# Creating an Accessible Science Laboratory Environment for Students with Disabilities

Prepared on behalf of the
Council of Ontario Universities by:

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## Project Rationale

Students with disabilities are not well represented in science, technology, engineering and mathematics (STEM) disciplines (Moon, Todd, Morton, and Ivey, 2012; National Science Foundation, 2013; Pence, Workman, and Riecke, 2003). Perceived and actual barriers play a large role in deterring students with disabilities from pursuing careers in the sciences (Hilliard, Dunston, McGlothin, and Duerstock, 2011; Disability Service Provider G). Students are often discouraged from an early age, and also within higher education, from pursuing laboratory-based science programs (Hilliard, Dunston, McGlothin, and Duerstock, 2011; Miner, Nieman, Swanson, and Woods, 2001; Moon et al., 2012).

Obstacles experienced by students with disabilities include:

- lack of mentors in the field;
- inaccessible laboratories;
- negative attitudes of instructors and others in the educational setting;
- a knowledge gap about how to instruct a student with a disability (Burgstahler, 1994); and
- lack of knowledge surrounding how to instruct using computer simulation learning for students who are blind or have low vision (Educator Interview, 2013).

The Disabilities, Opportunities, Internetworking, and Technology, or DO-IT (2011) program, based at the University of Washington, emphasizes that "academic preparation from an early age, self advocacy, universal design of learning and work environments, and acceptance by educators, employers and peers, [are] a recipe for success in STEM for individuals with disabilities." The intent of this report, and the accompanying resources on making science laboratories accessible for persons with disabilities, is therefore to explore effective academic supports that will encourage the participation of students with disabilities in lab-based STEM fields (Street, Koff, Fields, Kuehne, Handlin, Getty, and Parker, 2012).

This report and resources guide will underscore the vital role that faculty play in creating an inclusive laboratory experience. They will also enhance faculty knowledge of inclusive teaching practices, adaptive equipment, accessibility features, and accommodations in science laboratories, which would enable the safe participation of students with disabilities in the sciences.

## Project Scope

This project has been undertaken as a service agreement with the Council of Ontario Universities (COU). The goal of this project was to create a comprehensive background report as well as an educational resource guide that would explain how to make all types of science laboratories accessible for students with disabilities at the undergraduate and graduate levels. These resources will be included in the COU's Educators' Accessibility Resource Kit, a series of tools designed to help Ontario universities create accessible learning environments (available at COU's **Accessible Campus** website). The scope of these resources will be comprehensive and cross-disability, inclusive of a broad range of scientific disciplines, and applicable to teaching and research-training environments for undergraduate and graduate students.

## Research Methodology

Our review of the literature revealed a very limited pool of Canadian research addressing barriers for students with disabilities in the sciences, or best practices for facilitating accessibility in the laboratory environment. The majority of the research and advancements in accommodations for students with disabilities in STEM has taken place in the United States. The impetus seems to be directly related to the *Americans with Disabilities Act*. Additionally, the U.S. National Science Foundation is governed by the *Science and Equal Opportunities Act*, ensuring funding of research and projects in this area. The literature that does exist primarily focuses on students with physical disabilities or low vision in primary and secondary educational system. There is minimal literature on supporting students who possess, for example, psychiatric disabilities, hearing loss and chronic health disabilities in science laboratories.

To ensure a comprehensive environmental scan for this project, we employed a number of methodologies. We began by reviewing our own previously developed resource entitled *Success in STEM: Studying and Pursuing a Science or Technology Career as a Post-Secondary Student with a Disability* (National Educational Association of Disabled Students, 2010), supported with a grant from the Imperial Oil Foundation, to gather pertinent information about students with disabilities in science, technology, engineering, and math fields.

At the beginning of our research, we posted an outreach message asking for resources and contacts on three electronic discussion forums related to disability and education: our own, NEADS-L; the Canadian Association of Disability Service Providers in Post-

Secondary Education (CADSPPE) listserv; and the e-forum of the Association on Higher Education and Disability (AHEAD), an American-based organization. Subsequently, we contacted educational, service provider, and scientific professional associations to identify resources, faculty protocols, and contacts who were willing to be interviewed. Several faculty – identified based on their knowledge and experience with students with disabilities in science laboratories – were contacted for interviews by email or telephone. Furthermore, experts in the field, as identified by the associations and through resources available on the **Science Careers** website, were approached for interviews regarding their own experiences as former students and as scientists. Our interview protocol, which consisted of eight questions, was emailed to the participants, unless they had requested a telephone conversation. Disability service providers working in publicly funded Ontario universities were also interviewed. Follow-up phone calls were made if more details were needed. Throughout this process, we gathered, read, and annotated resources to easily identify common themes and threads.

## Background and Literature Review

Many of the growing STEM-based careers in today's changing economy require at least the completion of a first-year university chemistry course (McDaniel, Wolf, Mahaffy, and Teggins, 1994). Furthermore, science is the basis of an increasing proportion of workforce opportunities (Hilliard et al., 2011). In addition to the science requirements for those pursuing careers in STEM, it is typical of postsecondary institutions to require non-science majors to complete at least one science credit, aimed at educating the non-scientist (Pence, Workman, and Riecke, 2003). As opportunities in technical and medical fields continue to grow, all students – including persons with disabilities – need a strong education in science to achieve their career goals.

Active experiences, where students engage in all aspects of laboratory activities, are critical to success in science-based careers, and students with disabilities are no exception. The under-representation of students with disabilities in STEM can be attributed to limited exposure to the sciences, and a lack of teacher training in inclusive teaching practices (Moon et al., 2012). Exposure to science education contributes to the development of an interest in the sciences. Young people with disabilities who lack exposure to science may never have the opportunity to develop this interest. A lack of teacher training around appropriate accommodations in the sciences, particularly in the laboratory environment, may create barriers for students with disabilities (Moon et al., 2012). This extends to educators at the postsecondary level, who are in a position to foster the development of students with disabilities in lab-based science courses, curricula, and programs of study.

Because of this lack of access to laboratory courses, previous reports have indicated that only 4.3% of postsecondary students with disabilities in the United States chose natural sciences as their fields of study (McDaniel et al., 1994). Canadian demographics in this area are lacking. However, based on a review of the academic and grey literature, the barriers to accessing science are much the same in Canada. While this analysis may initially seem disheartening, it suggests that removing barriers to access could help increase the number of students with disabilities who enroll in these programs of study, and also improve their numbers in science-related careers (Moon et al., 2012).

According to the National Science Foundation (NSF), barriers to success in STEM careers include:

- diminished support systems after secondary (students entering lab-based courses may not be aware of available supports in their university, or the supports simply may not be available);
- lack of awareness of successful role models (students may not be aware that there are, indeed, successful scientists with disabilities from whom they can learn);
- lack of access to technologies (students may not have access to the required assistive technology that would enable them to take part in lab activities);
- poor self-advocacy skills on the part of students;
- inadequate accommodations; and
- low expectations from faculty (Hilliard et al., 2011).

At best, the physical structure of most laboratories is unwelcoming to persons with physical disabilities; at worst, it is inaccessible. Many laboratories are difficult to navigate and visually obstructive. Lab spaces are often encumbered by high workbenches, inaccessible cabinets, and overcrowded fragile equipment (Hilliard et al., 2011). Faucets for sinks, gas hookups, power outlets, fume hoods and biological safety cabinets, eye wash stations, and other safety equipment also pose difficulties, because these areas of the lab are not easily accessible to persons unable to stand.

The STEM literature has not developed a standard design for an accessible science lab in any field (Moon et al., 2012). Also, the literature provides little in the way of examples for accessible laboratory equipment used in the instruction of STEM courses at the postsecondary level (Moon et al., 2012).

One initiative designed to increase opportunities for students with disabilities is the construction of Accessible Biomedical Immersion Laboratory (ABIL) at Purdue

University located in Lafayette, Indiana. The purpose of this project is to enable persons with physical disabilities to access standard laboratory and safety equipment. Modifications to a science laboratory at Purdue University's Discovery Learning Research Centre were made to facilitate scientific research for students with disabilities in a learning lab environment (Hilliard et al., 2011). A similar initiative, the iScience (Integrated Science) laboratory, has been undertaken at McMaster University located in Hamilton, Ontario, in the General Sciences program. This accessible lab opened in September 2013. The iScience laboratory is designed to teach numerous disciplines, including life science, physics, and chemistry. All utilities are in place in an integrated setting, with safety features fully considered. An excellent **YouTube video** on the McMaster program is available.

> "Most university lab settings are designed for able-bodied students with equipment that is not easily transferable to students with disabilities. Recognizing disabilities is also often difficult, and not all staff/teaching assistants are properly trained to handle these students. Students with disabilities often require additional time to complete labs, which is difficult to schedule."
> (Faculty Interview A)

Despite the barriers to accessing science laboratories for students with disabilities, several initiatives have been undertaken to facilitate a positive learning experience for these students. Initiatives include the dissemination of publications and resources on constructing accessible science laboratories and fostering mentorship opportunities. One such program that works to facilitate opportunities for students with disabilities is the DO-IT program at the University of Washington. DO-IT strives to increase the number of persons with disabilities pursuing careers in science. The program provides mentorship through a summer learning opportunity, and is host to an online community of scholars. It also is a hub of online resources for teachers, students, and faculty.

While the STEM literature has focused strongly on the creation of a physically accessible science laboratory environment, it has not discussed other aspects of a campus-wide culture of accessibility, including faculty-student interaction, inclusive teaching practices, content delivery, and mentorship. These other components of a culture of accessibility have a significant impact – as much and perhaps even more than physical accessibility – in defining, a student's ability to participate fully in science labs at the undergraduate and graduate levels. Moreover, a focus on the physical accessibility of the lab addresses the barriers faced by students with physical and sensory disabilities, but tends to exclude the challenges faced by students with "invisible" disabilities, such as mental health, learning or cognitive disabilities.

## Commentary: Application of Best Practices Across Disciplines

An identified need for further research goes beyond describing barriers to science: it provides educators with resources and best practices that address all aspects of the accessibility of a science laboratory.

Most literature on the accommodation of students with disabilities in the science lab setting has focused on chemistry education and/or accommodations at the secondary level. It is worthwhile to note, however, that the concepts of accessibility and universal design are translatable across multiple contexts and disciplines. Anecdotal evidence from students and young scientists with disabilities in various disciplines suggests that the accessibility of the science laboratory environment has a number of common themes. These include the importance of:

- creativity in addressing academic accommodations, particularly with technology adaptations;
- a strong relationship, or "partnership," with faculty – either the course instructor/coordinator or the thesis supervisor;
- a flexible teaching approach; and
- creativity in meeting the essential requirements for a course, program, and discipline.

Specifically, physical accessibility solutions are broadly applicable to wet-lab settings, regardless of discipline. This report will examine the adaptation of lessons from secondary to postsecondary lab environments, as well as the application of best practices from chemistry education to other strongly experimental lab environments.

In the following sections, we discuss the legal requirements of accommodating students in Ontario, strategies for faculty working with students with disabilities in the laboratory, suggestions for accommodating students and inclusive teaching practices, and challenges to the physical set up of a science laboratory. Finally, given the relative rarity of students with disabilities in the laboratory sciences, we also discuss the responsibilities of faculty with respect to mentorship.

## Legal Requirements in Ontario: Overview of Relevant Legislative Frameworks

(See *Glossary of Key Terms*)

The foundations of accommodation and access for persons with disabilities in Ontario are outlined in the *Ontario Human Rights Code* (the Code) and the *Accessibility for Ontarians with Disabilities Act 2005* (AODA), both of which aim for systemic reach and change.

The Code is a “rights-based framework with stronger, but more general procedural and substantive obligations” than the AODA (OHRC, 2009, p. 3). The Code “expects immediate compliance, and has an individual complaints mechanism to help enforce [these obligations]… It gives the Ontario Human Rights Commission (OHRC) a broad mandate… to promote and, if necessary, compel systemic change, including the development of interpretive policies and guidelines as well as powers to encourage education and cooperation… hold inquiries, intervene, or initiate applications. Ideally, though, its enforcement functions should be used as the avenue of last resort” (OHRC, 2009, p. 4).

Enacted in 2005, the AODA requires that all public sector organizations – including postsecondary institutions – make reasonable efforts to insure that services are accessible to persons with disabilities. It sets “prescriptive technical standards and timelines to progressively realize accessibility for a broad range of disabilities and the greatest number of people” (OHRC, 2009, p. 3). These regulations outline requirements to make Ontario fully accessible by 2025. The standards are: Customer Service (understanding the needs of people with disabilities); Employment; Information and Communication (such as websites and print material); Transportation; and the Built Environment (Government of Ontario, 2013).

Compliance with an AODA standard does not guarantee compliance with the Code, which “has legal primacy over all other laws including the AODA” (OHRC, 2009, p. 3). The OHRC (2010) highlighted that “Sections 3 and 38 of the AODA outline the basic parameters of the relationship between [these two frameworks]: if there is any conflict with an AODA standard and another piece of legislation, the provision with the highest level of accessibility shall prevail” (p. 4).

### Role of Education Providers

The OHRC (2004) states that the *education provider* – which includes faculty, lab coordinators, and lab supervisors – is responsible for supporting students with disabilities in the academic environment. These responsibilities encompass:

- “Take steps to include students with disabilities in in-class… activities;
- Accept a student’s request for accommodation in good faith (even when the request does not use any specific formal language), unless there are legitimate reasons for acting otherwise;
- Take an active role in ensuring that alternative approaches and possible accommodation solutions are investigated, and canvass various forms of possible accommodation and alternative solutions as part of the duty to accommodate; and,
- Maximize a student’s right to privacy and confidentiality, including only sharing information regarding the student’s disability with those directly involved in the accommodation process” (p. 33-34).

When a request for accommodation is made directly to faculty, they should “uphold institutional policies and procedures” and refer students through institutional channels, such as disability services offices (Scott and Gregg, 2000, p. 160). However, when the request for accommodation is made through the disability services office, faculty ought to then work to ensure that the appropriate accommodations are in place.

While faculty members have a role in making science laboratories accessible, they are not alone. The institution, disability services office and students with disabilities themselves all have roles in identifying needs and participating in discussions to make the laboratory accessible (**OHRC, 2004**). It is important and beneficial that students develop self-advocacy skills, become more aware of their own needs in diverse environments, and communicate these needs to faculty and disability services staff (DO-IT, 2011).

## Key Role of Faculty

Faculty members play a particularly important role in creating a welcoming and inclusive teaching environment, since “University faculty are on the front line of ensuring that students with disabilities receive a quality post-secondary education” (Zhang, Landmark, Reber, Hsu, Kwok, and Benz, 2010, p. 285). The “willingness [of faculty] to provide reasonable accommodations and related supports to students with disabilities is essential to the success of these students” (Zhang et al., 2010, p. 285). Furthermore, the quality of the services that faculty provide plays a significant role in the ability of these students to complete their higher education (Zhang et al., 2010, p. 285).

Cook, Rumrill, and Tankersley (2009) also note that “the success of any [university] student, particularly in the academic realm, is to some degree determined by the type and quality of interactions” with faculty (p. 84). Faculty members make crucial contributions to the campus climate and the learning environment; therefore, their priorities and behaviours “are important determinants of the quality of higher education for students with disabilities” (Cook et al., 2009, p. 84). Johnston and Doyle (2011) found that students with disabilities felt included, and better able to succeed, when faculty demonstrated an understanding of disability and accommodation, and then implemented inclusive teaching practices.

> “Professors’ acknowledgment and willingness to accommodate a student with disabilities (I feel) can be crucial in a student with disabilities success.” (Student Comment)

When faculty actively engage in using “effective educational practices, students will engage in them and benefit in desired ways” (Kuh, Laird, and Umbach, 2004, p. 30). In particular, faculty need to be flexible, solutions-oriented, and creative in designing tasks, tools, and the laboratory environment, to allow students with disabilities to actively participate in science laboratories (Heidari, 1996; Langley-Turnbaugh, Murphy, and Levine, 2004). As Miner et al. (2001) highlighted, “teaching chemistry to students with disabilities can provide new opportunities for teachers and students to use their creativity in the classroom and the laboratory” (p. 95). For example, Supalo, Mallouk, Rankel, Amorosi, and Graybill (2008) describe many low-cost laboratory adaptations available for students with low vision or who are blind, including tactile adaptive technologies, technological solutions, 3D models with drinking straws, and tactile two-dimensional models.

Moon et al. (2012) indicate that, while these accounts of accommodation solutions “may hold promise, the success of such solutions relies heavily on the personal motivation of individual instructors to meet the accessibility needs of their students” (p. 30). Furthermore, there is as yet no consensus on “a standard design for an accessible lab in any STEM field or at any educational level [and there are] few examples of accessible versions of advanced laboratory equipment…. [Therefore], neither a fully accessible lab nor other off-the-shelf accommodations may be available [to the student]. While this gap poses challenges for STEM instructors, it also represents an opportunity for faculty to develop their own solutions and adapt them to their particular needs” (p. 30-31).

Scott and Gregg (2000) also highlight the importance of faculty in referring students to services, maintaining academic standards, and determining essential requirements (p. 163). Faculty members have the responsibility of working with the student and the disability services office to ensure that the proposed accommodations do not substantially alter academic standards. Roberts (2013) highlights that "curriculum expectations often seem to be grounded in assumptions and decisions about content and delivery of curricula, without consideration for how students with disabilities participate in the course activities" (p. 27). For example, courses that rely heavily on videos for delivery of material do not take into account students with vision or hearing loss. Similarly, courses located in buildings that are not accessible to persons in wheelchairs do not take into account the needs of students with mobility disabilities.

### Essential Requirements

(See *Identifying the Essential Requirements of a Course or Program*)

Thinking about academic requirements more creatively and inclusively is necessary to determine which aspects of the course or program content are "essential requirements" for completion of the curriculum, and which aspects can be accommodated.
The OHRC (2003) states that "once appropriate accommodation is received, students must still be able to perform the essential requirements of the service" (p. 36). Furthermore, "while courts and tribunals have provided little guidance on the nature of essential duties and requirements, terms that have been used include indispensable, vital and very important…. [Thus], a requirement should not lightly be considered to be essential, but should be carefully scrutinized. This includes course requirements and standards. Educators must provide accommodation, up to the point of undue hardship, to enable students to meet these essential requirements" (OHRC, 2003, p. 62).

Rose (2009) highlights the essential requirements of a course or program "include (but are not necessarily limited to) the knowledge and skills that must be acquired or demonstrated in order for a student to successfully meet the learning objectives of that course or program" (p. 10). Oakley, Parsons, and Wideman (2012) stated the factors in identifying or defining essential requirements of a course include a:

1) Skill that must be necessarily demonstrated in order to meet the objectives of a course; and
2) Skill that must be demonstrated in a prescribed manner.

In other words, an essential requirement is an important learning outcome (p. 5).

COU states that “learning outcomes are used to align individual courses with degree level expectations… [and] define what a student should know, and be able to do, after successful completion of an assignment, activity, class, course or program” (p. 7). In order to identify what is an essential course requirement, “several questions can be applied to the requirement that help refine the rationale for its inclusion… [These include]:

- What is being tested?
- What is the nature of the task?
- Does it have to be done in only one way?
- If so, why?” (Roberts, 2013, p. 52)

When looking at whether tasks can be completed in an alternative way, it is necessary to examine whether modifying the way a specific task is completed will compromise the student’s ability to achieve the objective of the task (Roberts, 2013). For example, does a student who is blind need to physically hold the pipette in a chemistry lab, or can a lab assistant be employed to carry out visual tasks in the lab, as directed by the student? “If the objective of the task can be achieved with the use of an accommodation, the method of execution is not an essential requirement for the task” (Roberts, 2013, p. 52). While requirements for testing of course material, lab work, and assignments have been pre-determined, it is necessary to explore whether tasks have to be completed using a specific method to achieve a course objective, or whether alternative ways of completing these tasks can achieve the same objective.

Developing creative examination techniques of the course or program’s essential requirements cannot only serve to encourage evaluation of traditional testing techniques, but also introduce instructors to new methods of testing. For example, Miner et al., (2001) highlight that it is not necessary for all testing needs to be completed in a written form. They explain that “oral tests, presentations, and group work/projects are among a rich assortment of alternative methods to evaluate course understanding” (p. 45).

### Faculty Responsibilities Around Communication and Content Delivery

(See *Ensuring Effective Faculty-Student Interaction*)

While the faculty is knowledgeable about the essential content that must be delivered, and essential skills that must be learned and maintained, it is the staff from the disability service offices at colleges and universities who have information about the impact of a disability on learning. Thus, the interaction of faculty and disability services offices “cannot be partitioned; collaboration and communication between the two groups is vital" (Madaus, 2000, p. 19). It is also important for faculty and students with disabilities to develop a good working relationship with each other, and to keep communicating as the semester progresses; this is especially important in laboratories where different tasks arise throughout the course. The disability services office can help faculty with locating lab and classroom supports, organizing the transcription of materials, and planning for accommodations, but the faculty member will often see the student more frequently, and the student will have the best knowledge about his/her own disability (Miner et al., 2001). Effective communications between these two parties is thus critical.

Students themselves are often the best resources for information about their needs, and accommodations that will help them succeed in the classroom or lab. Therefore, a faculty member's concerns surrounding regarding what is working well and what is not working well in the lab can first be fielded to the student for feedback and suggestions (Miner et al., 2001). Certainly, the disability services office needs to be involved in the accommodation process, but since the faculty member and student have more frequent interaction, concerns can be resolved more quickly if they are addressed as they arise in the lab.

> "It is very helpful to be **shown** how to use the equipment needed for labs rather than just having to rely on written instructions in the manual or on the equipment. Also, it is helpful if instructors/TAs are available during equipment use to answer questions/help solve problems." Comment from a student with a disability (Johnston and Doyle, 2010). [Emphasis added.]

In addition to providing course accommodations, it is important for faculty to be aware of the accommodations that will permit students to participate fully in the lab. A lab assistant can be employed to carry out only those tasks that a student with a disability is physically unable to accomplish (Neely, 2007; Pence et al., 2003). For example, a lab assistant may read out measurements to a student who is blind, or measure and weigh materials (as instructed) for a student with dexterity or mobility challenges. A faculty member can assist in locating a lab assistant by suggesting a student who previously completed the course and who has mastered the required experimental techniques. At the graduate level, lab assistants can also be skilled technicians hired for this specific purpose. Students with disabilities in lab courses may be less experienced than their classmates, and therefore cannot always be relied upon to fill the role of lab assistant after successful completing the course (see *Hiring Lab Assistants for Students with Disabilities*). However, the use of a classmate should not be ruled out, especially since, according to disability service providers, it is the most frequent type of accommodation arrangement.

Faculty members should present potential safety hazards in the lab and suggest options for handling an emergency. This enables the student and lab assistant to establish general procedures with each other, and to determine the circumstances under which the student with a disability may require assistance (for example, if he/she cannot hear a safety alarm). It is also important to confirm a student's understanding of the safety instructions; this may be especially important for students such as those on the Autism Spectrum (Hughes, Milne, McCall, and Pepper, 2010). The student should also be given an opportunity to convey concerns for his/her own safety in the lab (Pence et al., 2003).

Safety and liability concerns should be discussed with the student and disability service provider at the beginning of the term, so that the former has time to become familiar with lab safety procedures. The instructor should prepare for possibilities like the evacuation of students with mobility and sensory disabilities from the building during emergencies (Disability Service Provider F). This is especially important to think about in advance of a course.

It is important to remember that very restricted laboratory use does not preclude a productive scientific career. With the right instruction, mentoring, and accommodations, a student with a disability can be just as successful in the laboratory as any other student. In sum, while accommodating students with disabilities is a legal obligation, what is most important is the spirit of the law: providing a welcoming and inclusive education by ensuring that there is appropriate accommodation and an accessible environment that honours the essential course curriculum.

## Inclusive Teaching Practices and Universal Design

There are two established approaches to making science labs and research environments accessible to students with disabilities: individualized accommodation and universal design. The individual accommodation approach is specific to the student's disability(ies) and course/program requirements. Scott, McGuire, and Shaw (2003) highlight that the needs of students with disabilities in the educational context have generally been met through accommodations. For example, students typically self-identify; provide the appropriate documentation to the disability services office; undergo an assessment of their accommodation needs (for example, sign language interpreter, lab partner, extra time for lab and bell ringer exercises and exams); and then wait for accommodations to be implemented. Personalized accommodations require the student to disclose.

However, many students, particularly those with hidden (learning disability, chronic and mental health) disabilities, may choose not to disclose. Given that increasing numbers of students with apparent and hidden disabilities are entering postsecondary education, there is a need for “new approaches to provide accessible and effective instruction” to this population (Scott, McGuire, and Shaw, 2003, p. 370). From the authors’ experience, if appropriate support systems are not in place, students with apparent and hidden disabilities are more likely to be academically at risk (Pence, et al., 2003). The concept of **universal design** is a global, proactive approach that, when applied to a learning environment, will support a range of student abilities and learning styles. This applies in all learning and professional contexts, including the laboratory environments in STEM fields.

> “Faculty can and do shape student performance by what they themselves value and do” (Kuh, Laird, and Umbach, 2004, p. 24).

Universal Instructional Design (UID) is a pedagogical approach to teaching that considers the needs of a variety of learners. UID stems from the **Principles of Universal Design** (Scott, McGuire, and Embry, 2002). Universal design (UD) is a set of established guidelines to design products and environments to be “usable by all people, to the greatest extent possible, without the need for adaptation or specialized design” (**Center for Universal Design, 1997**). When applied to the educational setting, UID “can be defined as the design of instruction to be usable by all students, without the need for adaptation or specialized design” (Burgstahler, 2011).

The Center for Applied Special Technology (**CAST, 2013**) in the United States, define Universal Design for Learning (UDL) or UID as “a set of principles for curriculum development that gives all individuals equal opportunities to learn. UDL [/UID] provides a blueprint for creating instructional goals, methods, materials, and assessments that work for everyone – not a single, one-size-fits-all solution – but rather flexible approaches that can be customized and adjusted for individual needs.”

UDL/UID is necessary because individuals bring a wide “variety of skills, needs and interests to learning…. [These differences] are as varied and unique as [a person’s genes or] our fingerprints” (CAST, 2013). In this context, students with disabilities fall along a continuum of learner differences, and do not themselves constitute a separate category (CAST, 2003). Thus, the following implications arise from this mode of thought:

- “Curriculum materials should be varied and diverse including digital and online resources, rather than centering on a single textbook.

- Instead of remediating students so that they can learn from a set curriculum, the curriculum should be made flexible to accommodate learner differences.
- Teacher adjustments for learner differences should occur for all students, not just those with disabilities” (CAST, 2003).

McGuire, Scott, and Shaw (2006) observe that “architects and designers implementing UD do not make claims of creating totally inclusive products and environments. They speak of designing products that are accessible to the greatest number of users” (p. 171). Similarly, while UID is meant to cover a range of abilities, “it is important to note that certain students will continue to require specific accommodations according to their individual needs above and beyond what UID can achieve” (Dawson, 2004). In reality, faculty who embrace the practice of UID or inclusive teaching practices allow “students with disabilities [to] have increased access to course participation with fewer special accommodations” (Shaw, 2011). In short, UID may reduce, but not fully eliminate, the need for accommodations (OHRC, 2003; Langley-Turnbaugh, Murphy, and Levine, 2004; Shaw, 2011).

Chickering and Gamson’s (1987) *Seven Principles of Good Practice in Undergraduate Education* has been widely acclaimed, practiced and adapted for use in higher education. The seven principles for active learning complement inclusive teaching methods, in particular the principles of Universal Instructional Design, in considering the needs of diverse learners (Brock University, 2012; Johnston and Doyle, 2011; University of Guelph, 2006). Universal Instructional Design (UID)/Universal design for learning (UDL) is therefore “the **philosophical foundation for inclusive teaching”** (Moon, Utschig, Todd, and Bozzorg, 2011, p. 332). Unfortunately, UID is not widely implemented in most postsecondary institutions. However, the OHRC (2004) indicates that, in order to ensure that students with disabilities have equal access to education, academic facilities, programs, policies, and services must be structured and designed for inclusiveness. To avoid creating barriers, education providers who make design choices have an obligation to be aware of the differences between individual students’ learning needs, as well as the differences that characterize groups of individuals.

Through accommodation and inclusive teaching practices, we know that “when students with disabilities are supported and made equal participants in our courses, they enhance the quality of the classroom experience for us, for themselves, and for their peers” (Johnston and Doyle, 2011, p. 53). In summary, Universal Instructional Design is a “positive approach [and] is more effective because it is accessible and inclusive from the start. Barrier prevention is much more preferable to barrier removal…” (OHRC, 2004, p. 10).

## Universal Instructional Design and Inclusive Teaching Practices in the Laboratory

(See *[Resources on Accessible Content Delivery and Universal Design]* and *[Inclusive Teaching Practices in the Lab Setting]*)

Sheryl Burgstahler (2012), Director of the DO-IT program at the University of Washington, provides a thorough review of the different approaches to universal design in a laboratory setting in her paper *Making Science Labs Accessible to Students with Disabilities.* The author reports that students face challenges to accessing labs, and that barriers in a lab setting can result in a lack of knowledge and participation. The two main approaches for making labs accessible relate to providing specific accommodations (alternative formats, adapted equipment, and modified lab spaces for wheelchair access) and universal design (Burgstahler, 2012).

> "Accessible labs will also permit smoother teaching of concepts, as staff/teaching assistants can teach to a common audience and not have to target specific sub-groups." (Faculty Interview B)

Making accommodations, as required by individual students who have disabilities in science programs, is reactive. Universal design is a proactive approach to addressing most barriers in a lab setting (Hilliard et al., 2011). When applying universal design in the lab, which will benefit all science students, it is necessary to consider different types of disabilities, including blindness/low vision, deafness/hearing loss, mobility disabilities (in particular persons who use wheelchairs or scooters), learning and attention difficulties, and health and mental health disabilities.

> "Universally designed, accessible laboratories promote the inclusion of students with disabilities without adaptations. Many changes can be made to the physical environment, which are unnoticeable to many. Likewise, adaptation such as an adjustable height lab bench accommodates everyone and can have many benefits for persons without disabilities. They are allowed to stand or sit based on the type of work that has been done and can also alleviate repetitive stress." (Faculty Interview C)

Universal design, as applied to the classroom situation, requires educators to teach their courses and design curricula for diverse learners, including those with disabilities. An example of an academic accommodation that benefits persons with disabilities – and at the same time supports the learning of others in the class – is the captioning of video and film presentations in academic course work. Captioning benefits deaf students in particular, but it also is a complimentary learning tool for many other students who are visual and auditory learners, or for whom English is a second language.

Course curricula, delivery methods, and evaluation methodologies should be designed inclusively from the outset. This may require the creative use of technology, such as posting materials online or selecting software that is compatible with screen readers. When online, web-based, or CD-based content is delivered, accessibility issues should be addressed upfront, in the development stage. Other examples include considering accessibility during the design of science laboratories and procurement of laboratory equipment. Indeed, many learning needs of students with disabilities can be accommodated with the creative adaptation of mainstream and off-the-shelf technology or equipment. For example, students with visual disabilities in a biology lab can take advantage of specialized scanners capable of imaging a microscope slide. While this technology is too expensive for teaching labs or individual research labs, it may be available as part of a core microscopy imaging service at the university, a nearby teaching hospital or research institute (see *Selecting Accessible Science Equipment*).

Curry, Cohen, and Lightbody, (2006) argue that “some of the best inquiry-based learning opportunities in science authentically simulate lab and field investigations undertaken by active researchers and scientists” (p. 34). Universal design guides the identification and selection of tools and equipment – including those used to prepare experiments, and gather and visualize data – that ensure participation of almost all learners while minimizing the need for individual accommodations. These tools can incorporate multimodal representations of the information they are designed to deliver, increasing the opportunity for diverse learners to capture accurately the evidence and data collected. These tools can also enable the collection of data in alternative formats or using different methodologies, ensuring the accessibility of experimental results to all students.

Computer-controlled laboratory equipment is one of many examples of universal design tools. Today, a number of laboratory devices, which are required for the majority of experiments in most fields, are computer-controlled, and therefore likely accessible to a diverse group of users. For example, in a chemistry lab, a sensor (or other interface hardware such as a temperature probe) is connected to a computer or handheld device, and specialized software controls the timing of measurements and the recording of data throughout the experiment. Because the data are recorded and displayed digitally, access can be customized for diverse learner needs and preferences.

It is also possible to retrofit traditional assistive technology solutions (for example, a closed circuit television, or CCTV) to serve specific purposes in the lab environment for students with disabilities. One example of this could be to use a CCTV as a dissection platform for animal surgery in a biological sciences lab. It is therefore important for faculty to be aware of available assistive technology resources, and to work with the student and staff from the disability services office on campus to determine the most applicable and creative uses for these technologies (see *Overview of Assistive Technologies*).

## Accommodation and Universal Design in Physical Accessibility of Science Labs

(See *Checklist for Making Science Labs Accessible for Students with Disabilities*)

As indicated earlier, universal design is “the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design” (**Center for Universal Design, 1997**). First implemented in the design of buildings, public spaces, and products, universal design has been hailed as cost-effective, because it seeks one integrated approach to accommodate diverse user characteristics, and addresses the needs of many people without stigmatizing any group.

The physical accessibility of a lab impacts whether students with disabilities are able to succeed. Physical accessibility can pertain to all aspects of the lab environment, specifically in relation to workbenches, sinks, fume hoods, showers, and eyewash stations. The fact that there are best practices in making labs accessible is, in itself, the evidence that supports the requirement to critically assess the physical accessibility of standard laboratory design. Supporting the independence and inclusion of persons with disabilities in the laboratory requires providing a safe, accessible environment with practical assistive solutions (Hilliard et al., 2011). A review of the literature reveals examples of laboratories in Canada (such as the iScience lab at McMaster University) and laboratories in the United States (such as the Accessible Biomedical Immersion Lab, or ABIL, at Purdue University) that have been constructed to accommodate students with physical disabilities (Hilliard et al., 2011).

> “Our teaching lab was recently renovated, and included features to be fully accessible. One of the doors has [power]-assist opening, the benches allow wheelchair access, one of the sinks is at a lower height with paddle-style faucet handles, and we designed a fume hood that can be raised or lowered depending on student requirements. Outside of the lab there’s a fully accessible washroom, an elevator, and the dropbox slots for assignments are at a proper height
>
> “Other design features include accessible light switches, wall phone, white boards, and SMART Board.

> “We also ensured the colour contrast between wall paint colour and door frame paint colour was great enough to meet AODA code for [students with low vision].” (Faculty Interview A)

The construction of ABIL was centred on the necessary architectural features required to perform wet laboratory research. Several modifications to the lab at Purdue University were made to enable students with physical impairments to access equipment with greater ease. The ABIL project itself was initiated by Prof. Brad Duerstock, a scientist with a spinal cord injury who specializes in the fields of neuroscience and assistive technology design. The lab design was based on Duerstock’s personal experience and expertise in the field. Duerstock also founded and leads the Institute for Accessible Science. In the Purdue laboratory, the lab bench, fume hood, and sink were identified as three main tools that students would need to access to perform hands-on scientific research. These tools were placed close to each other to enhance a student’s efficiency in the lab, yet insure that a student had the necessary room to maneuver (Hilliard et al., 2011). A traditional lab bench was replaced with an adjustable version that accommodates researchers with mobility disabilities. To improve access to needed equipment, several commonly used pieces of equipment were placed in close proximity to the adjustable lab bench, including a talking scale for low-vision users, motion-activated biohazards waste containers for researchers with mobility impairments, and an automated paper towel dispenser (Hilliard et al., 2011).

To insure the accessibility and usability of the sink, the counter height was lowered to accommodate students who are seated in wheelchairs or who are short in stature (Hilliard et al., 2011). The faucet neck and handles were placed parallel to one another near the front of the sink (Hilliard et al., 2011). Under the sink was cleared to accommodate wheelchair users.

The example above illustrates that many factors must be taken into account when considering the physical accessibility of a space. To make a space accessible to everyone, it is essential to consider table heights, open spaces for maneuverability, sink heights, table heights, object placement, and other issues. Other elements that can help to increase physical accessibility include mirrors above demonstrations, enlarged screens, lowered controls, electric stirrers, extended eyepieces for microscopes, and modified procedures. As with any accommodations pertaining to disabilities it is best to consult the science student with a disability or the professional scientist with a disability to find out what they need for success in the lab.

> “A 3-D computer simulation of ABIL has also been produced to permit visitation to this accessible lab. First-person ‘players’ can maneuver within the 3-D

simulation from either a standing or wheelchair point of view or with limited field of vision. http://iashub.org/abilvirtualtour

"Assistive Technology (AT) focused on performing lab-based or practical STEM techniques have also been developed by IAS researchers. **AccessScope** is a research-level microscope accessible for persons with upper limb mobility or visual impairments. Through high-speed Internet, it is possible to remotely control AccessScope to permit sharing and independent operation by quadriplegics and those with low vision.

"Research [has] also been conducted to permit persons with disabilities to control scientific instruments and equipment through alternative input methods, including speech recognition and gesture control. These input methods have also been tested to allow persons with upper limb mobility impairments to control robotic arms and mobile robots to perform lab tasks." (Faculty Interview D)

## Mentorship[1]

(See *Faculty Mentoring Students with Disabilities*)

Faculty members play an important mentorship role with students with disabilities taking lab-based science courses and programs. This is particularly true, and much more self-evident, for graduate programs of study, where there is a direct one-on-one relationship between the student and the supervisor, and where the mentorship relationship is formalized to a significant degree. However, even at the undergraduate level, anecdotal evidence suggests that students with disabilities will succeed in the sciences generally, and in lab courses specifically, with faculty who are more willing to be engaged and take an interest in the student's success. Conversely, faculty who appear as indifferent, unsure, discriminatory, or outright hostile will negatively affect the student's success, to the point that the student may simply drop the course or leave the program.

Students with disabilities will not often explicitly seek formal mentors at the undergraduate level. Given the relative dearth of role models for these students in the sciences, little thought is expended by the student on mentorship opportunities. If a faculty member demonstrates a willingness to engage with the student and an interest in their professional development, an informal mentorship relationship may take root. In these relationships, students are interested in:

[1] This section, and the attendant resource guide, was compiled based upon the cumulative trainee, teaching, and mentorship experiences in STEM of one of the authors.

- identifying a faculty member who is open-minded about the inclusion of disability in the sciences, and who demonstrates this open-mindedness in his/her interaction with the student;
- a champion or advocate who is able to help students navigate the discipline and laboratory setting, as well as interact with the academic environment, in a way that staff from the disability services office may not be able to;
- a faculty member who demonstrates creativity and willingness to critically think about the interface between disability and the lab-based environment; and
- a faculty member who is relatable, approachable, and responsive to student interaction.

It is worthwhile noting that a student who has identified a faculty member as a potential mentor is likely to allow the relationship to develop naturally, without actively seeking its formalization. In many instances, it may be up to the faculty member to recognize that a mentorship relationship is evolving, and to act accordingly. There is also the possibility that a student may gravitate toward a faculty member with whom he or she has had some prior interaction, but who currently is not involved in the student's courses.

At the graduate level, because of the importance of the graduate thesis supervisor and the relationships between the student, supervisor, and thesis advisory committee members, mentorship relationships are likely to evolve naturally. In this context, students with disabilities may not be fully aware of the differences between undergraduate and graduate training (for example, course-based vs. research and one-on-one/small group interaction), and may approach these relationships as they would have in undergraduate settings. Proper education of the student about the central importance of mentorship to graduate education in the sciences is then necessary. Regardless, graduate students with disabilities will continue to look for the same characteristics in a good mentor as they did at the undergraduate level.

Finally, several qualities of a good faculty mentor are worth highlighting, particularly regarding mentorship of students with disabilities. These include:

- **Being proactive:** Faculty members should be willing to reach out to and engage with the student on his/her own terms, as opposed to the student waiting for a crisis to initiate interaction.
- **Being responsive:** Mentors must respond to student engagement in a timely manner.
- **Being open-minded:** Faculty members should demonstrate an inclusive mindset regarding the involvement of students with disabilities in the sciences and science labs.

- **Being creative:** Those mentors who think creatively about issues faced by their students in the context of their disability, are more willing to think critically about adapting the essential requirements of the program to the student for his/her success.

The profiles of young scientists with disabilities contained on the **Science Careers** and **NEADS** websites speak strongly to the importance of the partnership between the student and faculty member at the graduate level and, by extension, in course-based situations.

## Summary and Conclusions

We have reviewed the elements of enhancing the accessibility of science labs in undergraduate and graduate education, irrespective of discipline. We have discussed the legal obligations incumbent upon faculty and institutions, highlighted the importance of creatively and critically examining the essential requirements of a program, and focused on four elements of improving accessibility of science labs:

- faculty responsibility around communication and student engagement
- accessible content delivery and inclusive teaching practices
- physical accessibility and adaptive equipment
- mentorship

All of these elements, taken together, serve to enhance the accessibility of the science lab environment and contribute to a culture of accessibility on campus and in science, technology, engineering, and math (STEM) disciplines. While it is easy to focus solely on the physical accessibility component, it is merely one facet of the overall picture. The resource guides and tools included here cover these elements in greater detail, and offer practical and implementable ideas for faculty to consider when working with students with disabilities in science labs. By addressing these challenges, we can ensure a future diverse workforce qualified to become leaders in the scientific community.

> “I believe the creation of more accessible laboratories can only help promote the full inclusion of people with disabilities in STEM. If we create accessible spaces it allows people with disabilities to participate fully in the experiences. It allows their talents and abilities to be the focus[,] not their disability.”
> (Faculty Interview E)

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