with impairments. The number of stem cells in the brains of youngsters who participated in the program and expressed an interest in building, programming, and learning about robots showed a significant rise. Koehler & Wild (2019) examined current studies to assess whether adequate accommodations and adaptations are being made by instructors in classes to address the specialized requirements of these kids, even though PVI has expressed an interest in sciences in education in the past. While the study revealed that PVI was included in science classroom experiences, they also did not participate in those experiences. Hill (2020) investigated adjustments made in the mainstream learning environment for visually impaired children enrolled in public day schools in British Columbia, Canada, to overcome this obstacle to learning. It has been demonstrated that elementary-level teachers attempted to make alterations to a larger extent than secondary-level teachers in their lessons. Because of their expertise in teaching practices and the concentration of the secondary study on sciences, instructors should feel comfortable communicating with the visual interface system in a conversational manner and a natural language. Research data from 66 teachers were examined by Topor & Rosenblum (2013) to demonstrate that most teachers used similar instructional strategies for English language learning when meeting the learning needs of their students. When instructing the students in Braille, they virtually always did so in the English language. Thirty percent of the teachers did not believe they were qualified to work with visually impaired kids or who were learning English as a second language. As far as encouraging the usage of tactile and print graphics, Zebehazy & Wilton's (2014) research highlighted the limitations and challenges that PVI encounter while utilizing these devices and the fact that they require specialized prerequisites. However, the study's most significant finding was the notion of time and the lack of it in generating high-quality materials and the success of the VIS in utilizing visuals efficiently.

Personal experiences

The theme of personal experiences of the PVI looked at relevant available literature and focused on the issues they experienced daily. PVI post-secondary education experiences were examined in detail in Reed's landmark study published in 2012. In conclusion, it was determined that impediments to higher education for students with visual impairments harm their overall educational experience. They also require specialized preparation in higher education and take significantly longer to get their degrees than their peers. In contrast to a recent previous study, Lourens & Swartz (2016) examined the physical sensations of VIS in connection to their bodies rather than the environment in which they interact. It demonstrated how bodily experiences might reflect the story of a person's struggle while also revealing crippling societal institutions. Byrne (2014) investigated the structural obstacles and shortcomings in the quality and timeliness of accommodations that make it difficult for such students to acquire the support they require, which creates barriers for students and causes them to become distracted from their education.

Social Experiences

Looking at the social experiences of PIV, in early research, MacCuspie (1990) discussed the difficulties of integrating PVI in educational settings and the importance of social acceptability among sighted students. Participants in the study observed that PVI in residential neighbourhoods demonstrated social interaction and behaviour patterns like those observed among sighted children in public schools. According to the findings of the Gold et al. (2010), having poor social skills is associated with difficulties that are exacerbated during adolescence, when youths who are visually impaired must face not only the usual life challenges that are associated with this at the developmental stage but also additional challenges that are affiliated with their visual impairments. They are more likely to engage in passive and moderately socially interactive activities than highly socially involved ones. A recent study by Zebehazy et al. (2020) looked at divergent thinking regarding practical problem solving for those PVI. It has been postulated that the developmental trajectory of fluency in divergent thinking for students with visual impairments may be different from that of their peers. Fichten et al. (2009) looked at predictors and correlations of grades and graduation rates between VIS and sighted classmates to determine which group performed better when it came to graduation. Higher course self-efficacy expectations, more vital perceived behavioural control over graduation, reporting a single disability rather than multiple disabilities, and a more positive attitude toward graduating was observed and affected favorable graduation rates.

Accessibility

The issue of accessibility does not apply solely to PVI but rather encompasses a broad spectrum of physical and mental impairments. The recurring problem is e-learning materials and computer technology that present challenges for VIS. Fichten et al. (2009) revealed that communication technologies are being employed on and off campuses. The most often employed technology is a screen magnification and optical character recognition (OCR) scanning. Compared to adaptive software used at home, it was discovered that the technology used at school had not been updated. For example, when it comes to making science more accessible, Schiafone et al. (2020) conducted a co-design study centered on the value of tactile graphics, an essential part of PVI. Improving access to scientific material in classrooms by participating in co-design sessions with VIS helped them better understand the accessibility problems. According to Mazer et al. (2003), the Assessment of Computer Task Performance (ACTP) was developed to assess the performance of children with low vision when performing sequences of actions that result in a computer command, both in terms of speed and accuracy. It was necessary to develop a valid and accurate test that could objectively assess the progression of students' performance over time. The exam increases the effectiveness and speed of occupational therapy intervention while utilizing the smallest number of resources possible. The ACTP was created to assess a person's ability to conduct actions or sequences of actions that result in a computer command as a performance assessment tool. Zebehazy & Wilton (2021), focusing on STEM, investigated the ability of students to engage with graphical resources that assist learning in the areas of science, technology, engineering, the arts, and mathematics (STEAM). This study discovered that tactile graphic users took significantly longer to complete tasks than non-tactile graphic users. This highlights the importance of frequently exposing PVI to graphics, allowing them to learn problem-solving skills and direct instruction on approaching and interpreting different graphic types.

Lived Experiences

Finally, the theme of lived experiences looks at existing research from PVI and their experiences and issues navigating the educational environment. Sahtout (2020) offered insights in her web article on her personal experiences conducting laboratory research as a PVI. The essential takeaway was establishing mentorship and professional groups that can assist graduate programs more accommodating for PVI. Also, making graduate education and research programs more accessible and fairer is the first step toward achieving that goal. Asking what PVI require to work at their highest level of performance is an essential first step.

Zahoor (2021) emphasized that to live a happy and healthy life, PVI must have more cooperation experiences, greater movement independence, and more opportunities to participate in activities with their peers. To improve the psychological well-being of PVI, it is necessary to gain a deeper understanding of their experiences in the social reality of their lives.

Boman (2006) found that challenges persisted while access to learning was readily available in her thesis research. For the most part, resolving these difficulties appeared to be beyond the control of the individual student. Her analysis is restricted to PVI and those who have completed post-secondary education, particularly in Canada.

According to the findings of the literature review for this MRP, in the Canadian context, themes are developed that link the educator to identifying the personal and social situations that PVI encounters daily. More importantly, it enhances knowledge gain regarding accessibility possibilities, which can both directly and indirectly, provide insights into the cues through the lived experiences shared by these individuals.

Methodology

For my MRP, a peer-reviewed search of publications, alongside a criterion selection of selected terms, was utilized in electronic searches using predetermined criteria. In addition to internet databases, support from librarians was needed to narrow down the vocabulary of phrases better to achieve better results. Keywords were used in Google scholar, PsychINFO, and the Education Resources Information Center (ERIC), the databases searched. All publications published during the last 10-15 years were searched for using the following keywords: STEM, disability, accessibility, visually impaired, blind, Canada, and STEM. The initial findings revealed a mixture of data from a cluster of other countries included in the investigation and narrowed it down to a handful of articles in Canada. I decided to employ a program to evaluate the global list of 256 articles accrued. Covidence (web-based) and NVivo (software-based) were the two platforms that allowed for easier management and systematic reviews of the articles and other types of research requiring screening citations. It also makes it easier to extract study characteristics and outcomes from studies. Over the year, I acquired many publications that assisted me in developing my research ideas. It provided me with a more comprehensive picture of visual impairment across the spectrum of an individual's post-secondary experience. Covidence and NVivo platforms enabled me to conduct an iterative analysis of the selected papers for this research.

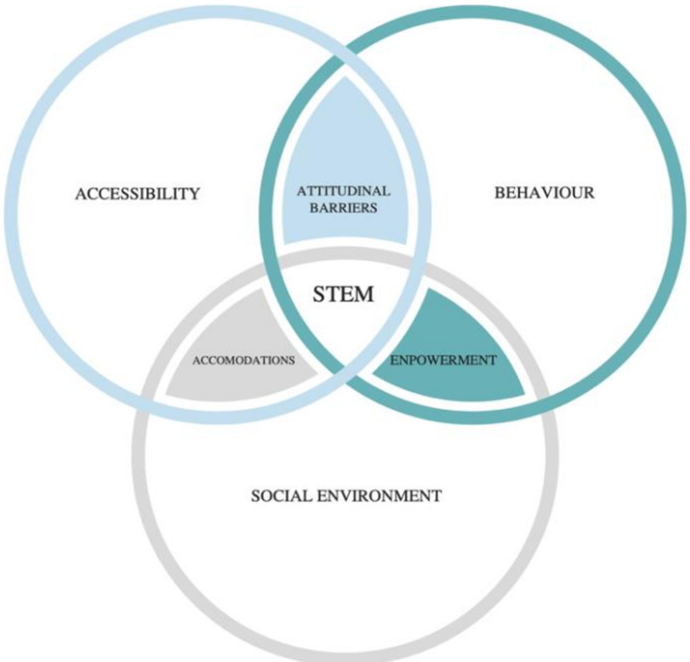
Article Selection and sorting

When examining the articles, the Covidence web tool provided the ability to include an inclusion criterion. The articles needed to contain content that looked at barriers in the personal, social, lived experience, and accessibility space for people with disabilities. There were significant papers highlighting teaching PVI from the standpoint of a teacher or educator. The articles would need to have a strong emphasis on post-secondary education. The problem was obtaining publications published in english in Canada, which was difficult because there were so few of them available through search databases. The articles were published during the last 10-15 years, with some dating back as long as 20 years in rare cases. Most books, research study designs, locations, lack of interventions, and the nation of origin were utilized as exclusion criteria.

Coding

NVivo, a coding research application, was utilized to manage, analyze, and organize the unstructured text found in the selected articles to provide thematic coding for all the 20 articles. It was possible to code each text portion to a distinct heading called a node, which could be grouped throughout all articles. This enabled the creation of thematic frameworks by grouping comparable nodes together and highlighting common themes that emerged because of the specific findings from the codes, as seen in figure 1. Additionally, the software-enabled file classification of the articles by scanning several variables such as gender, country, and age, among others, provide context and a more comprehensive perspective of all combined content. Additionally, there is the option to do mind mapping, code frequency analysis, and text analysis, all highlighted in the findings section. (See Appendix A.)

Figure 1: Venn diagram on findings



Findings

Concept mapping and visual representations

The use of NVivo made it possible to analyze the chosen literature for this study. I was able to classify text into distinct categories using thematic coding. The initial coding of text yielded 30 or more codes, which I categorically reduces to 25 and divided them into groups. By combining codes into thematic analysis, I was able to identify commonalities between the three main themes that emerged: accessibility, behaviour, and social environment, as well as the connections that were created between them. (See Appendix B.)

I was able to do this since the codes were grouped together. I'll go over each subject and my observations in more detail below in table 1. (See Appendix C.)

Table 1: NVivo review of articles yielded codes

Accessibility	**Social Environment**	**Behaviour**	**Stem**	**Training**
Accessible Tech	Skills & activities	Fear	Education	Educators
Post-Secondary Accommodation	Social Isolation	Self-reliance	Barriers	Barriers
Environment	Social Isolation	Behaviour types	Interventions	
Communication	Social support		Careers	
PS Barriers	Social Barriers			
E-learning	Mentors			
Graphic Tools	Educators			
Stem Barriers	Academic Standing			
Stem interventions				

Accessibility

Alternative formats of science materials for PVI may not be available to them in digital or hard copy form, and even if they do have access to such materials, the adaptation and transcription processes may cause significant discrepancies between the alternative format and the original material (Zebehazy & Wilton, 2014). According to all the accessibility papers, a prevalent theme is the lack of timely accommodations across all levels of post-secondary education. Many people with visual impairments are excellent users of tactile graphics, demonstrating high braille literacy skills and spatial cognitive abilities related to direction and mobility. According to Zebehazy & Wilton (2014), students they questioned frequently did not have access to graphics at the same time as their peers, resulting in compensating methods such as seeking a description. This is commonly noted in other studies in other nations with similar difficulties among the PIV. These obstacles are in addition to those encountered when accessing websites, using public spaces, participating in remote learning, and finding work. After their research, Fichten et al. (2015) discovered that

- close to 100 percent of PVI and 50 percent of those with limited vision claimed to use screen-reading devices.
- Scanning with optical character recognition was used by nearly 90 percent of PVI and a third of students with low impaired vision.
- According to the survey, screen magnification was the most frequently reported adaptive software by those with limited vision.
- Half of the students with low eyesight said they used a large-screen monitor.
- Their research revealed that electronic mail, course web pages, web-based discussion forums, and course-related Word files are readily available and easy to access.
- Videoconferencing technologies, online exams and quizzes, CD-ROM training, and Flash-based online content, on the other hand, were all unavailable.
- Several course notes and resources were not available, including PDF format.
- There was no web-based real-time chat option on the course websites or course management systems, making them inaccessible to screen readers, and images lacked "alt tags," which are descriptive text that screen readers can understand.

- Websites with fixed font sizes and incompatibility between adaptive software used by participants and course administration systems are two examples of accessibility issues.
- Some course notes and resources, including those in PDF format, are not accessible due to technical difficulties.
- The problem with PDFs is that their accessibility greatly depends on how they were prepared in the first place.
- According to research, PVI who utilize adaptive technology take longer to complete online tasks than sighted individuals.

This highlights and advocates that adopting educational approaches and products accessible to all students without modifications would go a long way toward eliminating the accessibility concerns currently existing.

Additionally, Fichten et al. (2015) indicated that students might experience challenges even when using adaptive software because of the limited availability and accessibility of information and communication technologies and some specialized forms of e-learning. Several Canadian government efforts that provide adaptive computer technologies to students with visual impairments for off-campus use focus solely on a specific type of technology—for example, text-to-speech screen readers—and do not consider other options.

According to these findings on accessibility, universities and institutions should upgrade their adaptive software to the most updated versions available on the market. The availability of cutting-edge technology for students when they are not on campus is critical. Both groups raised concerns about computer technology training and technical assistance, the availability of adaptive computer technology in specialized and general-use computer laboratories, online learning for testing, and the school's technology loan program. Distance education courses, informal technology support at school, access to the library's computer systems, and instructor-led e-learning are all examples of barriers that students face with using them. Students' computer technology training needs must be identified and assessed by colleges and universities in partnership with rehabilitation experts and educators, with any gaps in training being filled by the institutions themselves. Many universities and colleges provide just the most fundamental assistance and accommodations to PVI. Numerous Universities and Colleges offer accommodations for students with disabilities, typically defined by the types of disabilities present within the student body.

Behaviour

There is less discussion on PVI's passive behaviour when examining current studies in a Canadian setting than in other countries. On the other hand, Reed & Curtis (2011) conducted a comprehensive research analysis outcome that examined how behaviour of fear influences the social and motivational levels of numerous PVI. According to their findings, there is a persistent worry that prevents the majority of PVI from applying to post-secondary education because of the fear of the unknown, lack of knowledge, or environment they would be exposed to. A student's capacity to perform successfully may be impaired because of isolation, which in turn exposes a lack of self-confidence at the conclusion. According to Fichten et al., (2015), students must take an active role in the management of their own learning experiences. The students must investigate what adaptations may be available to assist them in efficiently using e-learning materials, understand adaptive technologies that may be available to assist them in accessing e-learning materials, request necessary accommodations, and seek assistance. The development of these aptitudes will aid PVI in achieving success in an increasingly technologically driven multimedia world. Suppose young people struggle to be identified by others at a mainstream school due to the stigma associated with their vision loss, according to Gold et al. (2010). In that case, they are more likely to be cautious about using any low vision or rehabilitative item that further or openly identifies them as visually impaired. Adolescents require the support of their peers and their social networks, friendships, and personal relationships as they transition from childhood to maturity.

As reported in NEADS (2018), an examination of the literature finds that attitudes have been and continue to be a significant hindrance to the advancement of persons with disabilities in science and technology occupations. Many businesses have fundamental misunderstandings about the limitations of impaired employees and the impact of these limitations on their ability to perform their jobs.

According to Reed & Curtis (2011), PVI is reliant on others causes them to have low self-esteem and lack self-confidence. Being self-sufficient and secure in one's abilities has not been instilled in them. PVI may have trouble with specific components of thinking skills or the application of strategies. Children with visual impairments must have divergent thinking, flexibility, and broader self-regulation. These skills transfer to other areas of functioning and show a person's lifelong ability to adapt and keep driving toward achieving goals. Figure 2 and figure 3 showcase the differences in behaviour between educators & PVI and the barriers they face.

Additionally, I have created graphical human icon prototypes to highlight visual representation for the figures showcasing behaviours to help showcase a graphical representation of the findings. (See Appendix D.)

Figure 2: Behavioural analysis findings

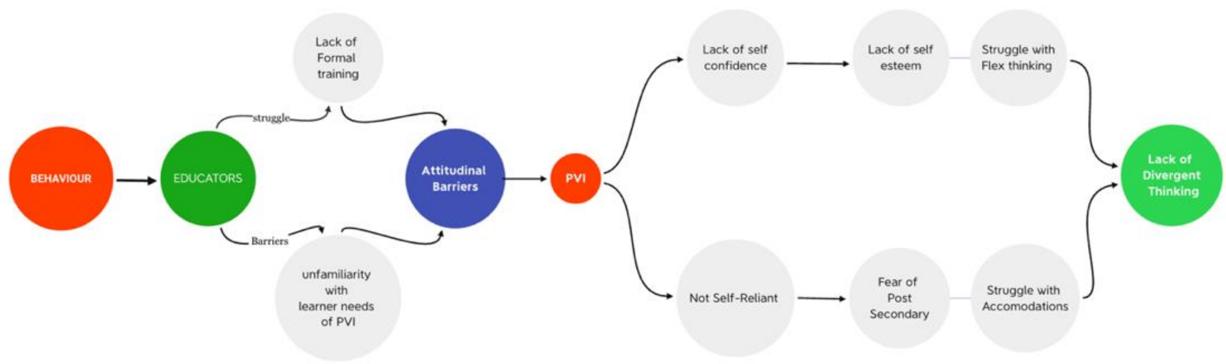
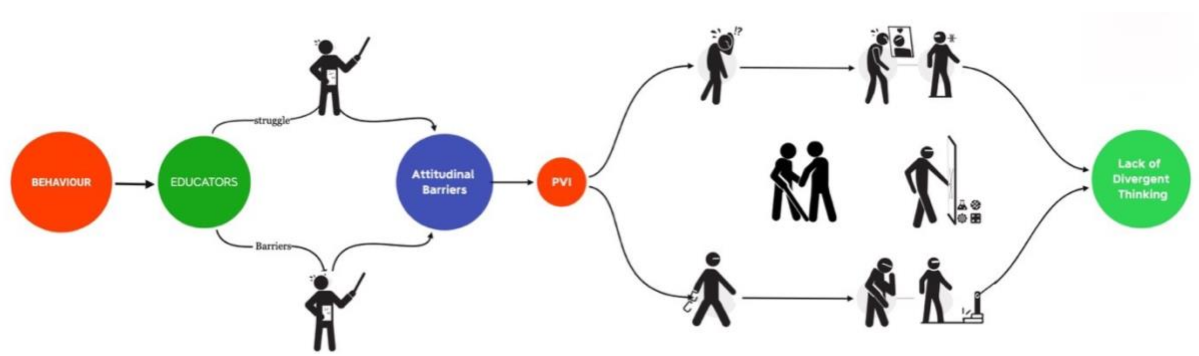


Figure 3: Behavioural analysis using human icons



Social Environment

Social skills

According to Gold et al. 2010, adolescents with vision impairments should receive social skills training as soon as possible. According to researchers, if children do not develop a strong foundation of socializing throughout their formative years, their ability to succeed as adults may be undermined in their professional and private lives. In Gold et al. 2010, participants in the study showed a trend toward more engagement in passive and moderately engaged social activities rather than fully engaging social activities when participating in the study. According to the findings, those with limited eyesight were much more involved in social and leisure activities than participants who were blind on a mid-level social scale. Teenagers with limited vision, on the other hand, had a higher proportion of sighted companions than did blind adolescents, according to the findings. Participants who were PVI spent more time socializing online than those who were visually handicapped. According to the study, they were more likely than those with limited vision to meet new people online. Youths with reduced eyesight tend to participate in many of the same passive activities as their visually impaired classmates. Still, they also appear to participate in activities that necessitate interpersonal interaction.

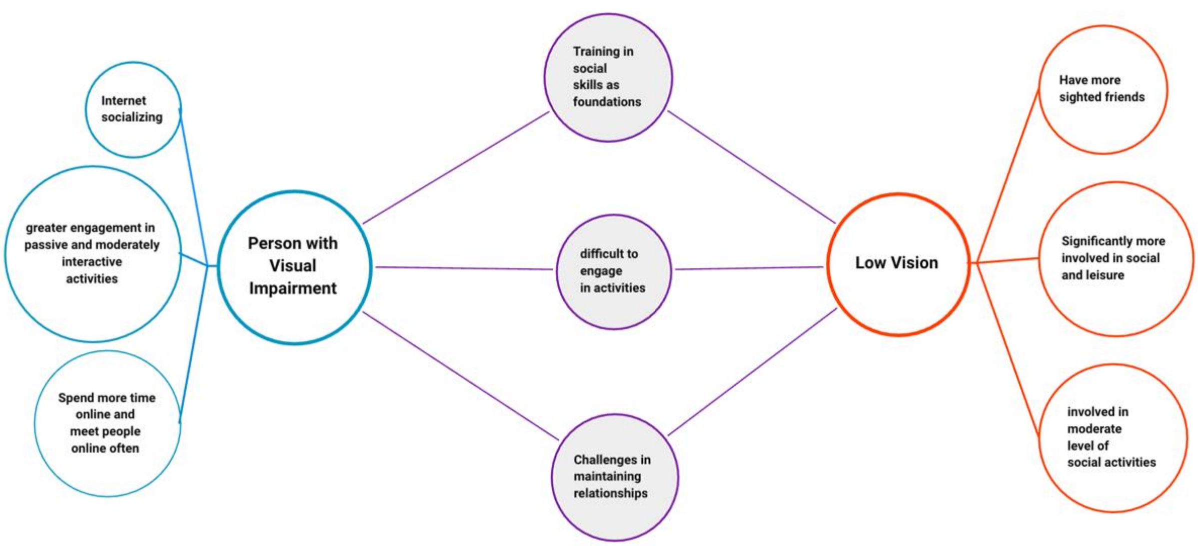
Even mild visual impairment can make it challenging to participate in certain social events. PVI was more likely to meet new people online than those with low vision could be explained by the incredible difficulty they may have made first contact in person. Young people who have vision impairments may find it challenging to establish or sustain intimate relationships as they grow older. Individuals with vision impairments may experience additional difficulties when participating in activities alongside their sighted peers.

Social isolation

Youth with visual impairments who are out of school for an extended period are more likely to be socially isolated than their peers. The diminished ability of visually challenged adolescents to learn spontaneously or accidentally extends to their ability to learn in the social domain and the academic arena. Children with visual impairments usually engage in self-centered behaviour, demonstrate an inability to respond to the concerns and interests of others, exhibit unusual linguistic patterns, and prefer to associate with adults, according to research (Gold et al., 2010). Inadequate social skills are worse during adolescence when visually impaired teenagers face the traditional life barriers connected with this developmental stage and additional obstacles associated with their visual impairments. As a result, young PVI may be tolerated but not necessarily accepted by their peers because of their impairments. A lack of contextual clues and "a lack of honest feedback from interactants," poor conduct by sighted individuals, and harmful views about visual impairment in society may make it harder to develop these talents (Gold et al., 2010). A greater likelihood of social isolation is associated with increased visual impairment and PVI are highly aware of the social stigma associated with their disease and have a strong desire to blend in with their peers.

Figure 4 below illustrates the distinctions and common shared links between low vision and PVI in terms of social contexts and skills and the skills that both groups possess and do not possess. The severity of blindness varies from person to person, and each level of blindness tackles a different set of concerns.

Figure 4: Analysis between low vision and PVI

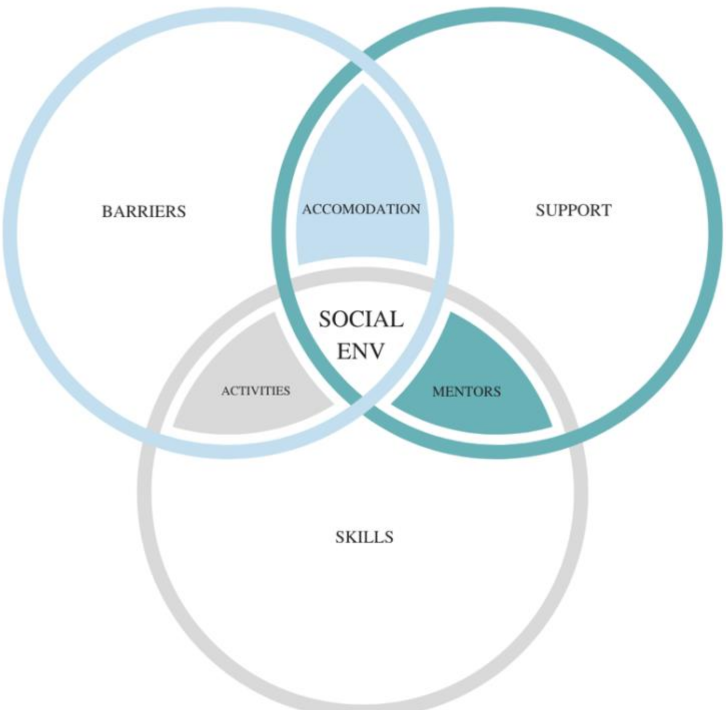


Social & mentoring support

NEADS (2018) cited mentors, including family members (especially parents), instructors, bosses, and co-workers, among other people, as potential sources of guidance. According to Gold et al. (2010), their research revealed that teenagers with low vision, as opposed to visually impaired youths had a higher proportion of friends who are sighted. A conversation is usually the starting point for empowerment; therefore, the first step toward ensuring that graduate education and research programs are both accessible and equitable is to have a conversation and ask what PVI require to perform their jobs at the highest level of their abilities. When faculty members and visually impaired students work together in a mentoring program, they have the potential to forge powerful, long-lasting bonds that can be leveraged to help them negotiate challenging situations (Sahtout, 2020). When it comes to expanding the participation of persons with disabilities in scientific and technological disciplines, mentors are crucial since they can assist students in overcoming hurdles and encouraging them to persevere in their chosen fields of study. In the NEADS (2018) research, mentorship presented itself in various ways, including the development of self-confidence and self-esteem; advocacy and coaching; education and counselling, among other things. This low representation of persons with disabilities in the science and technology professions has been widely discussed. Many point to a lack of prominent mentors and role models who have achieved success as a contributing factor. Beck-Winchatz & Riccobono (2008) speculated that PVI is increasingly being integrated into regular classrooms, and in many cases, they are the only visually impaired student at their institution. The lack of access to visually impaired peers and PVI adults who can serve as role models for students who are non-visual learners may prevent them from developing confidence in their ability to engage in science or become advocates for their own needs as non-visual learners. Bell

& Silverman (2018) remarked that although existing mentoring models with blind or visually impaired youth are limited, a comprehensive mentoring program for young people with disabilities can effectively address the demand for assisting youth with disabilities in their transition from school to work. Mentorship is a significant factor in achieving academic and career success and community integration in various settings, including school, employment, and community organizations (Whelley et al., 2003). Figure 5 highlights the intersection of support, barriers, and skills that this section has briefly described.

Figure 5: Venn diagram of the social environment



Mentoring success has been demonstrated in various contexts, and the variables that contribute to mentoring effectiveness have been well researched and investigated. Furthermore, research has indicated that having positive role models can enhance people's confidence in their ability to succeed in the STEM professions, which is a promising development (Wright &

Moskal, 2014). Due to the underrepresentation of PVI in these disciplines, it may be difficult for them to locate role models in these fields. Teachers who are encouraging and have high expectations of their students, as well as those who are knowledgeable about how to adapt and foster independence in children with impairments, may be successful in influencing children's perceptions of their possibilities of success in STEM-related disciplines (Bell & Silverman, 2018).

Accommodations

Although students are utilizing adaptive software, the lack of widespread availability and accessibility of information and communication technology and the inaccessibility of some specific forms of e-learning may provide challenges. According to Fichten et al. (2015), some Canadian government programs provide adaptive computer technologies for off-campus use for PVI use, though only one type of technology is provided (for example, text-to-speech screen readers) for students who are PVI at a time. Other concerns included scarcity of appropriate adaptive computing technology and a lack of knowledge about how to effectively use e-learning resources on their end, among other things. According to these findings, schools and colleges should ensure that their computers are running the most up-to-date versions of adaptive software available. The availability of up-to-date technologies for students when they are not on campus is essential. Among the concerns raised by both groups were computer technology training, technical support, the availability of adaptive computer technology in both specialist and general-use computer labs, the use of e-learning for testing, and the school's technology loan program, to name a few. A few examples of concerns that need to be handled include distance education courses, informal technology-related assistance at school, accessibility to library computer systems, and the use of e-learning by instructors. Schools and colleges, rehabilitation experts, and educators must identify and review the training they now provide pupils in using digital technology and remedy any gaps. Many universities and colleges give only the most basic services or accommodations for visually impaired students. At the same time, public schools provided a very high and personal level of assistance to PVI during their tenure at the institution (Reed & Curtis, 2011). Universities and colleges have varying representations of impairments, with the availability of accommodations being governed by the types of disabilities represented within their student bodies. The chance for students in high school who aspire to attend college or university to engage in self-directed learning activities should be made available to them.

On the other hand, those accommodations required to facilitate a PVI educational progress are generally considered too complex and expensive for schools. Various factors contribute to this lack of practical experience. PVI are sometimes denied opportunities to finish their work in scientific labs, which is one issue that needs to be addressed. Their sighted lab mates assist them in the conduct of the experiment while they provide directions to the blind participants in the experiment (Bell & Silverman, 2020). No matter how basic knowledge of the investigation the PVI may have, this does not teach them how to complete the activities independently without assistance once they have completed them. Due to their inability to execute scientific processes independently in the classroom, they may have the notion that they will not be able to be successful in a STEM career (Bell & Silverman, 2020).

Additionally, teachers find Braille a tough concession to make for students, even though they believe it is crucial for success in the classroom. Tactile graphics are yet another adaptation that may be poorly executed or completely absent in other cases. To do many STEM-related tasks, tactile graphics must be used; however, this challenges young students just starting in math and science because they are unfamiliar with some concepts. The notion of offering accommodations for students studying in the disciplines of science and technology may be intimidating to TVIs. PVI does not find success in these areas; as a result, so they do not pursue careers in these disciplines (Bell & Silverman, 2020).

STEM Accommodation

Universal Design Language (ULD) has been utilized as a conceptual framework to study STEM accessibility in early childhood and elementary and secondary education (Villanueva and Di Stefano, 2017). As a result, Universal Design for Learning (UDL) may be a potential option for teachers to facilitate accessible STEM education for all students, including PVI. This provides a cohesiveness in which all community members are actively engaged in each other's growth and success. Also, future engineering educators must treat all students as if they are part of a homogeneous group rather than considering the distinctive contextual learning experience that each student requires. Consideration of PVI’s prior knowledge continues to reinforce these concepts. It was noted that PVI’s sensory experiences could be increased with instructional strategies customized for their abilities.

Additionally, lesson planning can be improved, and students' reasoning development can be aided by using tailored strategies for their abilities. For STEM lesson design, PVI needs to encounter several modalities to help them learn core ideas in STEM. Educators have noted that not having formal and informal instructional chances for their students to grow and construct an identity around the topics they acquire in the classroom can severely affect their academic and everyday activities. In addition, these views can impair visually impaired students’ capacity to envisage themselves in STEM professions. The need for STEM curriculum design and STEM rationale development are essential factors for high school educators. For sensorial experiences, accessible technologies for tactile learning can help boost STEM learning and the interest in PVI (Villanueva and Di Stefano, 2017).

Social Activities

Developing lesson plans that are entirely accessible to PVI, according to Villanueva and Di Stefano (2017), is one of the most critical components of boosting students' understanding of STEM concepts and providing practical experiences to them. Teachers must consider the students' prior knowledge and repeat these concepts in succeeding modules to establish a common practice that incorporates those students into the STEM teaching-learning community. Allowing PVI to serve as their spokespersons and mentors is possible by providing them with the necessary materials and allowing them to take the initiative in group projects and assignments rather than assigning them to the role of notetaker, as this will discourage them from participating. Additionally, the visually impaired students must be provided with sufficient opportunity to learn through various representations and several types of action and involvement. Scientific Academies and Youth Slam programs and the Yerkes Astronomy Camps have boosted expectations among parents, teachers, STEM experts, and students themselves about what PVI and kids may do in science and technology disciplines (Beck-Winchatz & Riccobono, 2008).

Through the ability to work in groups with other non-sighted peer students, these activities assist them in overcoming the social isolation that they frequently encounter at their schools. The interaction with successful visually impaired STEM professionals who have first-hand knowledge of the crucial components that PVI requires to be successful in science is another benefit of these programs. As a concrete example, Villanueva and Di Stefano (2017) highlighted that academic teacher training programs for future engineering educators must treat all students as members of a homogeneous group rather than considering each student's specific situated learning experience requirements. It appears that incorporating Universal Design for Learning (UDL) in the context of the secondary education classroom may necessitate providing blind students with access to physical spaces and tools, based on what we learned from our interactions with PVI and teachers (both visually impaired and sighted) between 2013 and 2016.

The PVI point of view

Insights from lived experiences can be incredibly useful in aiding efficient communication, increased safety, and other areas. Highlighted below are details gathered from three research studies on lived experiences of PVI.

On Accessibility

According to Croft 2020, the PVI was given excessive and unwanted equipment due to a lack of feedback. It was noted that any access is frequently confined to modifications that focus on removing physical barriers, such as installing ramps or the use of disabled-friendly signage. The study pointed out that tensions inside the institution point to challenges of provision mismatch not only across higher education but also within institutions.

On Socializing

Living in shared spaces such as dorms or rooms, PVI faces social barriers. By emphasizing and publicizing their negative perceptions of PVI as "different," housemates marginalize and socially isolate PVI. There are Insults and invalidations that' occur in interpersonal and environmental contacts,' with micro-aggressive episodes. It was highlighted that organizational responses to the incident revealed poor perceptions of PVI inside the post-secondary institution, and in fact, the system aided and abetted the aggressors (Croft, 2020).

Furthermore, PVI regarded the wide-open spaces of an unknown university campus as strange and not created with their body in mind. They spoke about the threat of motor vehicles and obstructions in the environment, including gaps in sidewalks, low-hanging trees, and road works. Most had powerful emotions when thinking about or confronting walking freely. For those with low vision, reading took a long time for those who used Braille since they couldn't visually browse through an article or book. When it comes to reading, most PVI and those with low vision will rarely be able to skim over text; however, listening to audio recordings will make this impossible (Lourens & Swartz, 2016).

On Behaviour

There is a lot of anxiety and fear in those starting in post-secondary. The feelings they experience because they struggle with their physical surroundings might be so overwhelming that it takes up a lot of their 'brain space,' leaving them with little room for anything else. Also, requesting homework extensions was not always advantageous to students' emotional well-being, and attaining some level of similarity was often difficult alongside their peers (Lourens & Swartz, 2016).

Conclusions and Limitations

Before we begin to work on breaking down accessible barriers for PVI, more evidence-based research is needed to understand better the connections between identity, inclusiveness, and positionality in the context of STEM, behaviour, and social settings. The central gap in behavioural research on PVI in different demographic as they progress through varying levels of education into post-secondary. Having more lived experiences documented in other age groups can better analyze the social and behaviour of PVI and low vision. This research study has provided insights and highlighted deeper connections in understanding how accessibility, social skills, and behaviour affect PVI interactions and perception of life. Highlighted below is a summary.

- There are two groups of visually impaired individuals: PVI and low vision individuals.
- There are different ways of interacting and socializing between the two groups and among their sighted peers.
- Behaviour affects how performance is met for PVI when applying for education and thinking about long-term careers.
- Many educators do not have exposure to PVI, which makes accessibility practices rare and hard to undertake in lesson plans. This is most common in post-secondary.
- Mentors play an essential role in shaping the behaviour of most PVI.
- There is a lack of mental health support not identified in the research in schools and post-secondary.

Additionally, lived experiences such as human stories and case studies rationalize some of the complexities and concerns sometimes missing from the academic and program literature. While research is lacking on lived experiences, a few global studies shed light on the surface attitudinal barriers and deeper emotional aspects in day-to-day experiences and interactions with peers and sighted individuals.

While we hope to accommodate PVI in education so they may reach their career goals, there is also a great deal of empathy, understanding, and acknowledgment that mentors, educators, other groups of people need to not only support but realize that individual experience should not be used to substitute common action; instead, it should be used to inform themselves on how best to accommodate PVI in any field.

Limitations

Although this study supports the research objectives 1) to identify the breath of recent Canadian literature that focuses on their research outcomes on accommodations, challenges, and barriers persons with visual impairments face when navigating STEM learning; 2) to present the gathered data as information that will lay the foundation for further research inquiries, it does have certain drawbacks. First and foremost, there is a lack of lived experiences on qualitative data that consisted solely of high school students who are PVI. There is also a lack of new updated research in a Canadian context compared to other countries where large groups of PVI are captured in research; also, the lack of a comparison group with/without vision impairment or male versus female under similar circumstances can be viewed as a restriction when conducting research.

When conducting secondary research on a global scale, there is a significant amount of material to analyze. This MRP aimed to examine a topic more narrowly via the prism of Canada. By highlighting these articles, I was able to extract several themes that indicated how vital it is to understand behaviour, social environment, and accessibility when attempting to accommodate STEM.

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Appendices

Appendix A: Core article selection for coding

Article	Title
Lindsay 2019	Children with Disabilities Engaging in STEM: Exploring How a Group-Based Robotics Program Influences STEM Activation
Koehler 2019	Students with Visual Impairments' Access and Participation in the Science Curriculum: Views of Teachers of Students with Visual Impairments
Zebehazy 2014	Charting Success: The Experience of Teachers of Students with Visual Impairments in Promoting Student Use of Graphics
Personal Theme	
Reed 2011	Experiences of Students with Visual Impairments in Canadian Higher Education
Lourens 2016	Experiences of visually impaired students in higher education: bodily perspectives on inclusive education
Social Theme	
Gold-2010	The Social Lives of Canadian Youths with Visual Impairments
Fichten 2015	An exploratory study of college and university students with visual impairment in Canada: Grades and graduation
Zebehazy 2020	Divergent Thinking: The Performance of Students with Visual Impairments on Abstract and Scenario-Based Tasks and Their Correlates
Boman 2006	Post-secondary education for blind and partially sighted students
Lived Experience	
Sahtout 2020	How science should support researchers with visual impairments
Zahoor 2021	Lived Experience Qualitative Study
Accessibility	
Fichten 2009	Accessibility of e-Learning and Computer and Information Technologies for Students with Visual Impairments in Postsecondary Education
Zebehazy-2014	Graphic Reading Performance of Students with Visual Impairments and Its Implication for Instruction and Assessment

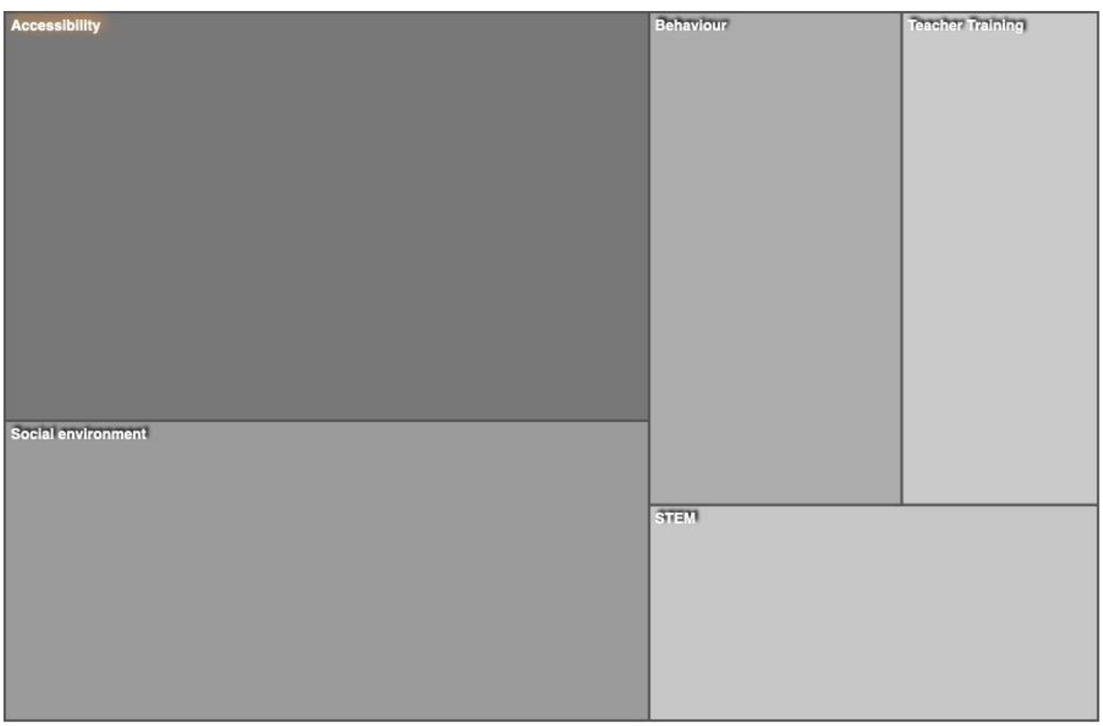
Appendix B: Core article selection demographic breakdown

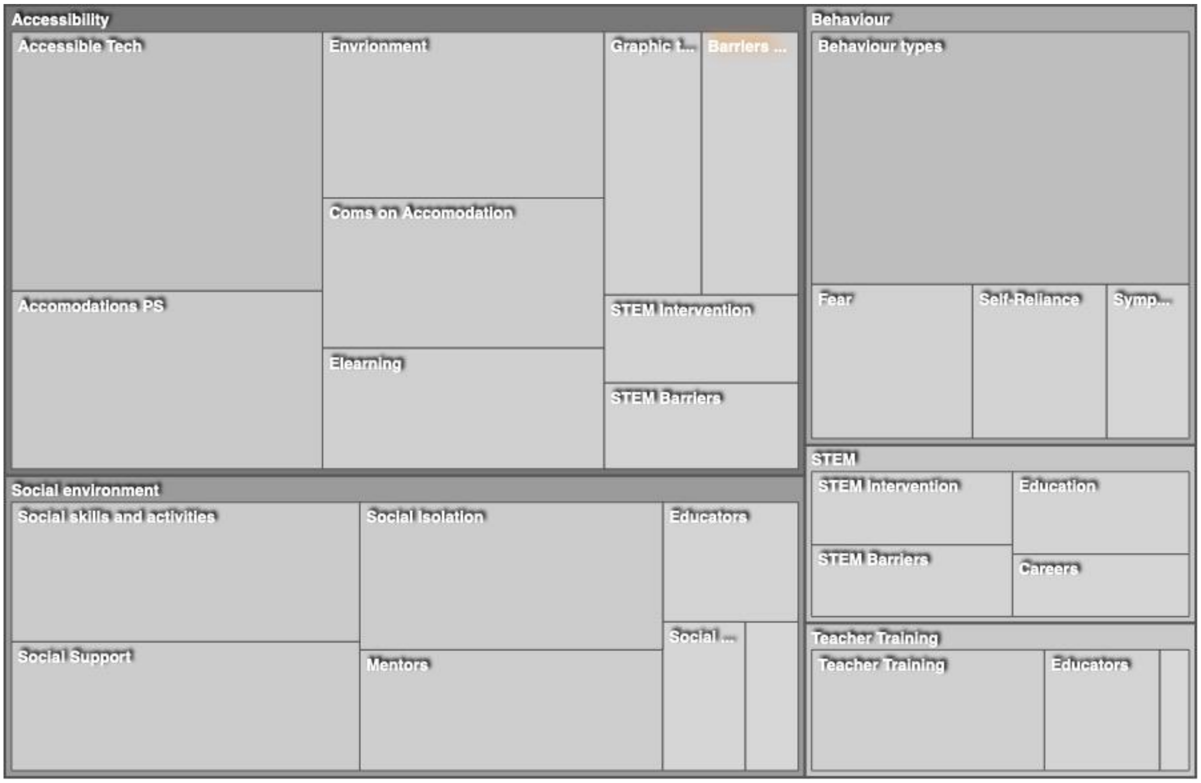
Breakdown of articles highlighting demographics.

Filename	Year	Children	Age	Median Age	Students	Teachers	adults	Stem (y)
Zebehazy 2020	2020	52	7-18	12	52			
Zebehazy 2014	2014	40	4-12	8				1
Zebehazy 2014	2014	40	9 to 17	13				
Lindsay 2019	2019	33	6-14	10				1
Lourens 2016	2016	15						
Gold 2010	2010		15-30	22	154		173	
Fichten 2009	2009		20-56	47	139			
Fichten 2015	2015			27	66			
Boman 2006	2006				12			
Reed 2011	2011					66		
Koehler 2019	2019					51		1
Sahtout 2020	2020						1	1
Zahoor 2021	2021						1	

Appendix C: NVivo thematic coding charts - high level and detailed analysis accessibility

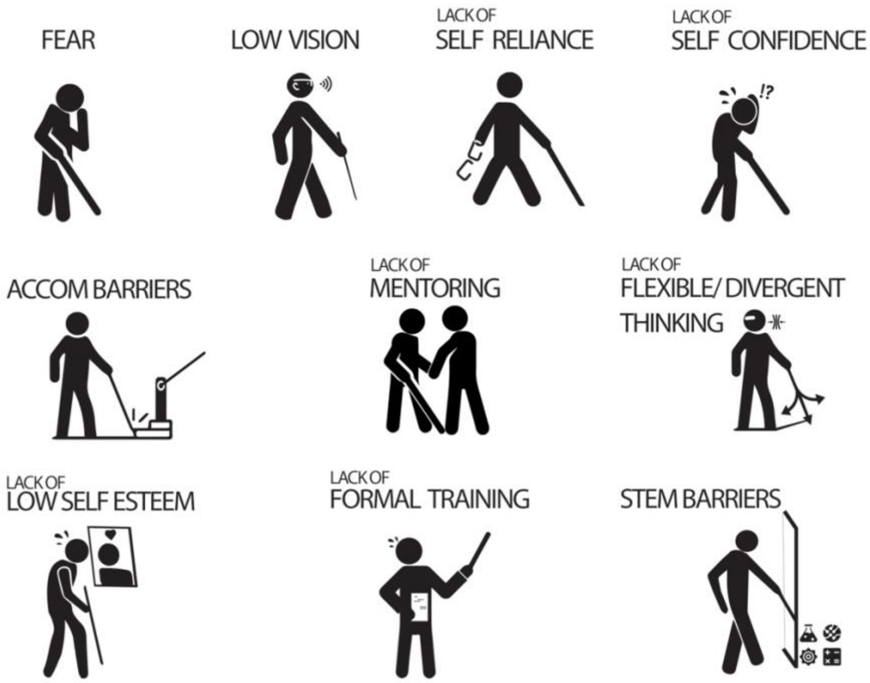
Breakdown of thematic coding of all articles producing the following charts from high level to a deeper level for each theme that was mentioned frequently in the articles.




Accessibility
Accessible Tech
Envrionment
Graphic t...
Barriers ...
Coms on Accomodation
Accomodations PS
STEM Intervention
Elearning
STEM Barriers
Behaviour
Behaviour types
Fear
Self-Reliance
Symp...
STEM
STEM Intervention
Education
STEM Barriers
Careers
Social environment
Social skills and activities
Social Isolation
Educators
Social Support
Mentors
Social ...
Teacher Training
Teacher Training
Educators

Appendix D: Graphical icon creation for low vision and PVI.

An illustrative icon concept was created to highlight behaviour of PVI as a graphical representation.



A second graphical representation below was created below for non-sighted user representation that can be adapted to behaviour like the PVI.