Inclusion of blind and visually impaired (BVI) students in a science laboratory

by

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Ethics Statement

Abstract

This study aims to examine the inclusion of students with blind and visual impairments (BVI) in science laboratory classrooms. The seven criteria for learning assessment tools were employed to determine the preparedness of science laboratory instructors. The seven criteria for student learning include 1. BVI students' safety and active participation in the lab, 2. BVI student engagement, 3. creating an inclusive environment for BVI students, 4. the ability of BVI students to contribute to group activities, 5. demonstrating required skills, 6. meeting all academic requirements and 7. acquiring equivalent knowledge as sighted students. The result showed that more than 60% of instructors agree that BVI students can meet all seven criteria of student learning in a science laboratory classroom. Therefore, the study's result encourages science instructors to adopt a universal design for learning curriculum within their science laboratory classrooms.

Keywords: Active participation; Blind and visually impaired; Inclusive education; Student engagement; Science labs; Universal design for learning

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List of Acronyms

BVI	Blind and visually impaired
CDT	Critical disability theory
STEM	Science, technology, engineering, and mathematics
UDL	Universal design for learning

Chapter 1. Introduction

The area of science has been inaccessible to students with blind and visual impairment. In science such as chemistry, biology, physics, and environments with laboratory components, the accessibility to blind students is even more impracticable. The inextricably bond between science and laboratory experience makes science more understandable and practical (Keeley, 2010). Including laboratories in science helps develop first-hand experience in observation and manipulation of science (Blosser, n.d.). Science lab experience encourages students to explore a scientific research method that supports science career decisions and active learning (Lopatto, 2007). Incorporating active learning helps students construct their understanding (Supalo, 2010).

At Simon Fraser University, every degree-seeking student takes at least six credits of science courses from biology, environmental science, chemistry, psychology, physics, health science or biomedical physiology, and kinesiology. More than 50% of these required science breath courses have integrated laboratory components in their course content and are STEM courses. The integrated laboratory component in STEM courses may sometimes deter blind students from enrolling in such classes, thereby discouraging blind students from enrolling in courses such as physics, chemistry, biology, and environmental science. Blind students will usually take laboratory courses involving a microscope and recording observation, which becomes impossible for BVI students (Moon et al., 2012).

Blindness is a lack of vision and leads to an individual being completely blind that they cannot see anything and do not see the light (*Blindness and Vision Loss*, n.d.). Visual impairment can be partial blindness, where an individual may have minimal vision (*Blindness and Vision Loss*, n.d.). Visual impairment ranges from loss of central vision, loss of peripheral vision, blurred vision, generalized haze, extreme light sensitivity, and night blindness (*Common Types of Visual Impairment* n.d.). Each level of visual impairment and blindness can affect an individual's learning capability (Silverstone et al., 2000).

Recently, laws and regulations have been enacted to enforce students with disabilities, including blind students, according to the United Nations Convention on the

Rights of Person with Disabilities (UNCRPD) article 24. "The UN prohibits discrimination against children with disabilities and mandates the right to inclusive education, making all classrooms accessible and inclusive for all students. The UN also encourages enhancing and including disabled and non-disabled students in one classroom (*Article 24 – Education | United Nations Enable*, n.d.). In 2010, Canada ratified the UN convention on the rights of persons with disability as a tool used to measure the inclusion of students with disabilities within the classroom (*Right to Education – Inclusive Education*, 2014).

Education for the blind in Canada started in the province of Ontario. Education for the blind and education for speech and hearing disabilities was grouped (Chandler et al., 2018). The education system separated and isolated the blind student from obtaining primary public education until the mid-twentieth century (Monbeck, 1973). In British Columbia, the first school for the blind was opened in September 1888 and was privately run. The school could not afford to run due to lack of funding and was closed down, and students had to attend approved schools for the deaf and blind outside British Columbia (Herie, 2005). The formation of the Canadian National Institute for the Blind (CNIB) ushered in rehabilitation, workshop, and adult education for the blind (*CNIB Consultation Response*, 2020). According to CNIB, the high school graduation rate for people with sight loss is 75%, and the reason for such a reduced percentage is due to a lack of teacher training and assistive technology(*CNIB Consultation Response*, 2020). The lack of a school board to train and integrate general education instructors with the necessary training to create an inclusive learning environment has led to less qualified available education instructors who cannot adequately support students with sight loss or braille users (*CNIB Consultation Response*, 2020). The CNIB also notes that there is little to no assistive technology through the Special Education Amount (SEA). The school board's assistive technology is also not practical for individual students(*CNIB Consultation Response*, 2020). During Internship or co-op, employers sometimes fail to provide the required accommodation for BVI students due to unfounded health and safety concerns from a social assumption about disability. This bias could lead to a blind students being restricted to the limited option of internship or co-op programs, thereby putting them at a disadvantage when it the time for them to enter the workforce(*CNIB Consultation Response*, 2020).

The lack of interest in STEM course participation among blind students has shown to occur when children with disabilities lack scientific experience during their early years of education. This lack of early exposure to science education could be due to a lack of teacher preparation in supporting students with disabilities(Moon et al., 2012). In post-secondary education, sometimes instructors are not aware of how to accommodate blind and visual learners within their classroom. The lack of awareness may lead to instructors discouraging blind students from taking their classes (Fraser & Maguvhe, 2008). Also, many instructors may presume that science laboratory courses can never be appropriate or attenable for students with blindness or visual impairment (Scadden, 2001). However, efforts are in place to provide brail and other assistive technology for blind students. The assistive technology for blind students to succeed in a science laboratory still lacks development. They need specific assistive technology in science labs to complete tasks such as tactile models and audible devices (Moon et al., 2012).

Blind students are less likely to enrol within the STEM disciplines, despite the recent development of blind students starting to venture into the STEM discipline than their sighted counterparts who are underrepresented in the STEM disciplines both as students and as employees (Moon et al., 2012). To assess the accessibility of science laboratory classes for BVI students, an evaluation of the preparedness of STEM instructors is conducted. Also, the readiness to foster universal design for learning within their classroom. The lack of instructor inexperience begs whether the blind student will be accepted and accommodated soon within science laboratories.

1.1. Study Problem and Purpose

Classroom instruction in post-secondary education relies heavily on visualization, including instructors' talk and gestures while writing on the whiteboard, their display of slides and laboratory procedures, graphs, diagrams, equations, and scientific equipment and demonstrations in the lab (Nolan & Perrett, 2016). Students with blind and visual impairment (BVI) are left behind and not encouraged to enrol in STEM classes. They do not receive the same educational opportunities as their peers in these classes (Hasper et al., 2015). Previous research asking BVI students about their "learning experience" reported that instructors failed to include BVI students in their classrooms (Hawley et al., 2013). non-inclusion of BVI students was often the case because instructors did not adapt classroom instructions or neglected to provide BVI students with accessible resources. Moreover, instructors may struggle to provide accommodation as they do not know how to do so (Whitburn, 2014).

Students with disabilities are discouraged that science is not an appropriate course for the blind due to the constant need to visually assess and evaluate scientific inquiry (Fraser & Maguvhe, 2008). Due to the percentage of BVI students among the population of students with disabilities, low vision does not attract many instructors to instructors' visual impairment training (Ambrose-Zaken & Bozeman, 2010). Also, assistive technology, accommodations, and modifications are expensive. It may require time and effort (McCollum, 1999) and the lack of regulation to ensure that a standard accommodation is in place to ensure the inclusion of BVI students within the classroom (Moon et al., 2012). Many manufacturers are available to modify scientific apparatus to meet the need of BVI students. However, this option is not well exploited because, unfortunately, many instructors lack the opportunity and time to dedicate their time to an inclusive and accessible laboratory classroom (Pence et al., 2003). When fewer instructors have ever had to teach any BVI student, it is difficult to see the relevance of getting adequate training. Lastly, few successful teaching methods or appropriate training on how instructors should prepare to teach science to BVI students (Fraser & Maguvhe, 2008). Instructors are expected to provide the same standard and quality of education to all learners without lowering or providing substantial education to a specific group. Therefore, inclusive education for BVI students should always be of equal academic standards as their sighted peers (*Reasonable Accommodations Explained*, n.d.). The ability of instructors to provide an equal learning opportunity to BVI students can be evaluated by their preparedness to offer an inclusive laboratory classroom using the following seven criteria adapted by Heard (2016), 1. The safe and active participation of BVI students in the classroom (Duerstock, 2013), 2. the engagement of blind students within the science laboratory classrooms (Sinatra et al., 2015) (Gormally et al., 2011). 3. The ability of other classmates to accept their blind classmates (Supalo, 2010), 4. The ability of blind students to contribute to group activities in the classroom (Gormally et al., 2011) (Gaudet et al., 2010) (Barbosa et al., 2004), 5. The ability of blind students to demonstrate required laboratory skills (Di Trapani & Clarke, 2012) (Hunt et al., 2012) (Fitch, 2007), 6. The ability of blind students to meet all academic requirements (Basham & Marino, 2013), 7. The ability of blind students to acquire knowledge commensurate with that of their sighted classmates (Edyburn, 2010). The seven criteria are hereafter described as the standard for students' learning.

1.2. Assumptions

This study assumed that instructors' perceptions and ability to accommodate blind students in their labs were due to a lack of training and experience working with blind students. The result obtained reflected their experience and perception. Data were collected anonymously through an online survey, and only science laboratory instructors were invited to participate in the online survey. To participate in the study, instructors needed computer and Internet access. Simon Fraser University email address and authentication were required to sign into the online survey portal; the online survey portal was made accessible for easy reading for participants who may need to use screen readers. Also, before publishing, the survey was checked and tested for visual accessibility and ease of reading and navigation.

Another assumption dealt with the grouping of all students with physical disabilities. Instructors may have thought about universal design within their labs for other physically disabled students but not for blind students. A one-fit-all model has never been a solution for catering for students with disability in education. All instructors assumed they were prepared to accommodate blind students within their labs, but realistically, they were catering to other physically disabled students. It was believed that each instructor would have heard about the universal learning design. Another assumption was the exclusion of other science instructors from the survey; it was assumed that blind students would have less struggle in a non-lab science course than in science lab courses. All other science instructors should have been included as non-lab science courses may sometimes require other non-lab skills such as reading graphs or understanding arithmetic or graphic illustration. Also, including all science instructors would have increased the sample size for the study and understood the perception of other science instructors regarding having a BVI in their class and their ability to incorporate universal design for learning within their curriculum. Another assumption was that instructors would have heard about assistive technology software to assist blind students within the classroom, but many instructors were not knowledgeable or aware of assistive software. Instructors did not understand or fully agree that assistive software will help blind students measure up to other sighted students' knowledge and skill level.

One assumption conceived before starting this study was the expectation and participation of blind or visually impaired students. The perception and input of the blind student studying at the post-secondary level would have incomparable and authentic to understanding the struggles of blind students within STEM. BVI students at Simon Fraser University did not respond to the survey, thereby limiting the participation of BVI students in the study. Also, due to time constraints and other logistics like ethics application and restrictions, no effort was made to expand the study to other post-secondary institutions within British Columbia, Canada. If any BVI student was included, they could have influenced the results based on their experiences with classmates, the instructor, or their grade, rather than basing their responses on the specific accommodations.

1.3. Scope and Significance

To evaluate the accessibility of STEM lab courses to BVI students, STEM laboratory instructors will partake in surveys around the seven criteria for learning. The seven criteria for learning are adapted from Heard (2016). The seven criteria evaluate the accessibility of BVI students to STEM laboratory classes based on these guidelines; Are BVI students able to (a) safely and actively participate in the laboratory activities (Jeannis et al., 2018), (b) be engaged in the class (Gormally et al., 2011) (Sinatra et al., 2015), (c) be accepted by classmates (Supalo, 2010), (d) contribute to group activities (Barbosa et al., 2004) (Gaudet et al., 2010), (Gormally et al., 2011), (e) demonstrate required skills (Di Trapani & Clarke, 2012) (Fitch, 2007) (Hunt et al., 2012), (f) meet all academic requirements (Richardson, 2015) and (g) acquire knowledge commensurate with that of their sighted classmates (Hackl & Ermolina, 2019) (Ahmad et al., 2019). For students with a physical disability to be included in STEM, they require active participation. Students with physical disabilities always observe rather than actively participate in science and engineering laboratory activities (Jeannis et al., 2018). The Inclusion of students with a physical disability is mainly limited to taking notes, writing papers, programming software, and other passive activities (Jeannis et al., 2018). According to the International Classification of functioning disability and health (ICF), the environment in which people live and conduct their lives is either a barrier or facilitator to the person’s activity and participation in their environment (Mihaylov et al., 2004) (World Health Organization, 2001). Inquiry-based instruction increases students' conceptual understanding and engagement in course content. Instructors adopting inquiry-based curricula often are unaware of the typical instructional challenges they may face. Instructors new to inquiry-based instruction can anticipate changes to teacher and student roles, a shift that may support instructor training and awareness of common student reactions (Gormally et al., 2011). Gormally et al. (2011) found that adopting an inquiry-based curriculum required a substantial investment in curriculum development and instructor training to facilitate the shift in instructional practices.

Further, innovative instruction such as inquiry-based learning is often met with resistance from students as they struggle to approach problems at a higher level (Gormally et al., 2011). A study by Supalo, Wohlers, and Humphrey (2011) on students with blindness exploring chemistry found that BVI students felt empowered and entirely accepted within their learning space. The students from Supalo, Wohlers, and Humphrey's (2011) study also felt no sense of judgment for their various ways of assimilation and understanding around the chemistry camp (Supalo et al., 2010). To increase accessibility to STEM classes for BVI students, BVI students should be encouraged to participate in group activities. The ability to contribute to group activity can be facilitated through the teacher's and students' actions, resulting in increased motivation, enhancing students' learning and, more broadly, their attitude toward citizenship (Barbosa et al., 2004). The collaborative, social building of knowledge in groups fundamentally differs from the individual knowledge construct (Barbosa et al., 2004). Finally, the colonial structure of knowledge necessitates establishing and maintaining a secure environment where instructors and students can identify needs, experiment, and take risks without fear of ridicule or rejection (Barbosa et al., 2004). Hunt, Koenders, and Gynnild (2012) outline ways of assessing laboratory skills, altering the assessment design to include more active participation and long-term learning (Hunt et al., 2012). Sometimes BVI fails to attain commensurate academic standards when compared to sighted students. A study on educational attainment in visually impaired students showed that Students with visual impairment alone were less likely to complete their modules and less likely to pass the modules that they had completed than sighted students. Still, they were just as likely to obtain good grades on the modules they had passed (Richardson, 2015).

Student participants were initially selected based on their visual disability, current enrolment within Simon Fraser University, and their use of service from the centre for accessibility for learning. Students who received the online survey questionnaire must have enrolled in at least one prerequisite science course at the university. The course may or not have included a laboratory component that met face-to-face. Instructors were selected based on their experience teaching any STEM lab course last year. Both instructor and student had to be enrolled at Simon Fraser University to adhere to the ethics application guiding the study ethics application. Both students and instructors had to have the technology and the internet to access the survey questions. The university was shut down during the survey period, and assisted technology could be provided within the university to both students and instructors.

The questionnaires in the study were written in English. Therefore, fluency in English was a requirement for study participation. The survey question was tested to confirm that accessibility to all readers was achieved. The terms blind and visually impaired were used for the study rather than focusing on only blind students or low to medium visual impairment. BVI students sometimes have partial vision or total blindness. Also, BVI students may have other challenges or disabilities due to their visual impairment, such as physical, intellectual, or emotional challenges that affect their learning.

Further, required laboratory activities in different STEM courses vary significantly, some presenting more significant challenges to students with BVI than others. Therefore, the generalization of study results should be made considering those considerations. Additionally, though grades are used across the globe to represent student learning, some instructors include non-achievement-based criteria in grades, and some artificially inflate grades (Sadler, 2009). Interpretation of instructor responses should include the possibility that some instructors may have awarded a passing grade to a student with BVI that does not accurately reflect actual student learning. This study aims to assess the preparedness of science lab instructors to create a universal learning space for BVI students. This study hopes to lay the groundwork for establishing the best practices in providing specific accommodations for students with BVI in the college biology laboratory and offer insight into methods for continued research.

1.4. Definition of Terms

The terms defined in this section are used throughout this dissertation. They are described to provide the clarity necessary to ensure the intended interpretation (Roberts, 2010). Terms defined include accessible, accommodations, assistive technology device, blind, seven criteria, universal design, and universal instructional design.

Accessibility is the ability to overcome the barrier and make learning more reachable for all learners (Babu & Singh, 2013).

Accommodation is "modifications or adjustments to the tasks, environment or how things are usually done that enable individuals with disabilities to have an equal opportunity to participate in an academic program" (*Reasonable Accommodations Explained*, n.d.).

Assistive technology devices “is defined as "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 functional capabilities of a child with a disability” (*ECTA Center: Federal Definitions of Assistive Technology*, n.d.).

A blind person does not perceive light (Vashist et al., 2017).

Seven criteria refer to 1. The safe and active participation of BVI students in the classroom (Duerstock, 2013), 2. the engagement of blind students within the science laboratory classrooms (Sinatra et al., 2015) (Gormally et al., 2011), 3. The ability of other classmates to accept their blind classmates (Supalo, 2010), 4. The ability of blind students to contribute to group activities in the classroom (Gormally et al., 2011) (Gaudet et al., 2010) (Barbosa et al., 2004), 5. The ability of blind students to demonstrate required laboratory skills (Di Trapani & Clarke, 2012) (Hunt et al., 2012) (Fitch, 2007), 6. The ability of blind students to meet all academic requirements (Basham & Marino, 2013), 7. The ability of blind students to acquire knowledge commensurate with that of their sighted classmates (Edyburn, 2010).

Universal design is the ability to modify and promote the consideration of the needs of all potential users in the planning and development of a space, product, or program" (Higbee & Goff, 2008)

Universal Instructional Design incorporates the tenets of universal design into education. The theory requires "considering the potential needs of all learners when designing and delivering instruction" while providing equal academic standards to all learners (Palmer & Caputo, 2003).

Chapter 2. Review of Literature

2.1. Enrolment of BVI Students in post-secondary

The inability of visually impaired students to access information material like other sighted students in post-secondary institutions has posed a big challenge for the visually impaired in post-secondary or thinking of attending post-secondary institutions (Gallagher et al., 2005). The factor affecting the assimilation of blind students into STEM is the lack of research-based instructional practices for blind students in STEM (Wild & Allen, 2009). Wild and Allen (2009) state that the lack of research-based instructional practices stems from a lack of academic and non-academic researchers. Secondly, there is a lack of universities researching blind students in STEM. Lastly, there are no emerging scholars to fill up the space of retired scholars or bring new, innovative ways and technology into science study for blind students (Wild & Allen, 2009). Also, few educators are less likely to venture into STEM education for blind students due to the lack of funding, and awareness of their needs, thereby decreasing the cases of universities developing or funding educational programs for the vision impaired (Silberman et al., 2004). For the adequate number of instructors equipped to teach STEM courses, not all are willing to accommodate or provide the appropriate adjustment to their curriculum to accommodate blind students in their labs or classrooms (Hill, 1996). A study at the University of Victoria, Canada, on students' perception regarding the adequacy of service provided (Hill, 1996). Forty-four per cent of the students rated the service received from the office of students with disabilities and faculty members as good or excellent, while thirty-five per cent of the students felt that their needs were not fully met (Hill, 1996). Twelve per cent of the students reported that faculty members were unwilling to approve their accommodation. In comparison, nine per cent said having to report the faculty member to the vice chancellor for denial of accommodation (Hill, 1996).

To successfully integrate into post-secondary, visually impaired students would need access to all print materials provided fully, access to computer-based materials, science, and mathematical materials, extracurricular activities, and a sense of independence (Kilmurray & Faba, 2005) (McBroom, 1997). Due to science and math, conventional instructional tools using visual techniques have made it difficult for blind students to get accommodation in STEM (Jitngernmadan et al., 2017). The use of spatial reasoning to manipulate the instructional skills in STEM may also be far reached for blind students as this skill is needed to navigate the understanding ad assimilation of STEM courses (Smith & Smothers, 2012). Also, the lack of incidental learning for blind students affects their accommodation in a STEM classroom (Zebehazy et al., 2012). The ability to learn from daily observation characterizes incidental learning. This concept of learning in STEM poses a substantial setback for blind students (Zebehazy et al., 2012). Blind students also have cognitive difficulty with math as they cannot visually scan graphics and spatial arrangements (Jitngernmadan et al., 2017). Due to the lack of vision, many instructors may be less receptive to accommodating blind students in their class or assume that blind students lack the cognitive skills to learn or understand STEM skills (Klingenberg et al., 2012). The lack of cognitive skills among blind students is not valid for all blind students. This misperception is one of the many that contributes to creating an access barrier for blind students in STEM.

Another problem blind students may encounter in STEM is accessing their textbooks, and they receive books with errors due to a lack of appropriate translation (Smith & Smothers, 2012). Blind students are also disadvantaged if their math worksheets have Nemeth errors, causing their textbooks inaccuracies (Herzberg & Rosenblum, 2014). As blind students wait for their book to get translated, this wait time may create a setback in their learning (Smith & Smothers, 2012). The use of tactile graphics in STEM also poses a challenge for blind students as the data points in the tactile graphics are sometimes unequal compared to what appears in the original print. This misrepresentation of graphs or text may blind students to misinterpreting the information depicted (Smith & Smothers, 2012). In addition, worksheets in tactile graphs lack consistent labelling or formatting, increasing the difficulty of navigating for blind students (Herzberg & Rosenblum, 2014). Accommodation changes the validity of an assessment due to error and misinterpretation Edward et al. (2019). Even when using assistive technology to translate textbooks, proper precaution should note that improper translation may affect the educational efficacy of the material (Zebehazy et al., 2012). The pairing of blind students with sighted students also affects their learning experience. The pairing experience for blind students means that blind students do not get the satisfaction of completing their work independently (Supalo et al., 2014). When blind students pair with sighted students, this is usually done to help blind students with the steps needed to complete an experiment and take notes in class (Supalo et al., 2014). This process helps blind students understand the procedures but cheats them away from experimenting with science or partaking in a scientific experiment which may, in turn, discourage blind students from going further with any STEM course (Supalo et al., 2014). Students are forced to work with unprepared, unwilling, or underqualified instructors to teach math and science skills. Herzberg and Rosenblum (2014). A study by Herzberg and Rosenblum (2014) evaluated the competency of transcribing a math worksheet using Nemeth code. The result showed that many instructors did not feel equipped to teach Nemeth code to their students (Herzberg & Rosenblum, 2014). A study shows that t instructors realise the importance of providing these accommodations. Instructors may also have economic, psychological, architectural, and attitudinal obstacles. Instructors do not know how to solve all problems by providing suitable accommodation for each student (Hawley et al., 2013). The inability to provide an appropriate and practical accommodation for a blind student also depends on the communication between the student's services assessing student accommodation needs and the instructors. This communication breach may add to the lack of knowledge on providing a conducive, accessible learning environment for blind students (Edward C. Bell & Arielle M. Silverman, 2019).

The visually impaired student may also lack the courage to advocate for themselves due to the constant reminder of being categorised as not capable (Beck-Winchatz & Riccobono, 2008). As assistive teaching technology and adequate accommodation become the most critical challenge for accepting blind students within STEM, this problem has been linked to the financial constrain to purchasing these technologies (Beck-Winchatz & Riccobono, 2008).

2.2. The Legal Mandate

Students with blind or visual impairment make a group of children grouped into a heterogeneous population. Blind and visually impaired students share some degree of blindness but are sometimes distinct from mild to total blindness. The degree of blindness also represents a broad spectrum of characteristics specific to cognitive ability, level of independence, physical agility, the severity of a disability, and the presence of additional disabilities (Canadian-National-Standards-Visually-Impaired., n.d.). The traditional definition of visual impairment or blindness is grounded in medical terminology and provides limited guidance for instructional content or strategies (Canadian-National-

Standards-Visually-Impaired., n.d.). It is necessary to include blind and visually impaired systems while designing curricula and various modes of instruction as education is a required skill needed to improve an individual's s personal and social skills. Education helps individuals gain meaningful financial independence, participate, and realize their potential within their environment (OHRC, 2018).

Canada lacks a single act or regulation that guides the right to provide equivalent education to students with disabilities. The closest to being equal for all people, notwithstanding their disability, is the Canadian Charter of Rights and Freedom section 15. This law guarantees that "every individual is equal before and under the law and has the right to the equal protection and equal benefit of the law without discrimination and, in particular, without discrimination based on race, national or ethnic origin, colour, religion, sex, age or mental or physical disability" (Heritage, 2017). In all provinces in Canada, Saskatchewan, Manitoba, Quebec, and Ontario, human rights codes acknowledge the right to education for people with disabilities (Stack, 2001). Since no provision of the Canadian Charter explicitly acknowledges the "civil" right to education for people with disabilities, considering that the acts governing both the Universal Declaration of Human Rights, Convention on the Right of Persons with Disabilities, and the United Nations Convention on the Rights of the Child will be employed. Canada is a member of the Universal Declaration of Human Rights, Convention on the Right of Persons with Disabilities, and the United Nations Convention on the Child's Rights. Since both bodies advocate for the civil and unrestricted right to education for students with learning disabilities, Canada may comply with these bodies' laws. According to the Universal Declaration of Human Rights Article 26,

"The right to education shall be accessible to everyone at least in the elementary and fundamental stage. Everyone is entitled to technical and professional education, and higher education shall be equally accessible on merit. Education involves fully developing the human personality and strengthening respect for human rights and fundamental freedoms. It shall promote understanding, tolerance, and friendship among all nations, racial or religious groups, and shall further the activities of the United Nations to maintain peace. Parents have a right to choose the kind of education given to their children" (Article 26, n.d.).

The Convention on the Rights of People with Disabilities Article 24 states,

" Supports the development of personality, talents, creativity, mental and physical abilities to enable them to participate in society." " Each country would ensure that persons with disabilities can access tertiary education, vocational training, adult education, and lifelong learning and shall face no discrimination. Each country shall provide reasonable accommodation" (Article 24 – Education | United Nations Enable, n.d.).

The United Nations Convention on the Rights of the Child protects the right to education for a student with disabilities under article 23 states,

“Disabled child has effective access to and receives education, training, health care services, rehabilitation services, preparation for employment and recreation opportunities in a manner conducive to the child's achieving the fullest possible social integration and individual development, including his or her cultural and spiritual development” (Convention on the Rights of the Child, n.d.).

2.3. Universal Design for Learning

Universal learning design (UDL) is a teaching, learning, and curriculum development paradigm that focuses on creating inclusivity through initial design rather than overcoming barriers later through individual adaptation (Rose et al., 2006). The universal learning design reduces the barrier for users with disabilities and increases availability to various users. Because UDL caters to a whole community rather than an individual, it encourages flexibility, designed to anticipate the need for alternative options and adaptation (Rose et al., 2005). UDLs are not unique or personal but rather accommodate all diversity and are inclusive. The framework guiding UDL founded around the neuroscience of learning emphasizes three principles of pedagogy; the means of representing information, the means of expression of knowledge, and the means of engagement in learning (Rose et al., 2005). Principle One of UDL: Multiple Means of Representation applies to the methods of teaching, which highlight critical features, emphasize big ideas, model inquiry, and connect new information to background knowledge. Multiple means of representation also emphasize the need to provide instructional information through various means (Rose et al., 2006). As students differ on how they navigate and express new concepts, the second principle, multiple means of expression, encourage the option of alternatives in mentoring, modelling, and assessment for learning and growth (Rose et al., 2006). The blind student may delay motor skills, limiting their physical actions and how they respond to or construct knowledge around STEM courses (Basham & Marino, 2013). The last principle, multiple means of engagement, will benefit students who differ in how they engage or are motivated to learn. Students engage through various means; some are engaged by risk and challenge in a learning environment while others seek safety and support, some adjust to dynamic social forms of learning, and others shy away and recede from social structures (Rose et al. 2006). It is an event where there is no one-fit way of engaging students that will be optimal for a range of diverse students. The third principle reflects that students are various means of extrinsic and intrinsic modes of motivation and so, therefore, alternative means of engagement should be well exploding in education (Rose et al., 2006).

2.4. Universal Design for Learning: Science for BVI Students

In science education, hands-on activity is imperative for learning across various STEM courses. Therefore, fostering an inclusive science education framework is ideal when developing curriculums. Developing an accessible curriculum and inclusive learning resources should comply with the characteristics of being accessible for the blind and visually impaired (designed for the blind as primary users). At the same time, they are also attractive and inclusive for individuals without such conditions (C. G. Reynaga-Peña & del Carmen López-Suero, 2020). For example, braille can use colour illustrations and regular printed text, while three-dimensional models should have an attractive resolution that will benefit blind and sighted students (C. G. Reynaga-Peña & del Carmen López-Suero, 2020). More sophisticated materials could also provide auditory and visual information in the same venue and smell. The inclusion of these senses will improve the participation of visually impaired students. However, it would also increase the opportunities for interaction with their sighted peers because they would use the same learning materials (C. G. Reynaga-Peña & del Carmen López-Suero, 2020).

The adaptation of science to include blind students started in 1970, with most transformations focusing on chemistry, which involved adapting ways to include blind students (Wood & Eddy, 1996). In chemistry, to help blind students with titration by using olfactory cues to indicate an endpoint of the titration of sodium hydroxide solutions with hydrochloric acid (Neppel et al., 2005). Using an odour indicator rather than the traditional phenolphthalein (the most used colour indicator) for chemistry experiments will include blind students in the laboratory. Bandyopadhyay and Rathod also develop a technology application for detecting the colour change of phenolphthalein at the titration endpoint (Bandyopadhyay & Rathod, 2017). Including the following application, as mentioned earlier, to the chemistry curriculum would foster a universal learning environment rather than having a sighted student paired with a BVI student who performs the tasks and shares the information with the BVI student (Supalo, 2012). An organisation also promotes the development of independence and science skills for blind students in science (Wedler et al., 2014). A successful inclusion experience for BVI students in STEM should always incorporate multi-sensorial activities and thoughtfully UDL teaching material and resources. The same importance should provide effective use of inclusive teaching strategies that promote active and autonomous learning by every student, which should facilitate spatial cues for safe manipulation in the science laboratory (C. G. Reynaga-Peña & del Carmen López-Suero, 2020). UDL is achievable for BVI students if a reasonable educational theoretical framework is employed.

The implementation of critical disability theory (CDT) is to challenge discrimination against people with disabilities. The critical disability theory (CDT) encompasses various social, political, and cultural discourses and institutions when analysing and describing their role in disability beliefs. In these ways, the critical theory also exposes the contingency of ideas or circumstances often presumed natural or unchangeable (Ellis et al., 2019). Diverse critical theories unite because they target ideology, distrust appearances, and often point out false consciousness towards the construct around ableism (Meekosha & Shuttleworth, 2009). There are four principles of critical disability theory. First, CDT is not deducible through quantitative analysis; quantitative analysis concerning CDT discourages this form of analysis and reduces the struggles of the affected to numbers, neglecting their epidemiological lived experiences (Samuels, 2003). The second principle focuses on autonomy, which focuses on the emancipation from hegemonic and hierarchical ideologies rather than being defined as a means of independence (Samuels, 2003). The third theory acknowledges the historicity of disability and how that affects the integration of the disabled in society. The fourth theory encourages dialogue across an organization that fights for the rights of people with disability (Meekosha & Shuttleworth, 2009). CDT also confirms that discrimination against people with disability is commonly accepted and has become invincible when it happens (Rocco, 2005). CDT also confronts the assumption of ignoring the differences in physical and mental abilities (Johnson, 2009). CDT provides all level of perspective that showcases the multilevel issues linked to disability, ranging from legal, economic, political, and social justification (Devlin & Pothier, 2006). CDT also examines the role of power and privilege and how these factors help categorize which group gets marginalized in society (Devlin & Pothier, 2006). When people with disabilities ask for an adaptation to their environment, this request is seen as a clear disadvantage to abled people, thereby creating an illusion of disabled people craving power (Rocco, 2005). Power is well known to reside in a group of people with power over economics, politics, and educational resources, and these people are usually not disabled (Rocco, 2005). The positive cultural assumption of ableism created disability (Pelka, 2012). When people with disability demand legislative rights, they are faced with the perpetuation of ableism (Hehir, 2007). Kumari-Campbell defines “ableism as follows: The production of ableness, the perfectible body and by default, the creation of a neologism that suggests a falling away from ableness that is a disability and a viewpoint that impairment is inherently negative which should, if the opportunity presents itself, be ameliorated, cured, or indeed eliminated" (Campbell, 2008).Disability is therefore cast as a diminished state of being human (Campbell, 2008). Ableism is also considered the better form of ability to perform societal norms (Storey, 2007). Ableism has become a dictator and discriminatory structure and practices deeply ingrained within educational systems, which subvert even the most well-intentioned policies by maintaining the substantive oppression of existing hierarchies (Beratan, 2006). The role of ableism in education should be acknowledged to make legitimate progress toward equity for people with disability. In many schools, disability is not usually part of the diversity discussion, and disability activists have long recognized the long-term negative influence of failing to recognize disability. Recognizing disability as a basic diversity issue is important in helping instructors and students with disabilities feel comfortable with their disability (Hehir, 2007). In education, the inclusion of diverse staff and educators rarely are people with a disability included in this dialogue (Storey, 2007). It is fascinating that people with disability are not included in these spaces knowing that ableism impacts the lives of people with disabilities from many different levels. Ableism impacts people with disabilities at different levels, such as individual, cultural, and institutional levels, and each of these levels must be addressed to combat ableism comprehensively (Storey, 2007). Ableism in education has been the norm for many centuries. A comprehensive understanding of the experiences of post-secondary students with diverse abilities is needed. How 'disabled' post-secondary students make meaning of their experiences in post-secondary education was explored by Hutcheon and Wolbring (2012). The study involved eight participants (self-identified disabled post-secondary students) from post-secondary institutions in Calgary, Alberta. The five themes identified: hegemonic voice, the voice of the body, the voice of silence, the voice of assertion, and the voice of change within a body-social-self framework. Also, the result showed an increased awareness of the critical examination of higher education policy and its capacity to address the difference in ability (Hutcheon & Wolbring, 2012).

2.5. UDL Adaptation for BVI Students in STEM

This section describes educational materials and adaptations for blind and visually impaired students in the science laboratory classroom.

Studies about the input of different groups have created tools to make scientific data accessible to BVI students. First on the list is auditory applications to communicate science to BVI students. Auditory applications output the reading and data as sound rather than graphics and numbers in a digital display. A commonly used auditory application in science is the Talking LabQuest 2. Talking LabQuest 2 is a sensor interface that uses Sci-Voice software and couples to Vernier sensors (for pH, temperature, motion, conductivity, UV-Vis Spectrophotometer). Using vernier sensors and LabQuest 2 makes collecting science data accessible for blind students (Isaacson et al., 2016). In Kroes, Lefler, Schmitt, and Supalo (2016) on the development of accessible laboratory experiments for visually impaired students, the Talking LabQuest 2 for an investigation on the exothermic and endothermic reaction measured relation pressure-volume in gas (Kroes et al., 2011. The study reported that LabQuest 2 was very useful to blind students. Both teacher and students fully agreed that the Talking LabQuest created an inclusive learning environment (Kroes et al., 2011).

Tactile, three-dimensional models are another innovative technology used to teach biological concepts of microscopic nature (cell biology, microbiology, plant tissues), which are inaccessible to blind and visually impaired students (C. G. Reynaga-Peña, 2015). Scientists conceptualized these models to have scientifically accurate information and were developed by visual arts students to be highly attractive to all learners. Tactile three-dimension (3D) models are based on the UDL principles, making them hold adequate tactile resolution, contrasting colours, and various tactile textures. Tactile three-dimension models have touch-response technology to provide auditory information and promote autonomous learning. 3D models can also be connected to sensors to transmit tactile and auditory signals. 3D models can also be individually wired, so the tangible auditory information related to each part of the 3D model is sent to the student (C. G. Reynaga-Peña & del Carmen López-Suero, 2020). Companies such as Touch Graphics develop touch-response material and educational technology that make science more accessible for BVI students. The touch graphic makes the Tactile Talking Tablet (TTT) hold auditory information for STEM subjects (Touch Graphics, n.d.).

Adaptations and safety are crucial in laboratory practices when promoting or seeking accessibility for BVI students in science. First, to encourage BVI students to work independently during the experimental sessions, a piece of 3D foam tape can be placed in the shape of a cross to divide sections on the laboratory table so that students can identify the materials and solutions. The instructions for the experiment could be in braille for students to read and verbally illustrate when giving directions on how to navigate the laboratory activities. It is worth -noting that being consistent with the lab set-up orientation may also help BVI student navigate their way around the laboratory (C. G. Reynaga-Peña & del Carmen López-Suero, 2020). A study by (C. Reynaga-Peña, 2014) on a group of science students, including BVI students, in a science workshop. Each student was wholly independent in these workshops and could conduct the experiments regularly. A study used a bulb and buzzer created from recycled materials to test for conductivity. The experiment was accessible to both sighted and BVI students (C. Reynaga-Peña, 2014).

The inclusion of inquiry-based learning, which uses multisensorial and hands-on activities, has shown to be beneficial (Shams & Seitz, 2008). Shams and Seitz (2008) argue, "The human brain has evolved to learn and operate in natural environments which guide behaviour by information integrated across multiple sensory modalities". The result concludes that multisensory protocols can better approximate natural settings and produce more significant and efficient learning (Shams & Seitz, 2008). A study by Reynaga-Peña used multisensorial activities within the natural environment for biology, chemistry, and physics workshop. The BVI students who participated in these non-formal science learning experiences reported having fun and positive experiences. Remarkably, some expressed that they had never performed experiments before and stated, "it was fantastic to be able to do things (by myself)" (C. G. Reynaga-Peña et al., 2018). The study documented the positive learning outcome for BVI students who can work independently due to the experiment being accessible (C. G. Reynaga-Peña et al., 2018). Inquiry-based learning has been a practical approach to teaching science in a non-formal environment (Minner et al., 2010). Inquiry-based learning fosters autonomy and develops generic skills, which are very useful in science education. Inquiry-based learning is based on the purpose of questioning, observing, researching, analyzing, and applying, and it has four essential stages: focalization, exploration, reflection, and application (Minner et al., 2010). The curriculum should engage all students to foster an inclusive STEM class and laboratory for students with visual impairment. The curriculum should include ways for visually impaired students to independently participate like their sighted peers. UDL is possible by producing and using teaching resources and curricula suitable for all students.

Chapter 3. Procedures and Methods

This study explores science laboratory instructors' preparedness when teaching BVI students. A description of the methods and procedures of this study is expressed. This section includes the research question, research design, and data collection from surveyed instructors within Simon Fraser University who teach STEM lab courses.

3.1. Research Questions

This study investigates inclusive education attitudes, perceptions, and knowledge among STEM lab instructors for blind and visually impaired students.

The research investigated the following question: How do instructors encourage BVI students in science labs? How does the science lab curriculum include BVI students? How are science labs accessible to BVI students? Classroom instruction in post-secondary education relies heavily on visualization, including instructors' talk and gestures while writing on the whiteboard, their display of slides and laboratory procedures, graphs, diagrams, equations, and scientific equipment and demonstrations in the lab (Nolan & Perrett, 2016). Students with blind and visual impairment (BVI) are left behind and not encouraged to enrol in STEM classes. They do not receive the same educational opportunities as their sighted peers' (Hasper et al., 2015). Previous research asking BVI students about their "learning experience" reported that instructors failed to include BVI students in their classrooms (Hawley et al., 2013). Therefore, the need to assess the preparedness of STEM instructors is imperative.

3.2. Setting

This study was carried out at Simon Fraser University. Simon Fraser University was chosen as the primary setting due to accessibility; the researcher and participants work/study at the university. Secondly, the university offers various science lab courses that all first-year students from all disciples are required to take. Data were collected through anonymous electronic surveys. SSL encryption was enabled on the survey tool (survey monkey) to mask the IP address and identity of the participants. Participants were ensured that any identifying information inadvertently included in their responses would be redacted.

3.3. Participants

3.3.1. Science Laboratory instructors

At least two instructors were contacted from these departments at SFU: biological sciences, biomedical physiology and kinesiology, chemistry, earth science, physics, and psychology. In total, forty-eight instructors were contacted from all six departments. Instructors were recruited by emailing individual lab instructors from the department mentioned above. BVI students were initially included in the study through the centre for accessible learning (CAL) at SFU, and no response was received from BVI students. The survey was open for eight weeks. At the end of the eight weeks, twenty-seven instructors participated in the survey, twenty-one did not participate in the study, and zero students participated. The decision was made to exclude the student participation option from the study. All participation was voluntary. The first page of the survey explained the research and required the respondent to check a box indicating their consent to participate in the study as designed. Anyone beginning the online questionnaire had the opportunity to stop at any time. Participants could skip any questions they chose not to answer. The STEM laboratory instructors completed the survey to assess their inclusion and preparedness for blind and visually impaired students within their classrooms.

3.4. Survey Question Themes

The survey instrument was used to investigate the preparedness of instructors to create an inclusive and accessible classroom for BVI students. The survey questions were drafted using the seven criteria for student learning adapted from Barbara Rae Heard (2016) (Heard, 2016). The seven criteria assessed;

1. BVI students' safety and active participation in the lab (Jeannis et al., 2018).

2. Student engagement (Gormally et al., 2011) (Sinatra et al., 2015).

3. We are creating a suitable environment for BVI students (Supalo et al., 2010).
4. Will students contribute to group activities equally (Barbosa et al., 2004) (Gaudet et al., 2010) (Gormally et al., 2011)?
5. Will BVI students demonstrate the required skills being taught (Di Trapani & Clarke, 2012) (Fitch, 2007) (Fitch, 2007)?
6. Will BVI students meet all academic requirements for the course (Richardson, 2015)?
7. Will BVI students acquire equivalate knowledge as sighted students (Peleg et al., 2016)?

The survey weblink was sent through SFU secured email in Spring 2021.

3.5. Instrumentation, Confidentiality, and Data Storage Plan

3.5.1. SFU WebSurvey

For the survey question, SFU WebSurvey was used. The SFU WebSurvey software was accessed through SFU Information Technology (IT) services. SFU WebSurvey was chosen due to its level of security compared to other survey tools. Data collected on SFU WebSurvey are stored locally at the SFU data centre, protecting confidential data for students and instructors.

3.5.2. Flash Drive

All data collected from this study will be stored in a flash drive. The flash drive will be locked with a combination code. Only the researcher and the principal investigator will have access to this code. The Flash drive will be stored in a safe at the Centre for Accessible Learning. Only the primary researcher and principal investigator will be allowed access to the flash drive. After the study period, the flash drive will be transferred to a different secured location (TBD) for five years, after which the flash drive will be destroyed through SFU IT services.

3.5.3. Data Analysis Plan

Surveyed questions collected from this study will be grouped according to the seven themes for accessing student learning. The data from the survey will be collected and analysed using Prism. The percentage of instructors' responses will be explored in the pie chart to show the percentage of instructors' responses. Participants will be questioned in this study regarding the seven student learning criteria.

Chapter 4. Study Results

The result of this study was collected from laboratory science instructors at Simon Fraser University. The seven criteria for student learning were used to formulate the survey for the science laboratory instructors. The seven criteria used to develop the survey questions examined the following; a. instructors' preparedness to provide a safe and active environment for BVI students, b. create an engaging classroom environment, c. provide an accepting conducive environment for BVI students, d. an environment that encourages BVI students to contribute intellectually, e. BVI students can demonstrate required skills, f. meet all academic requirements, and g. acquire knowledge equivalent to their sighted classmates. Due to the small number of participants, the data were converted to percentages to enable appropriate data representation in a bar graph.

4.1. Criterion One: Safety and Active Participation

The first of the seven criteria requires that instructors foster active participation and provide a safe laboratory for BVI students. The following questions were asked in this criterion: "Will laboratory grades represent active participation, will BVI students be safe in their laboratory classroom and will the curriculum foster group participation for BVI students?".

Figure 1a below represents the response from science lab instructors when asked if laboratory grade will include active participation. The result shows that 83 % of science lab instructors agree that active participation is well represented in a student's final lab grade. 14 % disagreed, and 3% were neutral about if active participation was expressed in a student's final lab grade. For the second question under this criterion, 89% agreed that a BVI student would be safe in their laboratory classroom, and 11% disagreed that BVI students would be secure in their laboratory classroom. Figure 1c shows that 68% of instructors disagree that their curriculum will foster group participation for BVI students, while 23% agree and 9% neither agree nor disagree.

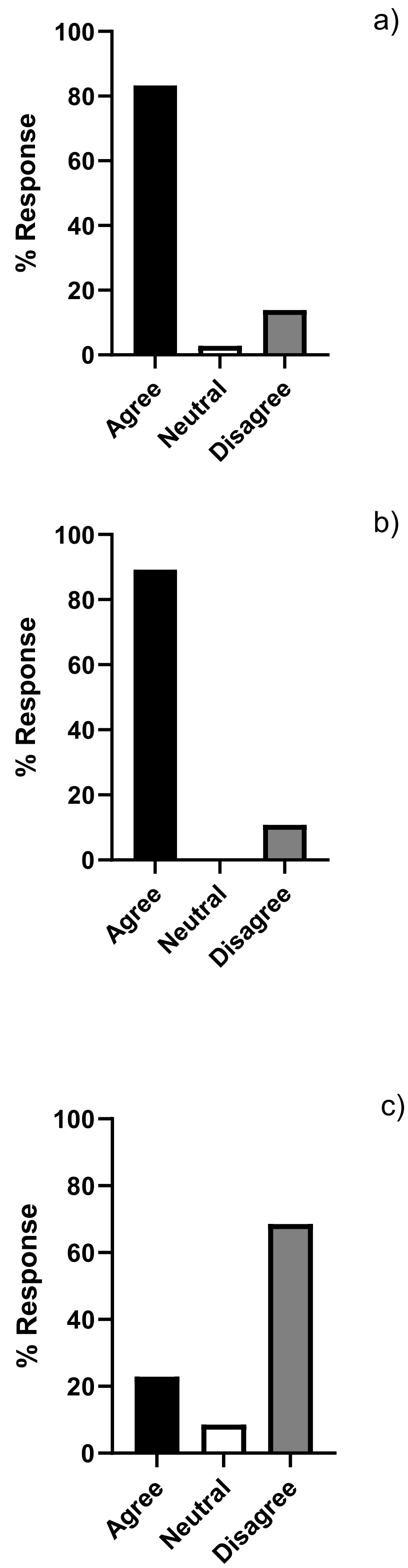


Figure 1. **a) Encouraging BVI students' active participation in the laboratory classroom. b) Providing a safe laboratory classroom for BVI students. c) Curriculum fosters group participation in BVI students**

4.2. Criterion Two: Student’s Engagement.

The second criterion examined the ability of science laboratory instructors to engage BVI students in their lab classroom; students' engagements were assessed using three questions. The curriculum would encourage BVI students to participate equally with sighted students, the laboratory activities would be well structured to engage BVI students, and laboratory activities would encourage BVI to work with sighted students. The result from the second criteria shows that 67% of instructors agree that their curriculum will encourage BVI students to participate equally with sighted students. In comparison, 18% disagree, and 15% neither agree nor disagree (figure 2a). In figure 2b, when asked if the laboratory activity is well structured to engage BVI students, 80% of instructors disagreed, while 14% agreed and 6% neither agreed nor disagreed. The last question for this criterion examined if the laboratory activities will encourage BVI students to work with sighted students. The result shows that 67% of instructors agree, while 11% disagree and 22% neither agree nor disagree. The degree of agreement between individual questions assessing students' engagement was inconsistent.

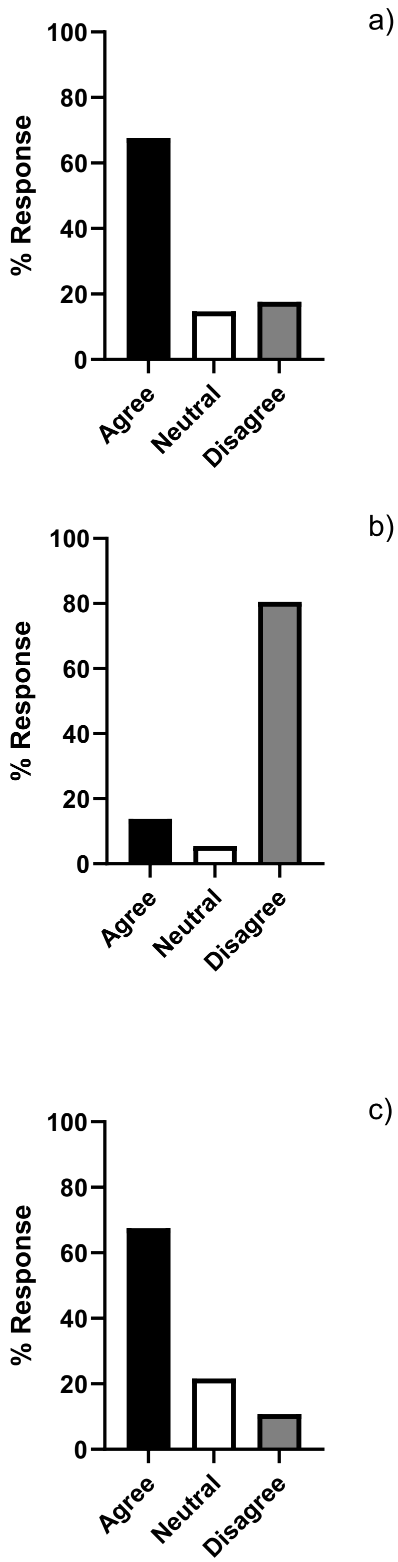


Figure 2. **a) Encouraging BVI students to participate equally with sighted students. b) Engaging BVI students in well-structured activities. c) Encouraging BVI students to work with sighted students**

4.3. Criterion Three: Reasonable Accommodation

The third criterion examines the required accommodations needed by BVI to make the lab environment more accommodating and acceptable. To address the issue of acceptance in laboratory classrooms, this criterion questions: 1. 'would a student aide be available to help the BVI student? 2. modification would be made to laboratory activities or grading to include BVI students, and 3. BVI students would be assigned a specific position away from other students. The bar graph below shows that 80% of instructors agree that student aid will always be available to help BVI students, and 20% disagree (figure 3a). In Figure 3b, 57% of instructors agree that modifications will be made to laboratory activities and grading, including BVI students, 34% of instructors disagree, and 9% neither agree nor disagree. Figure 3c analyzes instructors' responses when asked if students will be assigned a specific location away from sighted students. 3% of instructors agree, 84% disagree, and 13% neither agree nor disagree.

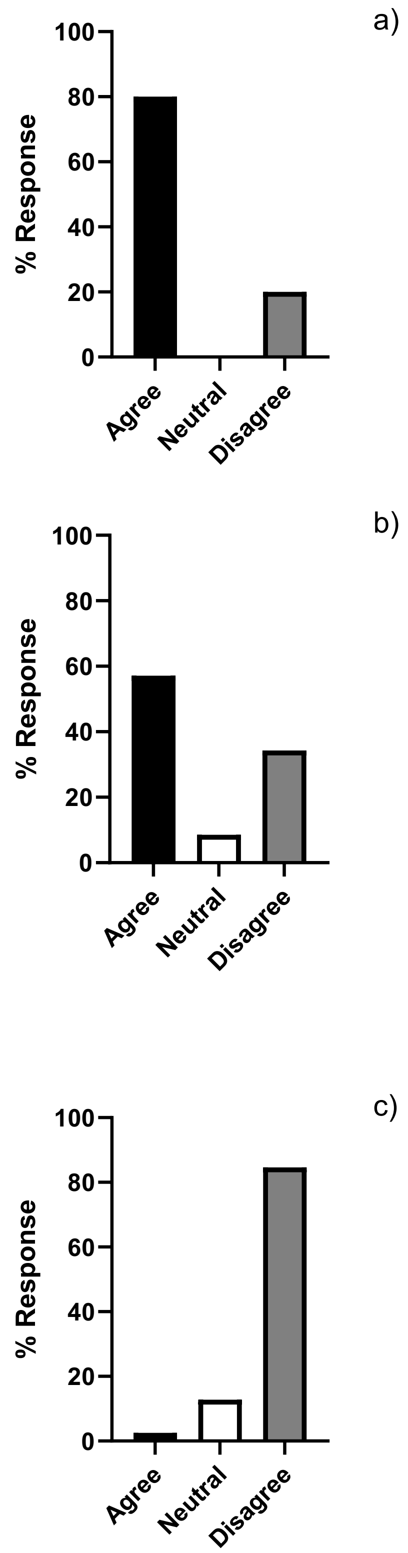
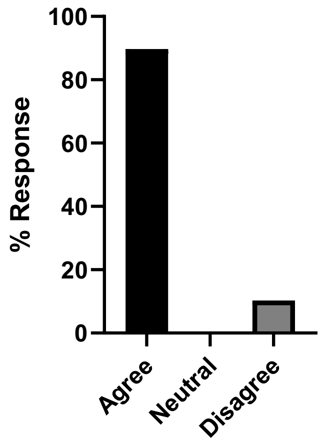


Figure 3. a) Student aid asks are available for BVI students in the lab. b) Modifications will be made to laboratory or grading to include BVI students. c) BVI students assigned a specific position away from sighted students



4.4. Criterion Four: Contribute to group activities equally (Barbosa et .al 2004)

Instructors were asked if BVI students would be able to complete a lab activity. The response shows that 90% of instructors agree that BVI students will be able to complete lab activities with other students Figure 4.

Figure 4. BVI students can complete Lab activities with other students

4.5. Criterion Five: Demonstrates the required skills taught

The fifth criterion evaluate BVI students' ability to demonstrate skills required in labs. Since BVI students were not surveyed, this criterion was modified to assess the availability of assistive lab tools needed for BVI students to acquire basic science laboratory skills. The questions used to determine if instructors have provided the required tools for BVI students to develop basic laboratory skills include "do instructors have prior knowledge that assistive software and technologies exist for BVI students? BVI students can take science lab courses with the assistance of assistive lab tools/ software, and lastly, labs are equipped with some or all required assistive technology for BVI students. The result from criteria five shows that 81% of instructors agree that they have prior knowledge that assistive lab technology exists for BVI students, while 19% disagree (Figure 5a). Figure 5b shows that 81% of instructors believe BVI students can take their science lab courses with assistive technology, while 8% disagree and 11% neither agree nor disagree. The last question for this criterion shows that 94% of instructors disagree that their lab is equipped with some or all required assistive technology needed for a BVI student to acquire lab skills, and 6% of instructors agree with the figure (5c).

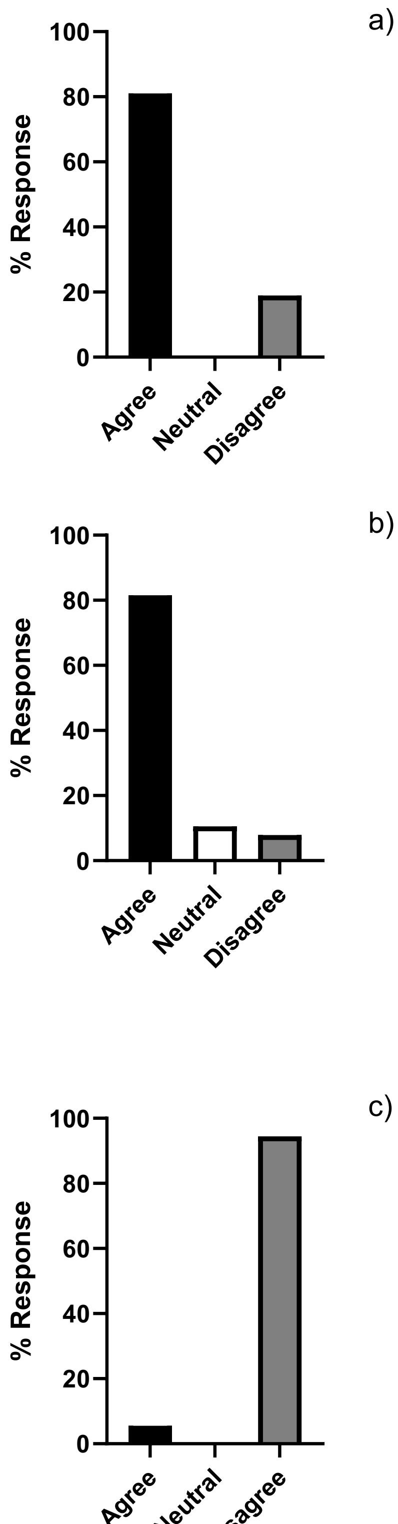


Figure 5. a) Prior knowledge about assistive technologies for BVI students. b) Belief that BVI students are capable of taking science lab courses with the assistance of assistive technology. c) Laboratory is equipped with some assistive technology for BVI students

4.6. Criterion Six: Meet All Academic Requirements

This criterion assesses the ability of BVI students to meet academic requirements comparable to sighted students when all specific accommodations have been met. For Figure 6a, 95% of instructors agree that BVI students' lab concepts and skills will be satisfied if their lab content were to be modified. 2% of instructors disagree, and 3% neither agree nor disagree that BVI students' lab concepts and skills will be met with proposed modifications to lab content. In figure 6b, 100% of instructors believe BVI students will be assessed on laboratory concepts. Lastly, in Figure 6c, 95% of instructors believe that BVI students will be evaluated on laboratory skills, while 5% of instructors disagree.

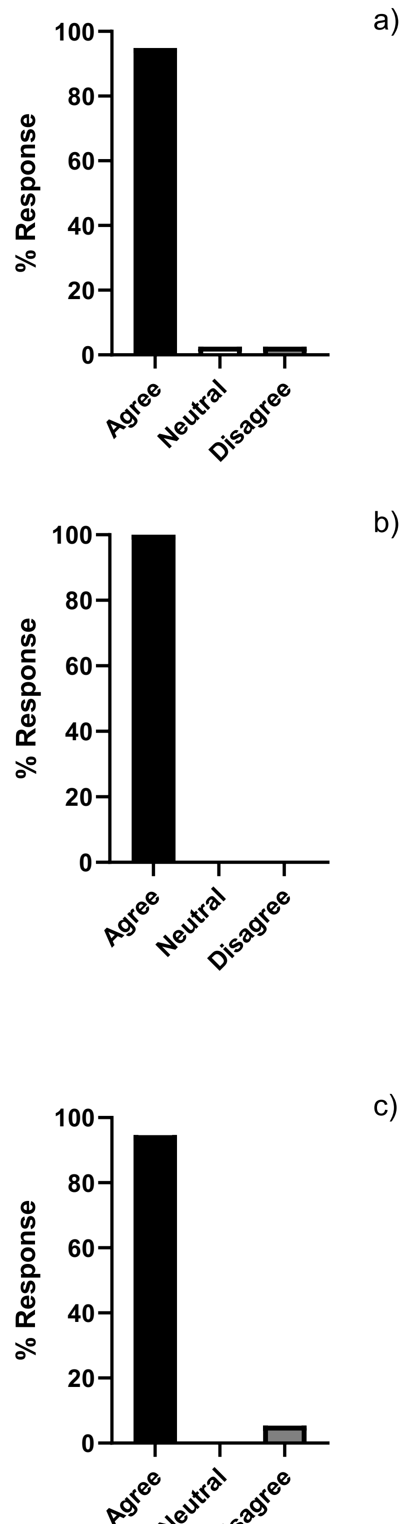


Figure 6. **a) Belief that BVI student laboratory concepts and skills be met with a lab modification. b) BVI students are assessed on laboratory concepts. c) BVI students are assessed on laboratory skills**

4.7. Criterion Seven: Acquire Equivalent Knowledge as Sighted Students.

The final criterion asked instructors if BVI students could acquire knowledge commensurate with the sighted students in the class. For this criterion, instructors were asked if BVI students could demonstrate an understanding of laboratory concepts at a level comparable to sighted students, and 100% of instructors agreed (Figure 7a). The second question asked if BVI students would demonstrate knowledge of laboratory skills equivalent to sighted students; 90% of instructors agreed, and 10 % disagreed (Figure 7b). The last question asked if the instructors perceive that BVI students will learn as much as sighted students. 86% agreed, 6% disagreed, and 9% neither agreed nor disagreed.

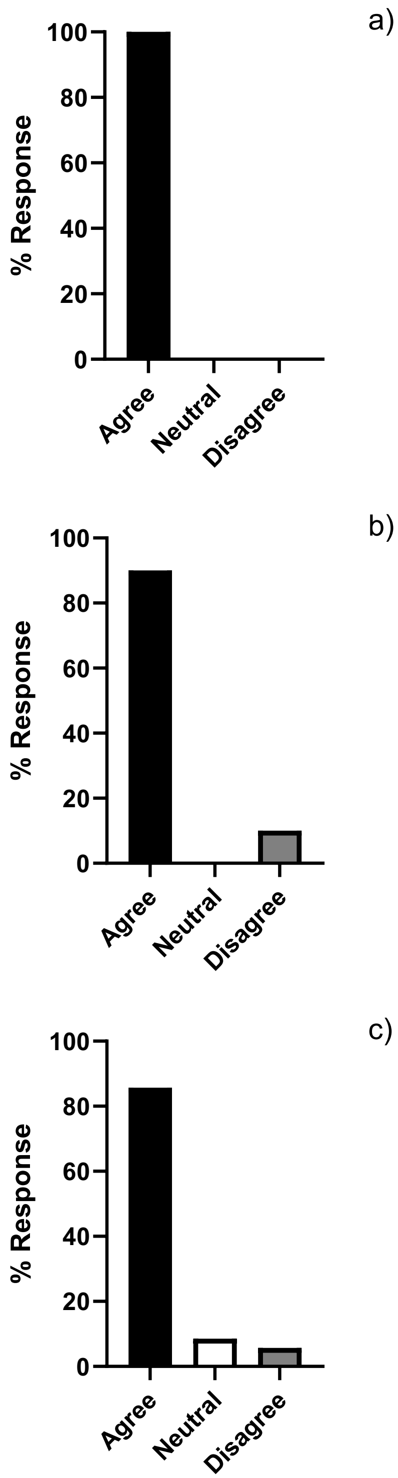


Figure 7. **a) BVI students demonstrate knowledge of laboratory concepts at a level comparable to sighted students. b) BVI students demonstrate knowledge of laboratory skills at a level comparable to sighted students. c) BVI students learn as much as sighted students.**

4.8. Miscellaneous Question

The following question assessed instructors' preparedness to accommodate BVI students in their classrooms. Instructors were asked if they had any training, knowledge, or experience working with BVI students. The results showed that only 10% of the instructors have training, knowledge, or experience working with BVI students, while 90% disagree (Figure 8a). Lastly, instructors were asked if they currently have a modified/ adapted lab textbook or report in brittle for BVI students, 0% of instructors agreed, and 100% disagreed.

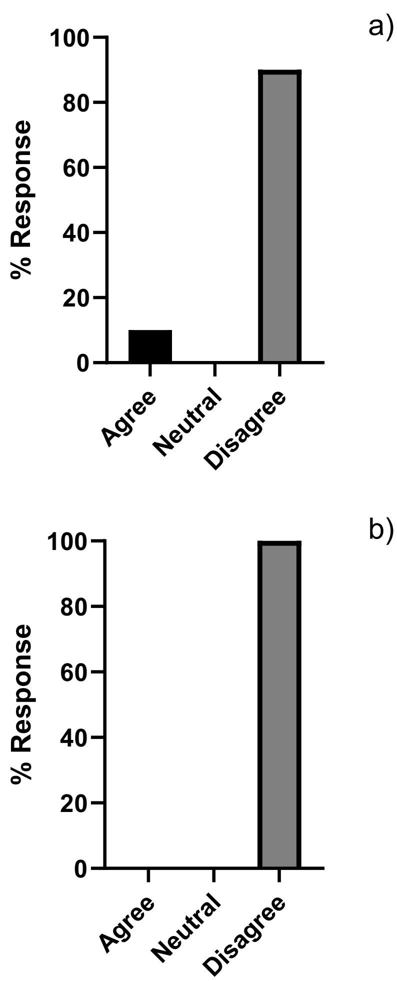


Figure 8. a) Instructor's training, knowledge, or experience working with BVI students. b) Adapted or modified laboratory textbook or report used

Chapter 5. Discussion

This study investigates STEM lab instructors' preparedness and ability to create an inclusive learning environment for blind and visually impaired students. The data will help assess how prepared STEM lab instructors are to have BVI students in their classrooms. This section will analyse the results and the study's limitations and conclusions.

5.1. Criterion One: Active Participation and Safety in Labs.

The survey results show that 86% of stem instructors agree that active participation enhances student learning. In contrast, 68% of instructors disagree that their curriculum will foster vibrant participation within their labs. Active learning is the alternative to instructor-led activities, consisting of short course-related individual or small group activities and responses presenting new information (Felder & Brent, 2009). The active participation learning process demands that the teacher and student spend time and effort on each learning activity. Active learning will foster thinking, responding and checking what the learner knows and does not; as a result, the teacher can make instantons adjustments to assist the student (Pratton & Hales, 1986). Active learning is a process for the learner to reimagine and recreate the concept taught independently or in a group. Active learning involves posing new questions to learners. Students who engage in active learning not only absorb the content of the knowledge but also increase their critical thinking, learn to manage their time, develop interpersonal skills, listening and speaking skills, become better writers, and develop cultural awareness. Student motivation and active participation are linked. Active learning assist student connects new academic concept to an existing academic idea (Peterson, 2001). Active participation integrates students into the workforce. It helps build management, communication skills, cross-sectional functional integration, teamwork and team building, and oral and written communication (Wright et al., 1994).

Concerning the safety of BVI students in the lab, 89% of instructors believe that a BVI student will feel safe in the laboratory. Regarding STEM education for BVI students, safety has always been a significant concern; yet numerous studies have shown that BVI students may safely participate in STEM education. Nepomuceno, Decker, Shaw, Boyes, Tantillo and Wedler (2006) demonstrated that BVI students could safely participate in a chemistry laboratory (Nepomuceno et al., 2016). Various methods were employed in including BVI in a chemistry lab, such as 1. BVI students are the central lead in selecting an assistant; BVI is responsible for interviewing their assistant to ascertain that the assistant meets their needs, is compatible and understands the struggles the BVI student may face.

On the other hand, the assistant is usually not a student in the assigned lab, making it possible for the BVI student to be the sole and only learner within this partnership (Nepomuceno et al., 2016). BVI students and assistants will undergo a series of safety procedures and understand that safety is both parties' first and foremost responsibility (Nepomuceno et al., 2016). Also, suppose safety issues arise that the BVI student is unaware of. In that case, the assistant can take appropriate action to solve the problem and not worry about telling the BVI student what they are doing (Nepomuceno et al., 2016). This approach helps ensure the BVI's student safety and confidence within the lab. The second recommendation was for both assistant and BVI to Before or before starting any laboratory work, study any method and background information toll and create an action plan before starting a lab session (Nepomuceno et al., 2016). The third suggestion is that the BVI student meets with their assistant after the lab to examine data, which is efficient and beneficial (Nepomuceno et al., 2016). Finally, instructors should check new student/assistant pairs regularly to ensure everything is operating well. A document describing acceptable student/assistant working practices for various courses and disabilities should be available (Nepomuceno et al., 2016).

As active participation, presence and achievement is part of student learning; therefore, all students should be part of the learning process (Booth & Ainscow, 2002). The definition of student learning with active participation, presence and achievement focused on the students (Booth & Ainscow, 2002). Studies have shown that active participation and involvement encourage inclusion in a learning environment (Mittler, 2012). Learning alongside others and cooperating in shared learning experiences requires active participation and a say in how education is experienced (Saxton, 2018). It is about being recognised, welcomed, and accepted. As a result, adopting these concepts, particularly inclusive education, which is concerned with all students' participation, involvement, and accomplishment, is essential (Booth & Ainscow, 2002). Studies have shown that by better understanding and reducing the barriers to participation for the most vulnerable groups, education provision improves, and, as a result, everyone benefits (Rieser, 2011).

The disabled body functions within the framework of society, history, the family of origin, and community values, according to critical disability theory (Saxton, 2018). Using CDT, it becomes clear that designing approaches to inclusion must consider this broad context (Saxton, 2018). Numerous historical, cultural, psychological, and logistical impediments intrude into the daily lives of disabled individuals, just as they do in other spheres of exclusion, such as barriers to education and career prospects. Barriers to active participation may appear even more formidable because physical movement reveals the physiological grounds for exclusion (Saxton, 2018). These barriers must be overcome through inventive, creative, and supportive techniques that welcome impaired people to participate, enjoy, thrive, and learn.

5.2. Criterion Two: Student's Engagement

The holy grail of learning is engagement (Sinatra et al., 2015) because of its connection to positive learning outcomes in and out of the classroom (Nussbaum & Sinatra, 2003). Who is involved in their learning experience of advantages, including increased motivation and achievement (Johnson & Sinatra, 2013)? Consistent participation can also contribute to long-term school involvement (Nussbaum & Sinatra, 2003). The increased focus on promoting STEM student engagement has prompted curiosity about its impact on STEM's significant persistence and career choice (Johnson & Sinatra, 2013). Any discipline, task, subject matter, or content area should involve a learning engagement (Sinatra et al., 2015).

There are several features of engagement that are domain specific. All interaction, for example, is likely to contain psychophysiological arousal, which triggers a cognitive, behavioural, or emotional response (Sinatra et al., 2015). Attention, metacognitive awareness, emotions (both positive and negative), and behaviour are some other domain-specific components of engagement (Sinatra et al., 2015). In science, one must be mindful of the motivational and emotional variables influencing how one approaches science information. Many elements, such as epistemic cognition and participation in scientific and engineering processes, misconceptions, topic emotions, attitudes, gender, identity, and disability barrier, affect science engagement differently(Sinatra et al., 2015). The study's result shows that the STEM instructor agrees that the laboratory curriculum and activities can engage BVI students. The result also indicates that instructors disagree that the current structure of their lab activity will engage a blind student. The result from these questions shows the need to continually foster an inclusive learning environment rather than waiting for blind students to attend their labs before trying to include them. Also, the result obtained from this study shows that visually impaired students showed student learning and engagement increased with this learning style (Capovilla et al., 2015).

5.3. Criterion Three: Reasonable Accommodation for BVI Students

A study conducted at Haverford College, Haverford, PA, USA, shows that various strategies were employed to make course administration, class meetings and course material accessible to BVI students. First, this research team recommends assembling an instructional team (Holt et al., 2019). BVI students can access one or more people who function as in-class helpers and outside tutors. The in-class assistant guarantees that all class materials are available to students while acting as a course instructor (Holt et al., 2019). An in-class assistant can explain visual elements in an interactive demonstration, clarify mathematical notation in a complex calculation, or describe images drawn on a chalkboard (Holt et al., 2019). When necessary, the tutor provides accessibility assistance and serves as a course tutor (Holt et al., 2019). Regular meetings for the entire instructional team were held throughout the semester to discuss student progress, exam material, instructional approaches, and accessibility difficulties (Holt et al., 2019). The second strategy; is making class meeting places accessible should choose a room that permits the student and class aide to converse quietly without disturbing the rest of the class. Students should be aware of the classroom arrangement and adaptive technology to facilitate technology usage, and location adjustments should be communicated as far as possible (Holt et al., 2019). The third strategy of preparing accessible course materials ensures that all materials are accessible; representation in audible or tactile formats (Holt et al., 2019). The fourth strategy encourages accessible assignments and exams for blind students.

5.4. Criterion Four: Contribute to Group Activity Equally

The result shows that ninety per cent of instructors agree that BVI students can contribute equally to group learning. The result indicates that BVI students can engage in cooperative learning among their peers. Collective learning is the ability to engage in a group activity (Barbosa et al., 2004). The class is divided into small groups in suitable classrooms to learn tasks or conduct investigations. Instead of simply dispensing material, the instructor in these classes serves as a "learning facilitator or resource." To complete their learning tasks, students rely on and develop their social interactive and cognitive skills; the students exchange information, generate ideas, and participate in active and multilateral communication. Students take on various roles in the learning process. Instead of the passive-receptive technique common in many classrooms, students' behaviour follows a broadly social constructivist approach to learning (Barbosa et al., 2004). The perspective behind cooperative learning is grounded in developmental and motivational theoretical perspectives (Barbosa et al., 2004). The developmental aspect increases learning by causing cognitive conflicts and exposing students to higher-quality thinking. Cooperative learning from a developmental perspective improves the interaction between children around practical tasks, allowing them to regulate essential concepts and skills better. The motivational philosophy emphasises the importance of rewarding groups based on the individual learning of all group members, establishing peer group norms and sanctions, and encouraging achievement-related efforts and active peer aid. It is critical to provide an incentive for group learning efforts to improve learning results (Barbosa et al., 2004). Science education has traditionally used the group for practical exercises and project-based learning work. Small-group discussions should help in science classrooms to assist students in examining their ideas and advancing toward more scientific concepts and explanations, according to one of the recommendations for practice that has come from constructivist research. The development of theories concerning social constructivism provided the impetus for incorporating small group discussions into science classrooms (Barbosa et al., 2004). Cooperative learning has a fundamental value in that they have the potential to open educational environments to a dimension that goes beyond knowledge acquisition by socialising and contextualising that knowledge and discussing the challenges that arise from it. The ability to participate in informed discussion and debate of scientific issues is critical to scientific literacy. Cooperative learning highlights the importance of encouraging small-group discussions in science classes. Therefore, communal creation and cooperation in learning education provide excellent opportunities for social cohesion. The primary purpose is to assist students in becoming whole and active members of society (Barbosa et al., 2004).

5.5. Criterion Five and Six: Demonstrate the Required Skills Taught and Meet Academic Requirements

To assess laboratory skills developed within laboratory courses, (Hunt et al., 2012) insist that assessment design should consist mainly of active participation and learning in the laboratory. Active participation should also involve direct observation of student participation and continuous learning over a prolonged period of weekly laboratory sessions (Hunt et al., 2012). The result obtained from figure 5b and Figures 6a, b, and c show that most instructors agree that BVI students can demonstrate the required laboratory skills and academic requirements if all required accommodations and assistive technology are present. A study assessing the skills needed of BVI students in a chemistry lab showed that the chemistry lab is entirely visual, and BVI students need assistance to obtain accurate data. BVI students using the sense of smell as a chemical indicator is as valid as using other senses, such as eyesight, to make chemical observations. BVI students think about chemistry the same way sighted people believe; the only difference is that BVI may require assistance from readers and lab assistants. Lastly, BVI students imagine chemistry as travelling, the way we imagine the layout of city streets, paths on campus and buildings in mind; this is the same way BVI students imagine and visualise atoms and molecules (Wedler et al., 2014). Demonstrating required science skills for BVI students is not dependent on BVI students but also relies on instructors' preparedness and ability to foster a safe and engaging learning environment and the knowledge of effective assistive technology for BVI students. The result obtained from this study shows that 94% of instructors do not believe that their labs are well equipped to accommodate BVI students. A survey by Kirch et al., 2005, on inclusive science education: a study on classroom teacher and science educator experiences in Creating Laboratory Access for Science Student (CLASS) workshop showed increased success with making science lab accessible to all kinds of students. Instructors who partook in the CLASS workshop reported significant gains in their preparedness to teach science to BVI students. Participants also reported improvements in their familiarity with instructional strategies, curricula, and resources and their ability to design, select, and modify activities for BVI students (Kirch et al., 2005).

5.6. Criterion Seven: Acquire Equivalent Knowledge as Sighted Students

The result from this section shows that most instructors agree that the BVI students can receive commensurate laboratory knowledge compared to their sighted lab mates. A study between BVI and sighted students on learning dynamic complex systems in science showed that BVI students received commensurate equivalent knowledge. BVI and sighted students were pre-tested before engaging in a complex dynamic complex science experiment; the pre-test showed no statistically significant difference between BVI and sighted students. The post-test result obtained the auditory representation computer model supported sighted and blind students in more substantial diffusion learning. However, regarding two central systems concepts: interactions between individuals and uncertainty, blind students learned and applied these concepts earlier and faster when compared to sighted students (Peleg et al., 2016).

Critical theory in this study helps to seek the disparity between the ability and disability of students in science laboratory classrooms. The survey result shows that more than 50% of instructors believe that blind students can participate actively and conduct experiments safely, contribute equally to group activity, and BVI students will be able to meet equivalent academic knowledge as sighted students. The result obtained from the laboratory curriculum structure to include all learners showed that 80% of instructors disagreed. 94% of instructors also believe that their laboratory is not equipped with some or all assistive technology to assist BVI students. According to the Council of Ontario Universities, there are different ways to address the disparity between blind and sighted students. First, identify the physical barrier that may exist in labs that may hinder blind students from participating actively in science labs and creating or provision for a functional space (Sukhai et al., 2014). Available space is "a learning setting in which students can participate in active learning and demonstrate their grasp of the practical components of a discipline through hands-on activities” (Sukhai et al., 2014). Education providers also have a significant role in accommodating students with disability within their classrooms by including students with disabilities in-class activities. Educators should also ensure that alternative teaching and learning approaches are available as well as possible accommodation solutions and canvassing alternative solutions as part of the duty to accommodate and maximise a student's right to privacy (Sukhai et al., 2014).

Implementing a universal learning design has been shown to close the gap between ability and disability. Effective curriculum design is key to providing meaningful access to STEM education to all students, especially those with impairments and unique learning needs. The academic standards and key ideas linked with education, student diversity in the learning environment, flexible instructional methods and data for timely progress monitoring should all be part of the design (Basham & Marino, 2013). UDL in laboratories is especially interested in seeing UDL research focus on specific teaching contexts, such as venues for teaching and learning that are different from the standard classroom instruction. It is not just about providing digital media and minimising dependency on paper when providing alternative representation methods in the lab. Within the multiple interactive dimensions that the lab setting provides to the student, one needs to address accessibility. Applying UDL in this domain is possible but requires a deep, environment-specific reflection.

Limitations of Study

The main limitation of this study was the sample size of instructors and BVI students. The study was open for eight weeks for instructors and students to participate in the survey. Forty-eight instructors were invited to participate in the survey, and twenty-seven instructors completed the study. According to Hill (1998), the sample size for behavioural research such as this study should have more than 30 participants or more than seventy-five percent of the population participating in a study (Hill, 1998). From the response received, only twenty-seven instructors completed the survey, about fifty-six percent of the instructors. Also, instructors who agreed to participate in the study may reflect the most motivated staff due to their worries about providing an accessible classroom. For BVI students contacted through the centre for accessible learning at Simon Fraser University, none responded to the survey. The inability of BVI students to respond to the survey makes it difficult to comprehensively analyze the effectiveness and the usefulness of creating an accessible laboratory classroom for BVI students. Also, the sample size included in this study was only specific to the population at Simon Fraser University. The result obtained from this study would only be specific to Simon Fraser University. The result of the study cannot be extrapolated to the population of lab instructors or BVI students in other post-secondary education in Canada or elsewhere. The survey questions used for this study may have hindered the effectiveness of the study. The structure of the survey question used for this study was a closed-ended Likert-scale format. The design of the survey question may have restricted some instructors from inputting their experience about creating an inclusive lab for BVI students.

The study also failed to differentiate the students' visual function levels. Blind and visually students were categorised as a single group. Visually challenged students may have fewer difficulties assessing scientific laboratories than blind students. Individuals with less functional vision and lower accommodation levels are likely to have different experiences than those with higher capacity and more functional vision. The final constraint of this study was relying on indirect observation rather than direct observation. Instructors speculated on concerns such as whether BVI students will engage actively in their laboratories and if BVI students can meet the exact academic requirements of sighted students. Direct observation, such as tracking students over time to determine if they enrol in and finish a scientific laboratory course while watching their experiences firsthand.

Conclusion

Visually impaired students experience obstacles requiring special preparation for scientific classes and knowledge of relevant adaptive technology. One strategy to address some of the issues surrounding accessible scientific laboratory instruction for blind students in science instructors needs to give more information about disability instructors so that they may provide tailored planning for students who want to attend. Although teaching a student with a visual impairment might be intimidating at first, instructors who are made aware of and purchase or designing of adapted resources and activities have demonstrated an ability to create an inclusive classroom. Instructors should think about their teaching and continually improve their education methods for all students. As a result, schools should invest in all students by supporting adapted materials for individuals with visual impairments; these tactile or electronically enlarged materials should be accessible to all students in the class if appropriate. Students with visual impairments may achieve much more than just finishing their degrees. Students' satisfaction should also be a metric for success in science education. Increasing student success necessitates thinking about making academic and social integration into higher education more accessible for students, overcoming perceived hurdles, and providing modifications that fit their requirements.

To make science more accessible to blind students, instructors should plan time for all activities and create accessible course materials. Instructors should also employ critical assistive technologies and best practices for presenting knowledge in class and ensure that all computer tools are as accessible as feasible. Students gain when instructors clarify topics in a category or employ auditory and tactile assistance, illustrating one of the Universal Design for Learning (UDL) principles. According to research, sighted students value the added tactile and 3D graphical help. The addition of UDL drives the need to consider new methods of communicating science to all audiences.

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