Creating Disability-Friendly and Inclusive Accessible Spaces in Higher Education

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WHY UNIVERSAL DESIGN FOR LEARNING?

For the first time in history, we have the power to include everyone.

– David Berman (2022)

Steven Wright's book *Harold* (2023) takes place entirely within the imagination of a 7-year-old boy on a single school day. In the story, Harold, the protagonist, is scolded by his teacher to pay attention. However, Harold responds under his breath: "I am paying attention, to the thought I am having, and not the thought you want me to pay attention to." This is independent thought at its finest. As people who work at the intersection of education and industry, we are often asking science, technology, engineering, and mathematics (STEM) educators and employers what they are looking for in the future workforce. Oftentimes, we hear curiosity, independent thought, creativity, problem-solving, and imagination. Though this is what they desire, unfortunately, there is a disconnect between how we structure education and skills: what are we asking for and what do we need? Education is where we are learning a set body of knowledge, and skills is the specific sequence and way we are asking for it. Our education systems still define learning too narrowly and emphasize conforming to the instruction of a specific set of knowledge and skills. Human difference is considered a hinderance rather than an asset. It is important to remember that difference is part of the rich tapestry of human experience, and we should and must embrace it.[1]

Defining expectations for what, how, and when to learn too narrowly contributes to the elimination of differences and the social construction of disadvantage. This is where people with

[1] The authors have chosen to use person-first (person with a disability) and identity-first (disabled person) language interchangeably to reflect the varying perspectives on language from professionals and members of the disability community (Callahan, 2018).

disabilities/disabled people or those with unique abilities are viewed as incapable or inferior in intellect or their capacity to learn or work. Discrimination affecting how well people with disabilities/disabled people can enjoy their civil rights may be based as much on other people's perceptions, myths, and stereotypes as on the existence of any actual functional limitations in the individual (OHRC, 2016). The social construction of disability is also acknowledged in civil rights legislation such as the Americans with Disabilities Act (ADA) of 1990 (P.L. 101-336), which defines disability not just in terms of having an impairment that limits one or more of life's major activities but also as having a history or record of such an impairment or being perceived by others as having such an impairment (U.S. Department of Justice, 2020).

Socially constructed disadvantage is enacted through customs and policies that favor inclusion for one group at the exclusion of others. For people with disabilities/disabled people, such customs and policies are known as *ableism* when they favor the needs, preferences, and interests of so-called able-bodied people (or when they rest on the belief that being able-bodied/minded is a preferred way of living that is better than others). The flip side of ableism is *disablism*,[2] which is discrimination against people with disabilities/disabled people (DUSC, 2022). In both cases, discrimination and its consequences in denying equitable opportunities for people with disabilities/disabled people is the root problem.

If the social construction disadvantage seems like an abstract concept, consider the experience of approximately 10 percent of the world's population who are left-handed. For much of history, left-handedness was seen as a significant disability, one in dire need of remediation. One of this paper's authors experienced traumatizing corporal punishment and humiliation for

[2] There are two spelling conventions "disablism" and "disableism" that are used by various scholars, with both referring to discrimination against or exclusion of people with disabilities. In this publication, we defer to the author's selected preference of the term *disablism*.

using her left hand as a 5-year-old. While the effort to remediate failed, the trauma of that experience was felt in subsequent learning environments for many years. Today, some terms are still in use that reminds us of how we marginalized left-handed individuals—*gauche*, the word for *left* in French, is used to mean inappropriate or awkward. The simple yet revolutionary invention of the ballpoint pen, which replaced the quill and ink pot as the means of writing, changed how left-handed people looked as writers. No longer did a left-handed person (in Romance languages, where writing moves across the page from left to right) smudge as they wrote, leaving their hands ink stained and their writing illegible. Design denied left-handed people the ability to write, and then a change in design enabled them to write, deconstructing the particular disadvantage of being left-handed. The flaw was always in the design, not in the ability to write of the left-handed person.

As noted by Dr. Caroline Solomon (Caudel et al., 2023) the disability community itself challenges the social construction of disadvantage by reframing disability as an asset rather than a deficit. An example of this reframing is the term *Deaf Gain*, which members of the Deaf community have coined in opposition to "hearing loss" (Bauman and Murray, 2014). Deaf Gain challenges the notion that language has to be synonymous with speech but can instead be just as easily signed as spoken. Deaf individuals who communicate through sign language can develop a range of visual-tactile processing acuities that, along with their lived experience, can provide insights in practices ranging from architecture to bilingual education. As the performance artist Aaron Williamson has noted, what if instead of telling him he was losing his hearing, his doctors had told him he was "gaining his deafness"? (Bauman and Murray, 2014).

Universal Design for Learning (UDL) centers human difference. Whether it is left-handedness or a learning difference, difference is considered an asset that can be leveraged to improve designs by incorporating a variety of perspectives and insights that drive innovation. Microsoft, in its Inclusive Design Toolkit, refers to it as "learning from diversity" (Microsoft, n.d.), where including more people in the design process and widening the talent pool is key to addressing important societal challenges, so-called wicked problems. For example, as our society moves to quickly adopt artificial intelligence (AI) and machine learning in ways that affect all areas of our lives, there is both potential for greater inclusion or exclusion depending on the way the AI is designed and implemented. Including people with disabilities/disabled people and those with other differences in the design of the AI may help safeguard against the negative effects of bias in AI, which is essential if we are to build an AI-driven future that is equitable for everyone in society. Moreover, many technologies we take for granted today, from captioning to audiobooks and text translated into speech, were created because of the lived experience of people with disabilities/disabled people (Ovide, 2021). Throughout history, examples abound of the "curb-cut effect" in action, which states that when we design for people with disabilities/disabled people, we make things better for everyone in the process (Blackwell, 2017). For example, curb cuts on sidewalks made it easier for people pushing strollers, the elderly with walkers, or those rolling a bag behind them.

UDL starts with accessibility as a foundational component of inclusively designed learning environments and experiences. However, it recognizes that accessibility by itself is "essential but not sufficient." Truly inclusive learning also must consider the affective dimensions of learning that drive learners to want to learn and remain invested in it as a lifelong pursuit, and the social dimensions of learning that balance demands and resources to ensure each individual can find the optimal level of challenge and support to do their best learning.

UNIVERSAL DESIGN FOR LEARNING OVERVIEW

Universal Design for Learning (Rose and Meyer, 2002) is an evidence-based framework drawing from the learning sciences and research-based instructional methods to design for the widest range of learners from the outset. Aligned with universal design in architecture and product development, which aims to make spaces, tools, and information more accessible to individuals with disabilities/disabled people (CEUD, n.d.), the UDL framework offers concrete approaches for designing learning environments and learning experiences that are flexible, customizable, and accessible to all learners (Rose and Meyer, 2002; Meyer et al., 2014; CAST, 2018).

Repeatedly, the greatest insights have come from making learning work for those in the margins and then moving those approaches to the middle (Meyer and Rose, 2005). Most education systems are designed with the opposite approach—design for the middle (the mythical average) and hope you can reach some of the margins. UDL from the outset was a way to act on the insight that the barrier to including students with disabilities/disabled people in the classroom was in how we designed our curriculum and our learning environment, not in the learners themselves. The curriculum, that is, the goals, materials, methods, and assessments, were broken, not the child (Meyer et al., 2014). The UDL framework provides a way for reducing barriers and designing for variability.

UDL is grounded in three core principles:

- Using **multiple methods for engaging** students in learning that celebrate diverse neurology, culture, personal relevance, subjectivity, background knowledge, and more (the “why” of learning)

- Using **multiple methods for representing information**, catering to differences in how learners absorb and process information (the “what” of learning)
- Using **multiple means of action and expression** that allow learners to best express what they know based on personal preference and talent (the “how” of learning; Rose and Meyer, 2002; Meyer et al., 2014, CAST, 2018)

Starting with accessible, barrier-free learning methods and materials as a foundation, UDL applies intentional design to create the conditions for learners to develop their own learning expertise. This concept, expert learning—or the mastery of learning itself—is viewed as an essential skill for lifelong learning, both for educators and learners (CAST, 2011, 2018).

While UDL emerged from a focus on groups of learners—historically those with disabilities who were not well served by one-size-fits-all approaches to education—the UDL framework has repeatedly shown that systematically planning and designing for variability in how people perceive information, demonstrate understanding, and are engaged can create practices that are more effective for everyone (Meyer et al., 2014). This includes practitioners and staff, since learning is a lifelong process that does not stop with formal schooling but is a requirement for keeping up with change in the workplace, including technological innovations.

The UDL Guidelines (CAST, 2011, 2018) have a foundation that includes more than 800 peer-reviewed research articles, providing benchmarks that guide educators in the development and implementation of curriculum (the learning goals, materials and technologies, methods and assessments used to help learners develop knowledge, skills, and abilities). These guidelines provide a tool for evaluating the curriculum to ensure it does not present barriers to learners. The UDL Guidelines, which CAST developed and maintains, undergo revisions with input from the broader UDL practitioner community to make sure they keep up with the latest developments in neuroscience, public policy, learning technologies, and the sociocultural context in which education and learning take place. Rather than being a static document, the UDL Guidelines are regularly updated to reflect the changes both in how we understand learning and in the contexts that enable it. Currently, the UDL Guidelines are being updated to more explicitly address the role of identity and culture in learning. This update, also known as "Guidelines 3.0" is being informed by a broadened and robust research base coupled with extensive community engagement. This will set a new foundation that unflinchingly addresses gaps and leads to significant learning opportunities for all students. These efforts are being facilitated by CAST with extensive input from an advisory board of experts and practitioners whose work focuses on educational equity (bit.ly/CASTGuidelines3).

UDL IN HIGHER EDUCATION

First defined in the Higher Education Opportunity Act of 2008 (P.L. 110-315), today, UDL is specifically referenced in all federal legislation that governs education and training (CAST, n.d.). It is either recommended or required as a framework schools and higher education institutions should use for designing learning environments that allow all learners to meet high standards, including students with disabilities/disabled students, English learners, and other underserved populations. UDL is called out as a recommended practice in both Department of Education and Department of Labor legislation and in programs in career and technical education, universities and community colleges, and apprenticeships.

While UDL has been used across the K–12 education system for two decades to reduce barriers in the learning environment, UDL adoption has rapidly increased in higher education for three reasons. First, there are more than 500 centers for teaching and learning at higher education institutions in the United States (Wright, n.d.). While many began as ways to help faculty use technology, the focus has shifted to helping faculty learn to teach, and where applicable, bring technology in to support effective teaching. Where subject-matter expertise used to be the expectation of faculty, that is no longer sufficient to ensure student learning and persistence as higher education institutions have diversified in terms of who attends, how they participate, and what they are there to accomplish. Second, while learning technologies have become ubiquitous across higher education, they now have the power to include everyone (Berman, 2022) or, when ineffectively used, exclude even more people. Third, many institutions have made commitments to diversity, equity, inclusion, and accessibility and need a means to follow through on that commitment in the classroom and other learning environments.

In the last several years, multiple books have been published on the use of UDL in higher education classrooms with case stories written by faculty and other higher education stakeholders on the implementation of UDL (Beck et al., 2014; Bracken and Novak, 2019; Fovet, 2021; Laist et al., 2022). Additionally, multiple higher education institutions and education organizations have invested in capacity building and created resources on the implementation of UDL in higher education classrooms, including work funded by the National Science Foundation (NSF). For example, case studies of UDL in higher education were funded and produced by the NSF Advanced Technological Education (ATE) program through the AccessATE project[3] and results published of an NSF-funded educator professional development conference that trained biology educators and American Sign Language (ASL) interpreters on UDL to increase access to STEM technician roles for deaf and hard-of-hearing students (Orndorf et al., 2022).

[3] For information on the ATE program, see https://new.nsf.gov/funding/opportunities/advanced-technological-education-ate; for information on the AccessATE project, see https://accessate.org/about.

UDL Theory and Practice provides an evidence-based and well-established road map for unifying advancement in diversity, equity, and inclusion of learning technology adoption, and the science of teaching and learning. “UDL depends upon advances in two domains: modern learning sciences and modern learning technologies. From the learning sciences—cognitive neuroscience, affective neuroscience, cognitive science, educational sciences—UDL draws upon research that articulates the consequential differences between learners, differences that must be addressed for a learning technology to be successful for the full spectrum of learners. From modern learning technologies—such as interactive multimedia and networked learning environments—UDL takes advantage of the enormous capacity for personalization and adaptivity that these new technologies offer but that is usually insufficiently realized” (Rappolt-Schlichtmann et al., n.d.).

Research on UDL in higher education has demonstrated that it enhances learning for all students, including students with disabilities/disabled students who are majoring in STEM (Izzo and Bauer, 2013). UDL application in higher education can improve the learner experience for performance, engagement, satisfaction, social presence, learning stress, and learning flexibility (Davies et al., 2013; Hall et al., 2015; He, 2014; Kumar and Wideman, 2014). When UDL-oriented curriculum is coupled with accessible technology such as text-to-speech software, media-rich experiences that incorporate visuals and video, and flexible technology-based assessment systems, there is better support for both teaching and learning (Basham et al., 2010; Dalton et al., 2011; Marino et al., 2014). Training upper-class students as tutors in UDL has significantly increased course pass rates in gateway STEM courses (ECU, 2017). Beyond higher education institutions, UDL is being utilized in and is recommended for use within pre-apprenticeship and apprenticeship programs for job seekers often marginalized in traditional school systems (SPR, 2020; Emerick and Marshall, 2017). A recent meta-analysis of experimental studies in UDL-based interventions across age and grade level found a moderate positive effect on learner achievement because of a UDL intervention compared to controls (King-Sears et al., 2023).

Perhaps the most exciting development with UDL becoming more prominent in higher education, is that it is helping to make possible new ways of thinking about intelligence: as reliant on differences and the distribution of intelligence across people and technologies all doing different things yet working across these differences in a deliberate and coordinated way to make meaning, to solve challenging problems, and to understand things in new ways (Fischer, 2006). UDL helps us to see that learning environments designed optimally for all learners are ones where everyone can learn from and with one another. Universally designed learning environments allow for distributed rather than individual intelligence to produce new skills and knowledge and advance our understanding.

This call for framing intelligence as distributed across people who learn from one another and with technology is not new. Communities of practice (Lave, 1991; Wenger, 1998) have as their hallmark the mixture of individual and collective learning to advance knowledge and skills. The community shares an intention, knowledge, skills, practices, and a commitment to one another to move learning forward in a specific domain (Wenger et al., 2011). Gerhard Fischer (2006) in his work on distributed intelligence and social creativity describes how “the construction of shared understanding requires the interaction and synthesis of several separate knowledge systems.” Fischer describes Campbell’s fish-scale model to illustrate that even disciplinary competence is a result of “collective achievement made possible by the overlap of narrow specialties.” Campbell’s analogy is that each narrow specialty is a fish scale that must know how to overlap with other fish scales' narrow specialties to achieve a comprehensive discipline, or, to fully cover the fish.

Framing intelligence as distributed rather than residing in the individual requires us to attend to and support differences in knowledge and skills, rather than similarities. Individuals who are dissimilar in ways learn to rely on one another because of those differences rather than avoid one another. In the same way we leave certain tasks to technology when a task is better done by technology, such as providing directions in the car, a view of intelligence as distributed allows for people to know and do different things. If we leaned into distributed intelligence, the world of education would better mirror the STEM workforce.

In the medical field, the primary care provider addresses heart disease prevention, the cardiologist monitors to ensure only necessary treatment is provided for those who require it, and the surgeon operates on heart disease in a small subset of cases when there is nothing else that can be done. Yet, this metaphor only deals with distributed intelligence once common skills and knowledge have already been developed (i.e., all these people have learned to be doctors). What if we considered a distributed intelligence model across our education system and wherever learning takes place? Would we not then be more likely to prevent heart disease because we would more readily have provided options for understanding heart disease and its causes? The person who loves to dig into the facts might receive a comprehensive pamphlet or a scientific paper, while the person who needs just-in-time information because they struggle with working memory might receive daily tips as needed. In both cases, the goal of helping people understand and adopt behaviors to prevent heart disease would be accomplished. Could attention to human differences lead to more people being able to know and do more things?

One important reason to dismantle ableism in STEM education and the workforce is that the tendency in diversity, equity, and inclusion efforts when we do not center ableism is to "cherry pick" those persons with disabilities/disabled people who can be most "remediated to normal," or whose perceived deficits are tolerable by "normal" people. Yet, if we really acknowledge how much we need different types of intelligence, including the intelligence developed through lived experience, and bring that into our education systems and workforce at all levels, we will both view and solve problems differently. Consider that only 2 percent of people classified as having an intellectual disability participate in higher education (Grigal, 2018), and while most students with disabilities/disabled students are included in K–12 general education—the pipeline into higher education—only 20 percent of students classified as having an intellectual disability are included in general education (NCES, 2023), and then when they are it is rarely to participate in STEM classes.

ACCESSIBILITY AND UDL: ESSENTIAL FOR SOME, HELPFUL FOR ALL

Accessibility means that a person with a disability can acquire the same information, engage in the same interactions, and enjoy the same services as a person without a disability in an equally effective and integrated manner, with substantially equivalent ease of use (U.S. Departments of Justice and Education, 2020). This definition comes from a Dear Colleague Letter the U.S. Departments of Justice and Education issued to college and university presidents in 2010 in response to a complaint related to the use of inaccessible e-book readers. The letter clarified that the use of inaccessible technology constitutes discrimination that is prohibited under civil rights legislation such as the ADA and Section 504 of the Rehabilitation Act of 1973 (P.L. 93-112; U.S. Departments of Justice and Education, 2020). In practice, the "equally effective” part of the definition has been interpreted to mean that students with disabilities/disabled students have access to the information they need for learning at the same time as their peers who do not have disabilities, so that they do not fall behind and continue to make progress in their education.

Accessibility is foundational to the UDL framework and is part of UDL’s origin story. Starting with their work with students with significant disabilities, researchers at CAST soon realized that the flexibility they were building into their technologies and materials could benefit all learners when made more widely available. Today, accessibility is explicitly called out as one of the layers of the UDL Guidelines. Horizontally, the guidelines are organized into three rows. The “access” row includes the guidelines that suggest ways to increase access to the learning goal by recruiting interest and by offering accessible options for perception and physical action. The “build” row includes the guidelines that suggest ways to develop effort and persistence, improve understanding of language and symbols, and support expression and communication. Finally, the “internalize” row includes the guidelines that suggest ways to empower learners through self-regulation, comprehension, and executive function (CAST, 2011, 2018). Together, these guidelines are meant to eliminate unnecessary barriers in the learning environment without eliminating the necessary challenges that are a part of all learning. UDL goes deeper than merely focusing on access to the learning environment, but focuses on access to all aspects of learning. This is an important distinction between UDL and a pure access orientation (CAST, 2011).

Following accessibility best practices and adopting accessible technologies to deliver content enables multiple means of representation and widens who can access the learning and work environment. With this access as an entry point to learning, the principles of UDL then support learners in taking ownership of their own learning and customizing the learning environment to suit their individual needs and preferences. The goal with UDL is to develop expert learners who know themselves well and possess three characteristics: they are purposeful and motivated, resourceful and knowledgeable, and strategic and goal directed (CAST, 2011, 2018). Key to being an expert learner is being able to self-advocate and effectively communicate what a learner or employee needs to do their best work and make a meaningful contribution. This skill becomes increasingly important as individuals move through their lifespan and into more self-directed environments such as higher education and the workplace. In advocating for themselves, individuals who use accessibility support also promote a culture of accessibility by helping to make documents and websites more usable and accessible for everyone.

As the world of education and work continues to evolve based on the impact of the COVID-19 pandemic, the need to consider accessibility and other inclusive practices will only grow. The new landscape of work has accelerated the adoption of software, digital materials, and remote communication systems in the workplace and ramped up business conducted by employees working at a distance and customer service delivered virtually. Today, the use of digital technology and materials for communication, collaboration, and general delivery of business is common throughout education and the workplace. This has made accessibility critical to ensuring reasonable accommodations. Higher education institutions and employers are required to ensure that the materials and technologies they use for communication, training, and within classrooms and employment are accessible if they are to meet the requirements of legal mandates such as the Americans with Disabilities Act.

To assist institutions of higher education and workforce development agencies in developing their accessibility infrastructure, the National Center on Accessible Educational

Materials at CAST (AEM Center) has developed seven Quality Indicators for implementing a systemwide initiative that addresses the components that need to be considered:

1. Coordination across departments and units
2. Clear definition and commitment to timely manner in the provision of accessible materials and technologies to all learners who need them
3. Written guidelines that are communicated in multiple ways and broadly disseminated to ensure sustainability of processes and procedures over time
4. Professional development and technical assistance to build capacity
5. Systematic data collection to evaluate the equitable and timely provision of accessible materials and technologies
6. The use of this data to drive continuous improvement cycles
7. Appropriate allocation of resources, including fiscal, human, and infrastructure resources

The National AEM Center website (aem.cast.org) has additional information about the Quality Indicators and their Critical Components (which make the indicators even more tailored to a higher education and workforce development audience). The website includes a study guide that provides information for taking actionable steps toward addressing each indicator. It is also important to consider other aspects of instruction, not just the materials and technologies. The AEM Quality Indicators simply provide a model for the collaboration and shared decision-making that is needed to create more accessible learning environments.

UDL AND ACCOMMODATIONS: PARTNERS IN INCLUSION

With both accessibility and UDL the goal is to address barriers proactively by considering them as early as possible in the design process in order to avoid costly and sometimes impossible retrofits. However, this does not mean that adjustments cannot be made after a design is implemented with learners to address changes in the learning context. With UDL doing the heavy lifting to address the variability we know from neuroscience is present in every population, accommodations can then be more targeted. The two approaches, accommodations, and flexible design through the application of UDL principles, are not exclusive of each other.

A UDL-first approach is needed to address some of the limitations of accommodation as experienced by one of the authors of this paper:

- Accommodations are easier to implement in more traditionally structured courses, which have a predictable structure that works well with the coordination that is required to provide accommodation in a timely manner (e.g., lecture-based class with a midterm and final exam where extra time or a separate setting can be easily provided). Accommodation may be less effective in advanced courses where students are pursuing more independent study or research opportunities that do not follow a traditional schedule. Yet these courses are the ones that are required for students to be able to pursue advanced degrees and other career opportunities.
- Accommodations that are targeted at the classroom do not reach into other aspects of the educational experience that are required to support learning in higher education, such as library services and both teaching and research labs. For these spaces to be more inclusive, attention to purchasing and procurement needs to be proactively considered to ensure tools (such as lab equipment, research databases, etc.) are

accessible from the start to learners who need them. The same challenge may arise in the workplace when only the accessibility of public spaces is considered, ignoring the needs of employees to have access to other spaces such as research labs, virtual meeting platforms and the like.

- Accommodations place much of the burden on students, career seekers, and employees who must self-identify as a person with a disability/disabled person and make an official request to have their accessibility needs met. For a variety of reasons, this approach may not meet the needs of everyone who needs accessibility support: individuals may not yet have a diagnosis of a disability but may still be experiencing challenges with their learning and employment, or they may have had a negative experience with accommodations in K–12 and are thus reluctant to make a request out of fear for the stigma they expect to follow the use of accommodations. The process for receiving accommodations is significantly different in K–12 and postsecondary and workplace settings. Whereas in K–12, students may have an Individualized Education Program, or IEP, or a Section 504 plan outlining their accommodations as determined by an entire team of professionals, in postsecondary and workplace settings the student, career seeker, or employee must self-advocate for their needed accommodations. Not all students develop these self-advocacy skills prior to making the transition from K–12 education into other settings.

An example of UDL and accommodations used together to increase access and promote inclusion is captioning used along with ASL. Captions are the digital equivalent of the curb cuts we see on many street corners. They were designed for one group of people (individuals who are deaf or hard of hearing) but have benefits for many others, including those learning a new language or a new subject with unfamiliar vocabulary. Captions are also helpful when environmental constraints make it impossible to hear the audio (such as in a loud restaurant or airport). As helpful as captioning can be, it does not fully capture the nuances of American Sign Language that are only possible through ASL interpreting, such as the embodied nature of ASL as its own language that uses gestures and facial expressions. Both captioning (a universal design solution) and ASL interpreting (an accommodation) are often necessary to provide a fully accessible experience to a learner, career seeker, or employee who is deaf or hard of hearing.

UDL IN THE CLASSROOM AND BEYOND

Creating more inclusive learning environments in STEM fields requires a holistic approach that considers the different settings involved in the preparation of professionals in these fields. That includes not just the work that happens in the classroom (whether in person or in virtual settings) but also the design of lab-based and fieldwork experiences. It also includes the work of preparing future researchers to contribute their lived experiences as well as their expertise to the field in ways that open the doors to greater representation and diversity in STEM research activities.

In this section, we describe practical tips we have co-designed with panelists of the Disrupting Ableism and Advancing STEM workshop series. Much more has been written about the application of UDL in classroom settings. Rather than repeating much of that content here, we refer readers to the Course Design section of the UDL on Campus website (udloncampus.cast.org). This paper focuses on the components that have received less attention in the literature: research, lab-based learning, and fieldwork.

SUGGESTIONS FOR INCLUSIVE RESEARCH

People with disabilities/disabled people continue to be underrepresented as STEM researchers. Over the past decade, less than 2 percent of funded investigators from the National Institutes of Health and less than 1 percent from the National Science Foundation reported having a disability (Swenor and Rizzo, 2022). Among doctorate recipients, the disability rate in most science fields of study was lower than the overall rate in 2019 (NCSES, 2021). More work needs to be done to build a pipeline of researchers with disabilities who can take on leadership roles as principal investigators and serve as role models for future STEM researchers. Ideas for increasing the participation of people with disabilities as leaders in STEM research include the following:

- Support peer mentoring programs that allow researchers who have disabilities/disabled researchers to share tips and strategies for succeeding as graduate and postgraduate students and early-career researchers. Where affinity groups of such students and researchers already exist, these efforts should be supported through additional funding and visibility. Peer mentoring can address questions students may not feel comfortable asking a faculty mentor, especially questions related to their experience (securing accommodations, managing academic stress, etc.). It is the answer to such questions that can often make the difference between persisting in a program or not.
- Ensure research findings are disseminated in accessible ways. Recently, the Office of Science and Technology Policy issued guidance for making federally supported research and publications available through open access. While this move is to be lauded, it is not enough for research findings to be more widely available to

researchers who have disabilities/disabled researchers. Those findings need to be disseminated in accessible formats (e.g., PDF files that have been tagged properly so that the content can easily be read aloud and navigated when using text-to-speech technology). Often the first step in writing a grant proposal to secure new funding is to conduct a review of the existing literature to understand what lines of investigation are new and build off existing research in meaningful ways. If the research is in inaccessible formats, researchers with disabilities/disabled researchers may not be able to conduct this critical preliminary phase to secure funding. Furthermore, the dominance of print for peer-reviewed research and oral communication for bringing the research community together represents a form of ableism that must be addressed if research is to be more inclusive of researchers with disabilities/disabled researchers. Print does not need to be the dominant form of communication in classrooms or research as we no longer rely exclusively on the printing press to codify knowledge (Rose et al., 2014).

- Question existing practices with the goal of identifying barriers that may preclude people with disabilities/disabled people from participating in research activities. Even small steps can make a difference. For example, we intend for this paper to be disseminated in a digital-first format and, as a result, have chosen to format the references to follow APA (American Psychological Association) format but with a small change that will make them more screen-reader friendly. Instead of including long web addresses, we have chosen to make the title of each article a descriptive link that will be more meaningful to someone listening to the information read aloud with a screen reader. This questioning must extend to those creating requirements for grant proposal submissions, grant reporting, and so forth, as they create the rules that investigators must follow to secure funding for existing and new lines of research.

SUGGESTIONS FOR INCLUSIVE LAB-BASED LEARNING

Much of the work of science takes place in a variety of lab settings, from teaching labs students may use either as part of a course or while conducting research overseen by a faculty mentor to research labs in industry, which includes internships and other work-based learning opportunities. These labs are where much of the experimentation and hypothesis testing that is crucial to work in the sciences takes place. As such, when accessibility in these spaces is treated as an afterthought or not considered at all, it places students with disabilities/disabled students and others who require accessibility support at a disadvantage in their pursuit of careers in STEM.

To create more inclusive lab spaces, academia and industry could consider the following:

- Incorporate universal design principles in the design of the lab space. Unlike digital accessibility, where regulations are still being worked out more than three decades after enactment of the Americans with Disabilities Act, standards for the design of ADA-compliant physical spaces are much clearer. As new spaces are approved for construction, engage architects, facilities leadership, and other relevant parties as early as possible to ensure universal design principles are considered from the start and the space does not require costly retrofitting to make it accessible after the fact. The Centre for Excellence in Universal Design (bit.ly/7UDLPrinciples) has clear explanations of each of the seven universal design principles that need to be considered when designing a new lab space to ensure it is accessible to as many people as possible.

- Explore accessible lab tools. The DO-IT program at the University of Washington maintains a list of products that can be mined for ideas on building a more accessible lab environment. These tools range from low-cost solutions such as measuring cups with high-contrast markings to more expensive talking data collection equipment such as the Sci-Voice Talking LabQuest, which makes data collection accessible to blind scientists by voicing data measurements in real time. The National Science Foundation issued a Dear Colleague Letter in 2021 to improve the inclusion of persons with disabilities/disabled people in STEM fields and education. This letter encouraged grantees with existing funding and those seeking funding from NSF "to support existing or new access to and engagement in STEM learning, research, and workforce development at proposing or awardee organizations for students, postdoctoral scholars, or faculty and staff with disabilities/disabled staff as participants in all aspects of grants and programs." Allowable spending examples included stipends for students and educators with disabilities/disabled students and educators to participate in research activities and training; funding to increase time and effort of people with disabilities/disabled people to work on STEM education and research; and tools, technologies, equipment, and instrumentation, including in adapted or modified formats, to ensure full participation of people with disabilities/disabled people (NSF, 2021).
- Vet digital materials for accessibility. Procuring accessible lab equipment is not of much help if the instructions for how to use it, lab manuals, and data collection and

analysis software are lacking in basic accessibility. All lab materials should be vetted for accessibility prior to procurement (or during development if created in-house). Use the four POUR principles (Perceivable, Operable, Understandable, and Robust) to ask questions related to these digital materials' accessibility. These four principles define four qualities of an accessible experience and are foundational to the Web Content Accessibility Guidelines, the international web accessibility standard that is often referenced in national accessibility laws such as Section 508 of the Rehabilitation Act of 1973. The National Center on Accessible Educational Materials at CAST (AEM Center) has developed Vetting for Accessibility (bit.ly/VettingAccessibility) as a resource to assist teams in evaluating the accessibility of digital materials, including those used in lab settings.

- Ensure information about accommodation for service animals is readily available. Use of a trained service animal in a lab space is an allowable accommodation under the Americans with Disabilities Act. Safety procedures to allow the service animal to do its work safely in the lab include, but are not limited to, the use of personal protective equipment, or PPE, such as protective booties and goggles. The service animal also needs a mat where it can rest during class time without presenting an obstruction to others while being easily accessible to its handler. To avoid misunderstandings, clear guidance about rights and responsibilities for everyone working in the lab (including service animal owners) should be made available and shared in a variety of formats.
- Create accessible virtual tours of lab facilities. An accessible video can help students with disabilities/disabled students familiarize themselves with the lab space and

equipment ahead of time, which can help them feel more comfortable and welcome when they finally arrive at the space to do lab work. Care should be taken to ensure such videos are accessible through captions, descriptive transcripts, and chapter markers for navigation of longer videos. A keyboard accessible player should also be used to distribute such videos in an accessible way.

New technologies may provide even more options for including people with disabilities/disabled people in lab spaces where they have been previously excluded. As Dr. Bradley Duerstock noted when this paper was first presented, telerobotics may allow a student who uses a service animal to participate in work that takes place in a clean room, where a service animal may not be allowed due to contamination concerns.

SUGGESTIONS FOR INCLUSIVE FIELDWORK

Communication is key to ensuring every student who participates in fieldwork has a positive experience at this key point in their educational journey, when it is finally time to put their classroom knowledge to the test in authentic settings and situations. Ensuring fieldwork placements are as inclusive as possible would include the following:

- Provide a way as part of fieldwork evaluations for students to report both positive and negative experiences as relate to the accessibility of their fieldwork placement. Use this information to create a list of fieldwork placements with information about accessibility and known barriers to help students make informed decisions about their fieldwork experiences.

- Set up tours of the facilities where fieldwork will take place to help students familiarize themselves with the environment. An accessible video can be used for the same purpose of providing exposure to the fieldwork setting in advance. For situations where safety is a concern, pair up individuals with similar fieldwork interests using a buddy system.
- Provide information about supports such as ASL interpreters and other means of communication. As Dr. Caroline Salomon noted when this paper was presented, in some cases these means of communication may actually be an asset. She cited the example of students working in a marine biology setting where verbal communication underwater may not be possible. As an example of Deaf Gain in action, ASL would be a superior means of communication in such a setting.

UDL IN AN AI-INFUSED FUTURE

Artificial intelligence is widely discussed in education and often with the fear it will replace teaching and learning. However, if AI is looked at as part of the larger effort to use distributed rather than individual intelligence to frame and resolve our most pressing problems, its utility can be better understood. AI can be defined in a variety of ways. The Office of Educational Technology at the U.S. Department of Education shared three definitions in an April 2022 blog post, each emphasizing a different relationship between AI and those who use it:

- “The theory and development of computer systems able to perform tasks normally requiring human intelligence.”
- “Computing that acts independently towards a goal based on inferences from theory or patterns in data.”

- "Augmented intelligence is a design pattern for a human-centered partnership model of people and artificial intelligence (AI) working together to enhance cognitive performance, including learning, decision making and new experiences."

Each of these definitions may be useful when discussing different implications of AI. Since we are mainly concerned with those for learning, we will draw primarily on the third definition, which emphasizes the role of AI to augment human intelligence and potential, rather than merely replace it. That is not to minimize the role of AI in disrupting the labor force in higher education or the ethical implications of using information that may be biased or inaccurate to make decisions about students. Rather, it is to limit this discussion's scope for practical reasons related to space. Plenty has been written about the potential negative effects of AI. The focus here is on how AI may be used along with UDL principles to provide more personalized experiences for learners.

AI may already be in widespread use by learners without their knowledge, often in ways that enhance the learning experience and go unnoticed. Some examples include the following:

- The creation of captions and transcripts at scale. AI is used in many automated or automatic speech recognition (ASR) systems to recognize speech patterns and convert the spoken content in media into captions and transcripts. Even when a human captioner is involved in the workflow, the use of ASR for a first pass can improve the speed of captioning and transcription significantly, which can result in more media with these accessibility features being available in a timelier manner. Captions are an important "essential for some, helpful for all" support for learning that benefits many types of learners: those who are deaf and hard of hearing, those learning a new language, and more.

- Improving the quality and accuracy of text-to-speech solutions that can benefit students with learning disabilities, those learning a new language, and/or those who just need an alternative format for print materials. The use of AI to produce narration provided through text-to-speech can increase the number of titles that are available to students who need to or prefer to read with their ears using audiobooks and read-aloud features that are now commonplace on many of the devices they use to access content. Apple now provides any publisher who uses Apple Books the option to have their books narrated with AI-generated voices. The idea is to reduce the barriers (cost, production time) for creating audiobooks.
- Creating alternative text for those who are blind. Object recognition can be used to provide automatic descriptions of visuals. For example, Microsoft Office applications can automatically generate a text alternative when an image is added to a Microsoft Word document or a PowerPoint presentation. The descriptions are not always accurate, but as they improve, they could provide a starting point that could save time for individual educators who wish to make the materials they create more accessible to all students, including those who rely on text descriptions due to visual impairments.
- Creating text summaries. AI excels at taking large amounts of information and recognizing patterns. This feature of AI can be helpful for creating plain language summaries of complex or technical information. Accessibility standards allow for the

> creation of these summaries when simplifying the information to meet a lower secondary reading level (grades 7–9) is not possible.

Despite these benefits, much of the conversation about AI in higher education centers on the use of AI for cheating on assessments. A new arms race is underway with companies developing AI-based detection software tools that detect when students are using AI to compose essays and complete other assignments that rely on writing. We hope that the reaction to the use of AI in higher education does not follow the model of laptop and cell phone bans, which have reduced access for students who rely on technology for access to the curriculum. Rather than banning the use of AI, the development of policies that emphasize the responsible use of AI offers a more productive path forward, where the benefits of AI can be realized while students learn about its responsible use as a key aspect of their education as digital citizens.

UDL can inform more authentic assessments that require students to go beyond the answers that can be quickly provided by crafting an appropriate prompt for an AI chatbot. These assessments should ask students to make connections between what they are learning and their individual experiences and local context. Without careful attention to bias in AI, it too can lead to ableism/disablism that keeps us from realizing the promise captured by the quote at the start of this article, that is, finally including everyone in our society.

A SYSTEMIC APPROACH TO UDL

To have the greatest effect, UDL cannot be a one-and-done approach to inclusive instructional design; UDL initiatives need time and coordination to result in the systemic changes that are the most beneficial for student learning. A framework for implementation can assist in building the coordination that is necessary to address the various aspects of UDL implementation, from instructional strategies at the classroom level to program wide changes related to infrastructure such as the inclusive design of physical spaces and procurement of accessible equipment, tools, and digital assets. As referenced in the discussion of accessibility, the Quality Indicators for the Provision of Accessible Educational Materials and Technologies from the National Center on Accessible Educational Materials can serve as one such model for systemic improvement, and leaders in higher education and workforce development can use the many resources available at the AEM Center (aem.cast.org/coordinate/quality-indicators-provision-accessible-materials-technologies) to get started in building a more robust accessibility infrastructure to support the implementation of UDL in their settings. Educators and staff should also be open to learn from each other's experiences rather than "reinventing the wheel." The College STAR Student Support Network (collegestar.org) provides an example of collaboration across institutions that can also be helpful in leveraging resources to support students with disabilities. Similarly, the UDL on Campus website from CAST (udloncampus.cast.org) maintains a list of programs with UDL initiatives that may have ideas and resources that can serve as a starting point for a new UDL initiative.

CONCLUSION

This paper has proposed ways for creating more inclusive learning environments by leveraging the flexibility instructional designs based on Universal Design for Learning afford. The suggestions address the various aspects of a student's experience that need to be considered to increase the recruitment, retention, and success of diverse learners who bring a range of learning needs and preferences to the various aspects of STEM learning: classroom instruction, lab-based learning, research, and fieldwork placements. However, we argue that they need to be addressed in the context of challenging and rethinking assumptions about intelligence and ability that shape the enactment of ableist and disablist practices in higher education, including in STEM fields. Addressing exclusionary attitudes, building a mindset and infrastructure for accessibility as a foundational practice, and considering accommodations as a partner for inclusion when implemented alongside UDL principles, we can get closer to achieving the vision laid out in the quote that opens this paper: “For the first time in history, we will have used our power to include everyone in STEM learning.”

ABOUT CAST

CAST is a nonprofit education research and development organization that pioneered Universal Design for Learning. Through research and development, and its application in professional learning settings, CAST adapts the UDL framework to specific problems of practice within a given context. These problems are often driven by new legislative, policy, and funding priorities that emphasize diversity, equity, and inclusion in school, training, and work. CAST teams co-design with the target audience around specific goals, develop educational software, design and review curricular and instructional interventions, and deliver customized technical assistance in response to identified needs. CAST runs multiple large federal technical assistance and research centers, including the National Center on Accessible Educational Materials. The AEM Center provides technical assistance to consumers, including K–12 and higher education and workforce development agencies, on the provision and use of accessible educational materials and technologies.

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- Dr. Jacquelyn Chini, Associate Professor and Undergraduate Program Associate Director, Department of Physics, University of Central Florida
- Dr. Bradley Duerstock, Professor of Engineering Practice, Weldon School of Biomedical Engineering and School of Industrial Engineering, Purdue University
- Dr. Caroline Solomon, Director, School of Science, Technology, Accessibility, Mathematics, and Public Health (STAMP) and Professor of Biology, and Interim Program Director, Public Health Program, Gallaudet University

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