

Supporting STEM graduate students with dis/abilities: Opportunities for Universal Design for Learning

D. C. Beardmore

Mx. Beardmore is currently a PhD student at the University of Colorado, Boulder. They study inclusive engineering education and construction engineering risk management. Their full bio and current and historical positionality statements can be found on their website at dbeardmore.com.

Robyn Sandekian (Director of Faculty Advancement)

Robyn Sandekian, PhD, is the Director of Faculty Advancement for the College of Engineering and Applied Science (CEAS) at the University of Colorado Boulder (CU Boulder). In this role, Robyn has a key leadership role with responsibilities for identifying, implementing, and assessing outcomes of policies, programs, and procedures to meet CEAS goals for faculty recruiting, hiring, retention, and advancement including increasing faculty diversity, equity, and inclusion (DEI). Dr. Sandekian earned degrees in Aerospace Engineering Sciences at CU Boulder (B.S. 1992/M.S. 1994), a Specialist in Education (Ed.S.) degree in Educational Leadership and Policy Studies (2011), and a Ph.D. in Higher Education and Student Affairs Leadership (2017), both from the University of Northern Colorado. She is a Founding Leader of the American Society of Engineering Education Virtual Community of Practice for LGBTQ+ Inclusion in Engineering and a facilitator of Safe Zone training and participates in various activities of the ASEE Commission of Diversity, Equity, and Inclusion (CDEI).

Angela R Bielefeldt (Professor)

Angela Bielefeldt, Ph.D., P.E., is a professor at the University of Colorado Boulder (CU) in the Department of Civil, Environmental, and Architectural Engineering (CEAE). She is also the Director for the Engineering Plus program, which is in the process of being renamed to Integrated Design Engineering. Bielefeldt also serves as the co-director for the Engineering Education and AI-Augmented Learning Integrated Research Theme (IRT) at CU. She has been a faculty member at CU since 1996, serving in various roles including Faculty Director of the Sustainable By Design Residential Academic Program (2014-2017), Director of the Environmental Engineering program (2006-2010), and ABET Assessment Coordinator for the CEAE Department (2008-2018). Bielefeldt is active in the American Society of Civil Engineers (ASCE), serving on the Civil Engineering Program Criteria Task Committee (2019-2022) and the Body of Knowledge 3 Task Committee (2016-2018). She is the Senior Editor for the International Journal for Service Learning in Engineering (IJSLE) and a Deputy Editor for the ASCE Journal of Civil Engineering Education. Her research focuses on engineering education, including ethics, social responsibility, sustainable engineering, and community engagement. Bielefeldt is also a Fellow of the American Society for Engineering Education.

Supporting STEM graduate students with dis/abilities: Opportunities for Universal Design for Learning

Abstract

While little is known about the enrollment and retention rates of STEM graduate students, studies indicate that the way higher education generally approaches STEM graduate programs overlooks and excludes individuals with dis/abilities. This research examines the experiences of STEM graduate students with non-apparent (also called “invisible”) dis/abilities as related through the lens of critical dis/ability theory. In this paper, we review the findings from the first phase of a larger study through the lens of Universal Design for Learning (UDL). We used Harvey’s interview process to explore the experiences of two STEM graduate students who self-identify as having “invisible” dis/abilities or “different abilities” through a progressive series of interviews. In this paper, we review a selection of the participant’s experiences and provide recommendations on how UDL can be implemented to overcome the barriers graduate students may be facing in their coursework, research, and advising. We provide these recommendations in an effort to create a more inclusive and welcoming environment for *all* graduate students. Further, we hope that our research findings help individuals serving university students at any level in any discipline ask what opportunities they have to create a more inclusive and welcoming environment through the tenants of UDL¹.

Introduction

Individuals with dis/abilities represent a significant portion of the population yet they are overlooked as key contributors to Science Technology Engineering and Mathematics (STEM) industry and academia [1]. While we know that graduate STEM education is difficult to access for many prospective and current students, there is a paucity of research aiming to change this. There is also a dearth of research engaged in learning about dis/abled student experiences and the barriers that limit access to graduate education. The Center for Disease Control estimates that around 25% of adults in the United States have dis/abilities [2]. A 2015-16 survey found that around 20% of undergraduate and 12% of graduate student respondents reported having a disability² [3]. The same report found that 18% of undergraduate and 7% of graduate Engineering, Computer Science, and Mathematics students report having a disability [3]. However, estimates suggest that the actual numbers are significantly higher than what is reported [1]. Additionally, a nationally representative longitudinal study, referred to as NLTS2, found that nearly 60% percent of undergraduate students, previously enrolled in special education, choose not to disclose their disability to their institution [4, p. 33]. It is likely that many people who choose not to disclose and/or experience invisible dis/abilities are overlooked in our current body of knowledge [5], [6].

¹ This document is available upon request in alternative formats such as large print, editable, and text-only. Please email D. C. Beardmore at dcbeardmore@gmail.com to request a copy.

² The National Center for Education Statistics [3] refers to a disability as one or more of the following: blindness or visual impairment that cannot be corrected by wearing glasses; hearing impairment (e.g., deaf or hard of hearing); orthopedic or mobility impairment; speech or language impairment; learning, mental, emotional, or psychiatric condition (e.g., serious learning disability, depression, ADD, or ADHD); or other health impairment or problem.

The National Survey of College Graduates found that only 9% of college graduates working in Science and Engineering occupations in 2019 reported having at least one disability [7]. While, little is known about the completion rates of graduate students with dis/abilities [8], [9], studies find that undergraduate students with disclosed dis/abilities complete their studies at a lower rate than undergraduate students who either do not have or do not report having dis/abilities [4], [10], [11]. The NLTS2 found the percentages to be 34% to 52%, respectively [4, p. 48].

The Council on Graduate studies states that “Attrition in U.S. graduate programs is a tremendous waste of American's financial resources and human energies... Improving completion rates for all doctoral students, and particularly for those from underrepresented groups, is vital to meeting our nation's present and future workforce needs” [12]. Despite this call for action, there is a scarcity of research on dis/ability in STEM higher education and dis/ability in graduate education. Studies suggest that students with dis/abilities may be the first to be affected by pedagogical/andragogical³ practices that ultimately affect all students [14]. We believe the insights and recommendations in this paper have the potential to benefit *all* college students.

Theoretical framing

We use the term dis/ability to 1) acknowledge the validity and value of humans who have disabilities, 2) emphasize the codependence of socio-cultural conceptualizations of disability and ability, and 3) recognize disability and ability as constructions of ableism⁴, and each individual's multidimensional⁵ experience and interpretation [22], [25]–[27]. We consider dis/abilities as a fluid spectrum. Some disabilities are readily apparent to the casual observer while others are not as readily apparent. The level of “visibility” of a person's dis/abilities depends on the context of the situation; however, “invisible” dis/abilities “are the most common type of disability among college students” [28]. Thompson notes that invisible, also called non-apparent or less apparent [29] dis/abilities, can be “a cognitive, developmental, intellectual, mental, or sensory condition that limits a person's behaviors, senses, or activities” [30]. Some common less apparent dis/abilities include anxiety, attention-deficit/hyperactivity disorder (ADHD), chronic pain, depression, lupus, post-traumatic stress disorder (PTSD), and traumatic brain injury (TBI) [28]. Both those experiencing more readily apparent and those with less apparent dis/abilities experience ableism, but often in different ways [31]. Despite this, most existing research on people with dis/abilities focuses on people with “visible” dis/abilities [31].

³ The term pedagogy was originally used to refer to the art and science of teaching children, whereas andragogy referred to that of adults. More recently, these terms are often used to represent separate sets of assumptions about learners of any age [13]. We use the term andragogy to represent the art and science of teaching college students (and the assumptions about learning informing these practices) in this paper.

⁴ Ableism refers to the socio-political ideology and practices that measure an individual's value, humanity, and success against the standard of the “normal” or “ideal” able-body/mind to oppress and exclude people who deviate from ableness [16]–[19].

⁵ Multidimensionality is an analytical framework for understanding how the interdependent systems of oppression [20], [21] and privilege [22], [23] interconnect, compound, conflict, and overlap in a person's experience—afforded by the convergence and divergence of the individual's socio-cultural categorizations, capital, and community cultural wealth [24]. Multidimensionality is sometimes differentiated from intersectionality as it intentionally includes systems of privilege [23]. A few examples socio-cultural categorizations include dis/ability, gender, sex, age, size, race, sexuality, socio-economic standing/class, family/marital/pregnancy status, nationality/immigration status, education, literacy, language, incarceration, and religion.

Disability is a complex, evolving, and nuanced concept, as are the words surrounding it [32], [33]. Some dis/abled people prefer identity-first language (e.g. “dis/abled”) because it upholds dis/ability as a non-negative identity [5]. While others prefer person-first language (e.g. person with a dis/ability) as it focuses on the humanity or personhood of the individual by separating them from what dis/ables them [5]. Since the language used to describe oneself is personal choice, we echo the language used by the participants and the authors we cite. While we desire to lift up the language used by each participant individually, we refrain from doing so as a way to further protect their identities, as discussed in the Research methodology section of this manuscript. Instead, we represent their preferences by using the formats interchangeably.

There are two primary models of disability in disability studies. The first model, referred to as the medical model, frames disability as impairment, i.e. a psychological, embodied, or medicalized deficit or abnormality [27]. The medical model of disability remains a dominant ideology in public opinion, professional practice, academic policy, and law in the U. S. today [1]. The legal definition of disability in the U. S. exemplifies the medical model. Section 3 of the Americans with Disabilities Act of 1990 and its 2008 amendment defines disability, with respect to an individual, as “(A) a physical or mental impairment that substantially limits one or more of the major life activities of such individual; (B) a record of such an impairment; or (C) being regarded as having such an impairment” [34]. The second model, called the social model of disability, emerged in the late 20th century [15] and has quickly become a widespread epistemology in disability studies [35]. The social model posits disability as a consequence of socio-cultural oppression of disabled people including the socially imposed restrictions and the socially-engendered undermining of their psycho-emotional well-being [15] [36].

Wanting to challenge the binary nature of defining disability as either a socially constructed or medical identity, critical disability scholars present disability through the lens of an interactionist model that acknowledges the medical reality of impairment; the socially enforced disablement and delimitation of “non-desirable others”; and an individuals’ own interpretations, prior experiences, and biases regarding disability [26], [37], [38]. This model recognizes the agency of disabled people; the politically legitimized subordination of disabled people; the co-construction of ability and disability through ableism [19], [27], [39]. It also recognizes the exclusion and segregation of disabled people in education and labor [26], [40].

All these conceptualizations of dis/ability are present in how higher education responds to dis/ability. The most pervasive way we treat disability in higher education, the “reasonable accommodation” framework, is grounded in the medical model of disability [5]. While very few programs treat disability in accordance with the social [41], [42] or interactional [43] models of dis/ability, there is a growing call for these models to be translated into higher education through Universal Design for Learning (UDL). We introduce UDL later in this paper.

Dis/abilities in higher education

The underreporting of disabilities is a well-known phenomenon in higher education. It is likely due to a multitude of factors including the limitations in how disability is defined. It could also be due to the institutional, interpersonal, and internalized stereotyping, stigma, and discrimination students face in disclosing dis/ability.

Individuals with less apparent dis/abilities must decide when, how, and if they wish to disclose their status. Graduate students are often considered the “best” and “brightest” of all graduates of higher education. Declaring one’s dis/abilities, as is often required, does not fit such a narrative. Thus, there is a commonly held belief among students, faculty, and staff that nondisclosure is necessary to be accepted as competent [44], avoid stigma [45]–[47] and prevent being discredited [14]. This is true for graduate students who navigate the dissidence between their academic identities, the ablest expectations they face, and being positioned as disabled [14]. It may be especially true for Black and indigenous graduate students who may face resistance from faculty to provide accommodations and a need to engage in higher levels of forced intimacy⁶ than their white peers [48]. It is also true for students in STEM fields where requests for access are considered a nuisance and perceived as a sign of weakness [5]. As Mingus notes in a keynote address at Femmes of Color 2011 “it can be very dangerous to identify as disabled when your survival depends on you denying it” [49].

Stigma is not the only barrier facing graduate students with dis/abilities. Several commonly held “normative” assumptions serve as hidden referents of ableism. Seymour and Hunter [50] discuss the normative culture in the sciences as contributing to the problem of low persistence of undergraduate students in STEM. They point to the commonly held assumption that “natural ability determines the capacity for STEM learning” as being problematic [50]. Further, they note that many STEM faculty exhibit a “fixed ability mindset” [50]. Another commonly held assumption is that graduate students have “made it through a first round of post-secondary education and have, as a result, developed appropriate strategies for success” [51]. However, this is not necessarily true. Disability justice introduces a concept known as access needs, positing that what each human needs in order to access or fully participate in a space is unique, fluid, and dependent on context [19]. Furthermore, many people develop or are diagnosed with dis/abilities after completing their K-12 education [23]. Moreover, the stress of graduate studies has been linked with the onset of dis/abilities related to mental health [52].

Hockings [53] asserts that many instructors/professors design curricula based on their assumptions about what students are “able” to do and “should” do, as well as what students “know” and “should know.” Therefore, many graduate students must demonstrate their “natural abilities” to prove their worth as independent researchers. However, graduate students often have difficulty identifying and recognizing what it is they are supposed to be doing or should be learning [54], [55], especially in engineering [56]. This hidden curriculum and the assumptions behind it can jeopardize a student’s confidence and identity as “a good student” [50]. Many students choose to leave the sciences rather than fight the status quo [50]. However, a primarily pedagogical framework known as Universal Design for Learning (UDL) has the potential to dissolve such hidden curricula and make learning more accessible to all students [57], [58].

Universal Design for Learning

The UDL framework was born out of a fundamental principle in engineering and architectural design referred to as Universal Design [59]. Universal Design challenges engineers and architects to design environments, buildings, products, and services so that they can be accessed, understood, and used to the greatest extent possible by all people [60]. Disability justice asserts

⁶ Forced intimacy refers to a person with dis/abilities being forced to exhibit extreme vulnerability in order to exist in hostile ableist environments, which are built for the “ideal” body/minded person [5]

that all people have access needs and that, as members of society, we are all responsible for meeting these needs. Similarly, the Universal Design principle asserts that meeting the needs of *all* people who use something is a fundamental condition of a good design [60].

UDL is a framework of innovative, research-informed, and technology-based educational resources and strategies. It aims to provide access to all students by eliminating barriers and maximizing learning for all students [61]. The UDL framework targets the needs, strengths, interests, and intersectional backgrounds of individual students. The Center for Applied Special Technology (CAST) UDL framework consists of three key principles:

1. Providing varied formats of content presentation to allow students to recognize the *what* of learning in different ways,
2. Allowing students to use varied tools, approaches, and strategies to express the *how* of learning in different ways, and
3. Offering options for students to engage in content to allow them to become interested in and motivated by it as they engage in the *why* of learning.

Although UDL has been around since the 1990s and there are online repositories for pedagogical UDL tools (e.g., <https://udlguidelines.cast.org/>), it is not commonly implemented in the classroom at any level—primary, secondary, or tertiary [59]. Similarly, while there are databases for UDL research (e.g., <https://udl-irn.org/research-database/>), there is little research into the application of UDL in the higher education classroom [53], [62]. Fovet [51] succinctly highlights the lack of UDL in graduate-level courses, and potential assumptions driving this shortcoming (i.e., that graduate education is selective and students will disclose their needs).

Ultimately, college faculty are instrumental in the provision of accessible curriculum and academic accommodations [63]. Under the current model, faculty are often asked to retrofit their course for a particular student after the course has already been developed, which can be a very difficult undertaking [43]. While some faculty members desire education on how their teaching style affects learners, such educational resources are often difficult to access [63]. Without resources on how to provide an inclusive education, faculty are often unsure what access needs students may have (especially those with disabilities and even more so with invisible disabilities) and how those needs could be met [63].

Purpose

Responding to this paucity in the current body of knowledge, this paper seeks to explore the alignment between UDL principles and the experiences of dis/abled STEM graduate students. Specifically, this manuscript has three goals:

1. Map participant experiences with barriers to relevant CAST UDL guidelines
2. Build on the CAST UDL guidelines with insights from the participants
3. Offer the academic community concrete recommendations
 - a. on how to provide students with options in their coursework and research, and
 - b. for creating a more accessible education that is inclusive of *all* college students

These goals are supportive of achieving equity and inclusion that supports diverse students in engineering.

Research methodology

We employed a phenomenographic methodology [64] of collective counter-narratives to describe the experiences of graduate students with non-apparent or invisible dis/abilities, related to the phenomena they encounter as they navigate their academic environment. While the overall study was segmented into two phases of data collection, this manuscript focuses on a portion of the data collected in the first phase. UDL was not used as a framework in the original study design, but rather was identified post-hoc as providing a useful lens to interpret the experiences and opinions shared by the participants. We amalgamated the participants' experiences in the form of collective counter-narratives [65], [66]. This strategy was preferred by the participants due to the concern that a reader might be able to identify an individual participant if a string of stories and descriptions were attributed to any one participant [65]. This human subjects research was reviewed and approved by an Institutional Review Board (Protocol #: 21-0217).

Recruitment

To date, this study has enrolled six participants from multiple universities across the U.S. The inclusion criteria for the study were graduate students who: 1) were currently enrolled (or had been enrolled since August 2020) in a STEM major at a university in the U.S.; 2) had previously earned at least one bachelor's degree; and 3) identified as having at least one invisible dis/ability.

The first phase of the broader study employed a convenience sample to recruit participants—i.e. we selected participants who were conveniently available or who were already known to meet the inclusion criteria [67]. This manuscript includes a selection of counter-narratives provided by two of the participants. We procured a massive depth and breadth of rich vivid data. Limiting the scope of this manuscript to a small-n leveraged the authors' ability to seek resonance (i.e., meaningful reverberation and ability to affect the audience). Specifically, this allowed us to select revealing, contextually situated stories to share and explore [68].

Interview protocol

The first author designed and conducted the interviews with the foremost intention of respecting each participant's agency, safety, and comfort throughout the entire research study. Keeping this in mind, the interviewer framed the first phase of the study around creating an open, participant-driven dialog using Harvey's dialogic serial interview process. Harvey's process is grounded in practical and relational ethics [69] which are defined in Tracy's eight criteria for quality in Qualitative Quality [70]. Following Harvey's process, the design for Phase 1 included four rounds of sequential one-on-one interviews with each participant. Each interview lasted around one hour and began with a loosely structured time to check-in and set boundaries. As described in the next section, the interviewer offered each participant an initial prompt and from there, the interview evolved into a participant-led informal conversation.

Data collection and analysis

The first author (whose pronouns are they/them) also collected and analyzed the data as described here. They documented the interviews using video and audio recordings, automated transcription, and field notes. During the first round of interviews, they asked each participant, "When you think about your experience as a graduate student with disabilities or different abilities, what comes to mind?" After the first round of interviews was complete, the first author

proceeded to build an initial list of themes or phenomena pertaining to the participants' descriptions of their experiences [64] using an open coding process [67], [71], [72]. They began this process by cleaning and de-identifying the transcripts while watching and listening to the interview recordings. While they cleaned the transcripts they flagged potential statements of interest with short descriptive labels [67]. Next, they reviewed the transcripts while organizing each participant's experiences into what Creswell refers to as "chunks"[67]. The first author took care in balancing divergent experiences with complementary experiences to retain the multivocality of the data during coding [68]. Then the first author iterated on the coding while reorganizing the chunks of data into loosely held themes [67], [71], [72].

After each round of open coding, the first author returned to each participant in each subsequent round of interviews. The first author shared the potential themes with the participants and asked "What are your thoughts on the preliminary themes?". The first author then worked with each participant to revise the themes. Using Harvey's process provided the first author and participants an opportunity to improve the qualitative credibility of the study. Qualitative credibility is an aspect of qualitative research quality that refers to dependability, trustworthiness, and expressing a reality that is plausible or seems true [70]. During each subsequent interview, the participants not only engaged in a process known as member reflection; they also co-analyzed the data with the first author, as described below. Member reflection refers to a process that allows participants to share, question, critique, and provide feedback or dialogue [70].

The participants and the first author repeated the data collection and analysis process. During the second round of interviews, each participant explored, focused, redefined, bounded, and provided clarification on the themes in their individual experiences. Then, in the third round, each participant explored, redefined, and expanded the complementary and divergent themes across the participants' experiences. They contextualized the themes in terms of their multidimensional experiences, identity, and perspectives.

After the third round of interviews, the first author built an initial phenomenography using thick descriptions of the participants' stories [68]. Instead of participating in the fourth round of interviews as is standard in Harvey's process [69], both participants opted to read and comment on the phenomenography draft.

Once the first author incorporated the participants' feedback, they shared the phenomenography with the co-authors. At that point, the three co-authors identified some alignment of the participants' descriptions of their graduate experiences with themes in UDL. Thus, we identified UDL as a lens through which to explore the experiences and perspectives shared by the participants. We then reviewed the data to identify experiences seeming to align with the CAST UDL guidelines. We amalgamated these experiences into collective counter-narratives. Finally, pursuing qualitative sincerity we reflected on the biases, interests, and intentions that informed our design, interpretation, and presentation of this research [70], [73], in the following sections.

Participants

The participants included two individuals who were enrolled in STEM programs seeking a master's and/or a doctoral degree at publicly funded universities with R1 (very high research

activity) Carnegie classifications [74]. The participants included individuals who had previously or concurrently served in the military, worked in industry, earned prior graduate degree(s), and/or entered graduate school immediately after earning their undergraduate degree(s). The participants held multiple roles at their institutions in that they were both taking classes and/or serving as employees while conducting research at the time of the study.

The participants described experiencing and/or being diagnosed with one or more of the following dis/abilities: environmental/chemical allergies and sensitivities, clinical anxiety, clinical depression, temporary partial vision loss, hearing loss, attention deficit hyperactivity disorder (ADHD), migraines, traumatic brain injury (TBI), and post-traumatic stress disorder (PTSD). Neither participant had “diagnoses” nor formal accommodations during their primary, secondary, or undergraduate education.

Collectively, the participants used the following terminology to describe themselves: Hispanic and white; gay, lesbian, bisexual, and pansexual; assigned female at birth; woman, nonbinary, and demi-woman; Bilingual and English speaking; “non-traditional” and “in my 20s”; “spiritual but not religious” and atheist; and American. Collectively they described being raised by middle-class and upper-class first-generation and nth-generation immigrants in the American Midwest and West.

Author positionality

Author 1 (they/them/theirs) is a Ph.D. student at the University of Colorado, Boulder. As a dis/abled graduate student interviewing other graduate students with dis/abilities, the first author found themselves comparing their own identity and experience to those of the participants. Although the first author has had dis/abilities since early childhood (including an autoimmune disease and PTSD), they went undiagnosed until after the first author completed their undergraduate education. After sustaining a TBI during their graduate studies, they had to relearn how to learn. They realized how different their approaches to learning were before and after the injury. This revelation led them to start exploring how other people learn. Their background knowledge in UDL, albeit limited, informed their perception of the participants’ statements and the probes the first author gave during the interviews. The first author provides an in-depth consideration of their current and historical understanding of their positionality on their website dcbeardmore.com.

Author 2 (she/her/hers) is a professional staff member at the University of Colorado Boulder. She personally holds multiple less-apparent identities that have framed her past experiences and current perceptions of STEM culture, including those that could be considered dis/abilities. She has limited academic background in dis/ability studies or UDL. Her work focuses on developing and supporting an inclusive academic environment for faculty and students across a spectrum of identities. Her primary research projects have included qualitative studies on the experiences of non-majority members of academia (students and faculty).

Author 3 (she/her/hers) is a faculty member at University of Colorado Boulder. She has limited background in dis/ability studies or UDL. In her 25-year teaching career she has had numerous students in undergraduate and graduate courses who have university-assigned accommodations.

While her primary experience in engineering education research has focused on undergraduate students and quantitative studies, she also has experience conducting qualitative studies that have included interviews.

Limitations

This post-hoc first phase of the study did not ask questions explicitly targeting elements in UDL, however upon data analysis, the authors discovered content that was clearly tied to two of the three primary principles of UDL—representation and action and expression. We felt that this discovery was useful to expand the resources available to practitioners and hence wrote this article. Another feature of this work that some could consider a limitation is that this study is not generalizable; however, it was not intended to be so. Using a convenience sample meant that the first author was somewhat familiar with each participant. This also meant that the first author filtered the stories that the participants shared through their own experiences and biases, as discussed in the author positionality statements. Conversely, this meant that the participants already knew about some of the first author's experiences as a dis/abled STEM graduate student and may have filtered the experiences they shared through that knowledge. Conducting research from a simultaneous insider/outsider perspective has benefits [75]. We believe that the first and second authors' insider identities, the participant-driven interview approach, and the limited sample size allowed the participants and the first author (interviewer) to establish a deeper level of trust, safety, and vulnerability than could otherwise have been developed in the short data collection timeframe [76]. Each author held a different role in the academy while embodying a spectrum of similar and dissimilar identities, experiences, and perspectives to the participants and the other authors. This helped us (the authors) review and discuss the results from multiple perspectives. We acknowledge the limitations in our own personal and social awareness. Further, we acknowledge the limitations of the language we use and cite in this study. We are actively learning and engaging with others to grow our worldviews, language, and practices.

Results and discussion

We frame and discuss our results within the CAST UDL framework [61]. The UDL framework includes three principles: providing multiple means for (1) representation, (2) action and expression, and (3) engagement. The CAST framework includes guidelines for each principle and checkpoints for each guideline [61]. Below we identify the UDL principles that were reflected in participants' experiences. Based on the interview findings we then offer suggestions to the academic community for implementing the UDL framework in their graduate level STEM courses and research advising practices. We believe the counter narratives we connect to each principle will also offer insights to higher education more broadly.

Representation

Each participant described having difficulty understanding what was being communicated to them. In UDL, this idea is termed representation (see Table 1). The primary topics that the participants described related to representation included information flow management, course modalities, information sharing modalities (e.g., written or oral), and interfacing with assistive technologies. We map the participants' experiences to the three guidelines associated with representation in the following subsections.

Table 1: CAST guidelines for providing multiple means of representation

Representation		
<p>Guideline 1: Provide options for Perception</p> <p>1.1 Offer ways of customizing the display of information</p> <p>1.2 Offer alternatives for auditory information</p> <p>1.3 Offer alternatives for visual information</p>	<p>Guideline 2: Provide options for Language & Symbols</p> <p>2.1 Clarify vocabulary & symbols</p> <p>2.2 Clarify syntax & structure</p> <p>2.3 Support decoding of text, mathematical notation, & symbols</p> <p>2.4 Promote understanding across languages</p> <p>2.5 Illustrate through multiple media</p>	<p>Guideline 3: Provide options for Comprehension</p> <p>3.1 Activate or supply background knowledge</p> <p>3.2 Highlight patterns, critical features, big ideas, and relationships</p> <p>3.3 Guide information processing and visualization</p> <p>3.4 Maximize transfer and generalization</p>

Note: Adapted from CAST website [61]. Copyright CAST. 2020.

Representation: Options for perception

Providing options for perception is a key guideline of UDL. It refers to how an educator provides content to a student (e.g., instructions for submitting a dissertation). This includes offering ways to customize the display of information. The participants emphasized the importance of how information was provided to them. They discussed presentations and formats that served as barriers to their perception. For example, a participant highlighted the importance of using closed captioning with oral communication during online instruction. They also emphasized the importance of recording and documenting all information and supplemental materials so that they can be reviewed later. The participant further stated that they believed that every course offered via a distance education modality needs to have closed captioning and lecture recordings.

A participant described how professors often require them to read journal articles, chapters, and other readings but only provide students with low-quality photocopies which are not screen reader accessible, despite the participant having a formal accommodation for alternative formats. They described how they believed their professors’ intent was to save students money instead of requiring them to purchase textbooks. However, the participant ended up having to purchase multiple texts so that they could obtain their assigned reading in a format accessible to their screen reading software.

Similarly, a participant remarked on how their ability to quickly understand information was impacted by the modality in which the information was delivered (e.g., written, oral, visual, tactile). They emphasized the importance of making sure that everything is communicated in full across all the modalities being used (e.g., written and oral) and not partially communicated over multiple different modalities. For instance, when their classmates typed questions into the

Zoom's chat box and the professor would orally respond without reading the question aloud or providing context, the participant was unable to use either modality to find complete information. This interrupted the participant's learning both inside and outside of class. This was true during class because they could not access the written questions in the chat fast enough. This was also true later when reviewing recorded lectures because the recordings did not include the chat so the participant was unable to find the original question. Both communication methods left the student frustrated and with incomplete information. Aside from repeating questions aloud before responding to student questions, the participant also emphasized the importance of saving and posting the content from lecture forums, polls, and/or chats.

Representation: Options for language and symbols

Providing options for language, mathematical expressions, and symbols is the second UDL guideline related to representation. A participant noted how the articles and texts they were required to read for their coursework and research, even ones that were supposedly screen reader accessible, included mathematical symbols and equations that their screen reader garbled. Specifically, the participant described how the screen readers (the one the university provided and the ones they had paid for themselves) could not read the mathematical equations in one of their textbooks. The time required to read just this one textbook severely limited the time available to them to do their reading assignments for other classes.

Representation: Options for comprehension

The third UDL guideline for the principle of representation is to provide options for comprehension. This guideline advocates for providing the scaffolds necessary to prime, activate, and provide prerequisite knowledge through the proper design and presentation of information. Providing multiple options for comprehension also includes highlighting patterns and relationships, as well as guiding information processing. It also means anchoring instruction by connecting to and activating relevant prior knowledge. A number of student experiences could be improved by attending to these issues.

Staff and faculty serving in advising and teaching roles need to recognize that individuals differ widely in their access to prior knowledge through which they can assimilate new information [61]. This is especially true for students who do not store and recall memory in a neuro-typical fashion. A participant described purchasing classes from Udemy, despite having previously taken those classes during their previous formal studies, because they found it challenging to remember and implement the knowledge they gained in prior coursework. Similarly, a participant described having lost all memory of one or two years of their life except "maybe one memory a year" due to trauma.

As another example, a participant described their frustration with remembering where to find things for their class in the course learning management system (LMS). They stated "Trying to find reading lists, trying to find these things, it's just hell because I don't remember the pathways and then I have to ask somebody." They went on to describe how the first time they asked someone to explain where to find something again "they're like oh yeah here"; however, they wished people wouldn't "fault" them for not remembering something that people believed "they should know" when they had to ask multiple times, saying "Can't you just tell me again?"

Action & expression

A second key principle in UDL is to provide multiple means of student expression and communication (Table 2). Each participant described having difficulty communicating their thoughts to others during their graduate studies. We map the participants' experiences to the guidelines associated with action and expression in the following subsections.

Table 2: CAST guidelines for providing multiple means of action & expression

Action & Expression		
Guideline 4: Provide options for Physical Action	Guideline 5: Provide options for Expression & Communication	Guideline 6: Provide options for Executive Functions
4.1 Vary the methods for response & navigation 4.2 Optimize access to tools & assistive technologies	5.1 Use multiple media for communication 5.2 Use multiple tools for construction & composition 5.3 Build fluencies with graduated levels of support for practice & performance	6.1 Guide appropriate goal-setting 6.2 Support planning & strategy development 6.3 Facilitate managing information & resources 6.4 Enhance capacity for monitoring progress

Note: Adapted from CAST website [61]. Copyright CAST. 2020.

Action & expression: Physical action

Providing options for physical action is another key guideline of UDL. It asserts that “all learners should be given the opportunity to use tools that might help them meet the goal of full participation in the classroom” [61]. A graduate student may benefit from a variety of tools to fully participate in their research and coursework (e.g., tools that could help a student navigate, interact with, and consume large amount of literature).

A participant shared the arduous process of finding and learning how to use tools that might help them better participate in their graduate studies. They explained how their disability services office contact tried giving them two different tools (one they tried out during one semester and the other the subsequent semester) but neither of those tools worked for them. They described “struggling to figure out how to keep up” as they learned how to use each tool and tried adapting it to the research process. After being reprimanded by their adviser for falling behind, they tried pushing forward on their literature review without assistive technology; however, this only led to them falling further behind.

The participant noted that neither their university's Disability Services Office nor research adviser had the resources they needed nor “any idea on how to help someone with different abilities tackle the research.” They tried to find tools on their own, but ultimately found it to be “another effort of finding what doesn't work.” Indeed, the majority of the assistive technology

options provided by student disability services offices focus on meeting the needs of undergraduate student coursework [77], [78]. Therefore, the participants we interviewed may not be alone in feeling they hold the sole responsibility for finding, paying for, and learning how to use tools and assistive technologies as a graduate student.

Action & expression: Expression & communication

Providing students with options to demonstrate their understanding is the second UDL guideline related to expression and communication. The UDL guidance from CAST states that “there is no medium of expression that is equally suited for all learners or for all kinds of communication” [61]. CAST further asserts that it is important for each learner to learn their optimal medium for communicating any particular content of expression [61]. These ideas were evident in the stories shared by the participants.

A participant described having difficulty communicating with their advisor. The participant felt comfortable communicating orally but found it more difficult to express themselves in writing; however they stated that their advisor “managed me by telling me how [they] needed to receive information from me ...[they] needed to see things in writing”. This applied in both the individualized instruction setting of research between the participant(s) and their advisor(s) as well as in their coursework. For example, a participant hired tutors to help them work through problems in a course. The participant was able to successfully communicate their understanding verbally with their tutors. However, they were unable to successfully demonstrate their understanding on their written exams for the course.

Oh, the tutors that I found were great. We would go through problems together. I would explain verbally my understanding of the problem and then they would show me what that looks like in terms of like ‘R’ [software/programming] equations or something.... But I mean it was weird. To them, the way I was able to verbally communicate these... ‘like, okay you're understanding this,’ ‘you’re understanding! You’re understanding!’ I said, ‘I feel like I do. I really feel like I do.’ And then, when I took the test, I totally bombed it. In fact, every test that I took in that class I felt like I did well on. And I did not. I did horribly. So it was very weird.

CAST also notes that it is important for students to learn the optimal medium for their audience. Looking back at the first experience in this subsection, the participant’s optimal medium of communication was oral expression, while their adviser’s was written expression. The challenge is to find what combination of communication methods would work for both parties and for the person in the position of power to accept that each student may need to use different methods to connect especially if the student’s most effective mode of communication differs from the advisor’s. Similarly, this balance may need to be found in doctoral and master’s examination committees—e.g., the format (oral, written, or combination) of a student’s defense.

Action & expression: Executive functions

The third UDL framework guideline for expression and communication is to provide options for executive functions. This acknowledges that learners will not necessarily set appropriate goals to guide their work. Indicative of this issue, a participant felt they were not getting the coaching from their adviser that they believed other students were getting. They felt lost, not knowing

where to start. They did not know what equipment and methods existed for them to use, how to design a research study, nor put together a literature review or research proposal. They described their frustration when their adviser told them they were falling behind because they had not yet taken a required PhD qualifying exam. Their frustration was not with the requirements themselves but with not knowing the scope and timing of the exam until after they were supposed to have already taken the exam. Realizing that other students seemed to be getting coaching and guidance on these things, they noted that perhaps they had received coaching on these expectations but had not perceived it as such. During the interview process, the student realized that there might have been a disconnect between their adviser's representation of expectations and the participant's perception of what had been conveyed.

Beyond the cascading academic consequences of this potential failure in communication, the participant noted the time, money, and energy spent as “struggle on my own” and “hunt down” everything they learned. For example, the participant did not know what a literature review entailed. Thus, they exerted an immense amount of time and executive functioning searching for different examples to piece together what one is and what they needed to do to create one.

A vital component of graduate training is to support an individual in becoming an independent researcher. Some graduate programs include an Introduction to Research Methods course that presumably covers this content. This would likely be helpful to students in all research-based programs. We recommend academic advisers work with each of their advisees to help them learn to develop appropriately challenging goals, plans, and strategies to guide their research. Working with graduate students in such a way has the potential to help both parties recognize unnamed assumptions and find a coaching approach that works well for both the student and adviser.

Additionally, a participant noted that the way written/electronic communication was delivered and stored mattered. The participant explained that they did not “know what’s going on” whenever a class or team used Slack or Discord platforms. They explained this was because they had to turn off the notifications from these platforms to be able to focus; however, they would forget to check the platforms without the notifications. In contrast, they described how limiting such communications to texting helped them remember where to find information regarding their research and remember to go to research meetings. Similarly, a participant described “spinning around” from the difficulty of trying to remember where to find communications across the multiple messaging platforms used in their different classes and groups. They described their frustration at being expected to “dig” through their institution’s online learning management systems (LMS) and groups’ Google drives to find content. While in theory an online LMS can make managing information and resources easier (especially during the shift to remote instruction), it can also create challenges. An organizational structure that is logical to one person may not be equally logical to others.

Another facet of supporting executive functions is to facilitate managing information and resources. One participant noted how helpful it was when their instructor eased into class by reviewing the previous class, demonstrating where content could be found, and directly linking anything that was needed for the lecture in the chat. Similarly, they noted how helpful it was when this instructor contextualized content and summarized, expanded upon, repeated, and reviewed instructions. In UDL, the instructor’s practice is referred to as facilitating managing

information and resources. This might be particularly helpful for students who struggle with organization [79].

Recommendations

Following the UDL guidelines can increase an individual's capacity to engage in executive functions, improve their productivity, and give them the support they need to fully participate in their educational environment. In this section we apply the participant's experiences to the CAST UDL guidelines to offer recommendations to the academic community. Individual faculty and course instructors cannot be solely responsible for making graduate education more accessible. We outline opportunities in Tables 3-6 for faculty/instructors teaching or supervising the research of graduate students, programs/departments, and graduate schools/colleges.

We try to provide a broad list of recommendations. However, we would like to note that a simple first step could be providing multiple methods of information sharing, such as presenting information in written and oral modalities. Additionally, recording lectures and providing optional closed captioning⁷ are simple opportunities to make online courses and meetings more accessible. Please note that in addition to the opportunities listed below recommendations can be found on the CAST website [61].

Table 3: Recommendations regarding differentiated instruction and feedback for faculty and instructors teaching graduate coursework and advising/supervising graduate student research

Differentiated Andragogical and Advising Practices for Faculty/Instructors
<p>Provide differentiated (tailored to individual student needs) feedback, communication, and instruction (see, for example, differentiated classroom instruction [83], [84])</p> <ol style="list-style-type: none">1. Work with each student to support their memory and ability to draw connections to the concepts they have learned throughout their coursework/experience by incorporating explicit opportunities for students to review, practice, revisit, and metacognitively reflect on critical prerequisite concepts in lectures/research meetings.2. Encourage students to experiment with different notetaking modalities (e.g., concept maps, graphic organizers, checklists, dictated notes, and color-coded annotations).3. Communicate instructions, feedback, updates, and action items verbally during meetings, as well as via multimedia formats (e.g., a video/audio recording/ voice mail) and text (e.g., email/instant message, Google doc, captions, or printed handouts).4. Emphasize key information with verbal cues, repetition, and visual highlighting.5. Help students create digital or printed guides, templates, graphic representations, flow charts, and/or electronic reminders related to their dissertation/thesis research topic/scope, literature review, methods, findings, milestones, and expectations.

⁷ Providing students with captioning can improve comprehension, attention, and memory [80]. While imperfect, educators can use automated speech to text software (see, for example, [81]) to provide students (in person or remote) with closed captioning (tuned on/off by viewer) on their laptops or mobile devices, so long as the speaker is within range or a connected microphone. Programs like PowerPoint and google slides provide open captioning (turned on/off for everyone by the presenter); however, this may not be ideal as some people find captioning distracting [82].

Table 4: Recommendations regarding materials and content for faculty and instructors teaching graduate coursework and advising/supervising graduate student research

Recommendations Regarding Content and Materials for Faculty/Instructors
<p>Provide materials and content (e.g., slides, assignment prompts, handouts, articles, media, links to websites and references/readings)</p> <ol style="list-style-type: none">1. In multiple formats or modalities (e.g., oral/auditory delivery with transcription, digital materials with printed/tactile materials, and text with graphics).2. That are accessible to screen readers, include alternate (alt) text, and provide captions for in-text descriptions for figures, graphics, and equations (if they include text).3. With sans serif font, large print (≥ 16pt), and high color contrast. If using color coding, temporarily convert document to grayscale and check if the contrast is distinguishable.4. In an editable format (shared via QR code and link if printed) so the student can adjust<ol style="list-style-type: none">a. the font, size, color, contrast, line spacing, and kerning in text-based files⁸.b. volume, speed, and closed captioning in video/audio files.5. Using techniques such as process-driven math⁹ to decode mathematical notation.

Table 5: Recommendations for program/department staff for campus partnerships & offerings

Graduate Program/Department Offerings
<ol style="list-style-type: none">1. Identify and provide a variety of assistive technologies that could help dis/abled and “abled” graduate students fully participate in navigating, interacting with, and composing independent research in their field.2. Recruit a department/program taskforce for diversity, equity, and inclusion¹⁰ similar to those previously suggested for mental health [52] and student success [94].<ol style="list-style-type: none">a. Review department culture, practices, policies, curriculum, hiring, and budgets to identify barriers and opportunities for diversity, equity, and inclusion.b. Periodically collaborate with faculty leaders to create and offer discipline specific and culturally appropriate faculty training on inclusive andragogy, UDL, and embedding assistive technology options into their courses.

⁸ Additional information on creating accessible materials is available at the following links: [creating accessible flyers/infographics](#) [85], [printed posters](#) [86], [presentations](#) [87], [audience-specific content considerations](#) [88], [the Microsoft sweet accessibility checker](#) [89], and [the Acrobat Pro PDF accessibility checker](#) [90]. This paper is designed for digital use; if viewing a printed version, note the full URLs are provided in the References section.

⁹ The process-driven approach overcomes the “garbling” of equations by breaking complex equations down into their components and subcomponents in the text descriptions of the equation. See, for example, [91], [92].

¹⁰ This taskforce could include students and faculty leaders as well as external stakeholder such as Student Affairs, Diversity offices, Disability Services, Counseling offices, and Human Resources.

Table 6: Recommendations for graduate school and college staff for offerings

Graduate School, College, or University Offerings
<ol style="list-style-type: none">1. Provide college wide or university wide graduate student bridge programs, orientations, seminars, and/or short courses offered by the college or graduate school to help students learn about their specific learning and access needs.<ol style="list-style-type: none">a. Provide students training on planning and strategy development. Focus on helping students learn to set goals through graduated scaffolds (breaking components into smaller elements that are both challenging and realistic) and reachable short-term objectives.<ol style="list-style-type: none">i. Help students estimate the effort and difficulty of tasks so that if a task is taking significantly more time or cognitive resources than expected, the student can pause and check in on their understandingii. Encourage and remind students to develop healthy task management and self-care practices that incorporate regular breaks (such as using a Pomodoro app, see for example, [93])2. Provide students with resources in a variety of modalities especially for assessment/placement-based resources<ol style="list-style-type: none">a. Readings, video tutorials, handouts, examples, assignments, modules, recitation/review sessions, mentor pairing, and even course recommendationsb. Guides for data collection, note taking, categorizing, and systematizingc. Connect students with coaches/mentors that model think-alouds of the process3. Periodically collaborate with the student and employee disability services/accommodations offices, programs/departments leaders to identify and provide various resources, assistive technology options, and training.

We hope university faculty and staff work together to proactively create physical and virtual learning environments that are more inclusive and universally accessible by following the principles of UDL. Our culture and perception of diversity, roles, student needs, and students' prior knowledge can block progress toward inclusivity [95]–[98]. While individual faculty and staff may be able to incorporate the recommendations we provide, we must work collectively to effectively create a more inclusive learning experience. We must create communities of practice that encourage each of us to critically examine our practices [99]. Through such communities, we must engage in conversation with those who have diverse opinions to identify and critically examine our assumptions [95], [96] and practices through a lens critical of systemic oppression and ableism [99].

Concluding remarks

Increasing the completion rates for graduate STEM studies, in ways that support the full breadth of students now enrolled in graduate studies, is a moral imperative. Finding a dearth of knowledge related to the experiences of graduate students with dis/abilities, we sought to explore, motivate, and prioritize future areas of research. During this process we identified barriers to success that were being experienced by dis/abled STEM graduate students. Neither the interview questions nor the original study design incorporated UDL as an explicit lens to

explore the participant's experiences. However, when we went back through the data, we noticed a striking resemblance in the challenges the participants were facing and the barriers the first two UDL principles ("Representation" and "Action & expression") were designed to prevent. This paper maps the participant's experiences with these barriers to the UDL principles that could eliminate them and builds on the guidelines in the CAST UDL framework to offer recommendations on how to expand access within STEM graduate programs. We believe that the use of UDL in graduate programs would help to increase the number of qualified students who are able to successfully navigate the requirements of STEM graduate programs.

We recognize that this paper includes many potential actions that faculty could incorporate into their courses and individual research advising activities. There is no expectation that anyone can incorporate all of these at one time, but we recommend that faculty and others find a small number of actions that they could implement each semester or year. We also encourage faculty advisers, departments, and instructors to consider what strengths their approaches to advising, curricula, and instruction already have (what UDL guidelines they may already be following) and how they might use those strengths as a foundation to build upon.

Acknowledgments

We would like to thank the participants for their vulnerability in sharing their stories. We would also like to thank them for their contribution to co-analyzing the data in the broader study.

This work was conducted while we (the authors) were employed by the University of Colorado Boulder. We honor and acknowledge that the University is located on the land of the Ute, Cheyenne, and Arapaho peoples. Further, we acknowledge that 48 contemporary tribal nations are historically tied to the lands that make up the state of Colorado. Although we do not disclose the land where each of the participants was located during this study, we honor the Tribal Nations to whom each land belongs. We recognize the Indigenous peoples as the original stewards of the land, water, plants, and animals who called these places home. We also acknowledge the painful history of genocide and forced removal from these territories. We respect the many diverse Indigenous peoples still connected to these lands. We pay our respect to them and give thanks to all Tribal Nations and the ancestors of these territories.

We have no conflicts of interest to report.

References

- [1] M. Lizotte and S. Clifford Simpican, "Doctoral Students With Disabilities: Challenges In Graduate Programs And Research Methodology," *J. Study Postsecond. Tert. Educ.*, vol. 2, pp. 181–193, 2017, doi: doi.org/10.28945/3900.
- [2] Center for Disease Control and Prevention, "CDC: 1 in 4 US adults live with a disability," *CDC Newsroom*, 2018. <https://www.cdc.gov/media/releases/2018/p0816-disability.html#:~:text=One%20in%204%20U.S.%20adults,affects%201%20in%207%20ad ults>. (accessed May 13, 2022).
- [3] National Center for Education Statistics, "Table 311.10. Number and percentage distribution of students enrolled in postsecondary institutions, by level, disability status, and selected

- student characteristics: 2015–16 [Data Table],” *Digest of education statistics*, 2018. https://nces.ed.gov/programs/digest/d20/tables/dt20_311.10.asp (accessed May 02, 2022).
- [4] L. Newman *et al.*, “The Post-High School Outcomes of Young Adults With Disabilities up to 8 Years After High School,” U.S. Department of Education, 2011. Accessed: May 02, 2022. [Online]. Available: <https://ies.ed.gov/ncser/pubs/20113005/pdf/20113005.pdf>
- [5] D. L. Reinholz and S. W. Ridgway, “Access Needs: Centering Students and Disrupting Ableist Norms in STEM,” *CBE—Life Sci. Educ.*, vol. 20, no. 3, p. es8, Sep. 2021, doi: 10.1187/cbe.21-01-0017.
- [6] R. Vergunst and L. Swartz, “‘He doesn’t understand that he’s struggling with the way I felt’ – university students, psychosocial disability and disclosure in the Western Cape, South Africa,” *Disabil. Soc.*, vol. 36, no. 2, pp. 226–239, 2021, doi: 10.1080/09687599.2020.1730159.
- [7] National Center for Science and Engineering Statistics, “Table 9-8 Employed scientists and engineers, by occupation, highest degree level, and disability status: 2019,” National Science Foundation, National Survey of College Graduates. [Online]. Available: <https://nces.nsf.gov/pubs/nsf21321/data-tables>
- [8] Institute of Education Sciences (IES), “Use the Data: Access IPEDS data submitted to NCES through our data tools or download the data to conduct your research,” *IPEDS Integrated Postsecondary Education Data System*. <https://nces.ed.gov/ipeds/use-the-data> (accessed Feb. 18, 2022).
- [9] K. P. Powers, “Graduate Student Graduation and Completion Rates Long Overdue,” *Institutes for Effectiveness in Higher Education*, 2021. <https://instituteforeffectiveness.org/graduate-student-graduation-and-completion-rates/> (accessed Feb. 02, 2022).
- [10] S. E. Hinz, C. A. Arbeit, and A. Bentz, “Table 11 in Characteristics and Outcomes of Undergraduates With Disabilities,” U.S. Department of Education, National Center for Education Statistics, NCES 2018-432, 2017. Accessed: Feb. 18, 2022. [Online]. Available: <https://nces.ed.gov/pubs2018/2018432.pdf>
- [11] M. Wagner, L. Newman, R. Cameto, N. Garza, and P. Levine, “After High School: A first look at the postschool experiences of youth with disabilities,” U.S. Department of Education, 2005.
- [12] Council of Graduate Schools, “Degree Completion,” *Best Practices*. <https://cgsnet.org/degree-completion> (accessed Feb. 01, 2022).
- [13] M. S. Knowles, *The modern practice of adult education: From pedagogy to andragogy*. New York, NY: Cambridge, The Adult Education Company, 1980. [Online]. Available: https://www.umsl.edu/~henschkej/articles/a_The_%20Modern_Practice_of_Adult_Education.pdf
- [14] A. Jacklin, “To be or not to be ‘a disabled student’ in higher education: the case of a postgraduate ‘non-declaring’ (disabled) student,” *J. Res. Spec. Educ. Needs*, vol. 11, no. 2, pp. 99–106, 2011, doi: 10.1111/j.1471-3802.2010.01157.x.
- [15] D. Goodley, “Dis/entangling critical disability studies,” *Disabil. Soc.*, vol. 28, no. 5, pp. 631–644, Jul. 2013, doi: 10.1080/09687599.2012.717884.
- [16] F. K. Campbell, *Contours of ableism: Territories, objects, disability’ and desire*. London, England: Palgrave Macmillan, 2009. [Online]. Available: <https://doi-org.colorado.idm.oclc.org/10.1057/9780230245181>

- [17] F. A. K. Campbell, "Exploring internalized ableism using critical race theory," *Disabil. Soc.*, vol. 23, no. 2, pp. 151–162, Mar. 2008, doi: 10.1080/09687590701841190.
- [18] Stop Ableism, "What is Ableism?," *Stop Ableism*, 2022. <http://www.stopableism.org/p/what-is-ableism.html> (accessed Apr. 26, 2022).
- [19] Sins Invalid, *Skin, Tooth, and Bone: The Basis of Movement is Our People*, 2nd ed. Berkeley CA, 2019. [Online]. Available: sinsinvalid.org
- [20] K. Crenshaw, "Mapping the margins: Intersectionality, identity politics, and violence against women of color.," *Stanford Law Rev.*, vol. 43, no. 6, p. 1241, 1991.
- [21] K. Crenshaw, "Demarginalizing the intersection of race and sex: A black feminist critique of antidiscrimination doctrine, feminist theory, and antiracist politics," *Univ. Chic. Leg. Forum*, pp. 138–167, 1989.
- [22] P. Hill Collins, *Intersectionality as Critical Social Theory*. Duke University Press, 2019. doi: 10.1515/9781478007098.
- [23] D. L. Hosking, "Critical Disability Theory," presented at the 4th Biennial Disability Studies Conference, Lancaster University, UK, 2008. [Online]. Available: https://www.lancaster.ac.uk/fass/events/disabilityconference_archive/2008/papers/hosking2008.pdf
- [24] T. J. Yosso, "Whose culture has capital? A critical race theory discussion of community cultural wealth," *Race Ethn. Educ.*, vol. 8, no. 1, pp. 69–91, 2005, doi: 10.1080/1361332052000341006.
- [25] S. A. Annamma, B. Ferri, and D. J. Connor, "Critical Race Theory: Exploring the Intersectional Lineage, Emergence, and Potential Futures of DisCrit in Education," *Rev. Res. Educ.*, vol. 42, no. 1, pp. 46–71, 2018, doi: 10.3102/0091732X18759041.
- [26] B. L. Auterman, "structural Ableism: Disability, Institutionalized Discrimination, and Denied Citizenship," Sarah Lawrence College, 2011. [Online]. Available: <https://www.proquest.com/dissertations-theses/structural-ableism-disability-institutionalized/docview/873567441/se-2?accountid=14503>
- [27] D. Goodley, R. Lawthom, K. Liddiard, and K. Runswick-Cole, "Provocations for Critical Disability Studies," *Disabil. Soc.*, vol. 34, no. 6, pp. 972–997, Jul. 2019, doi: 10.1080/09687599.2019.1566889.
- [28] Disabled World, "Invisible Disabilities: List and General Information," *Disabled World*, 2021. <https://www.disabled-world.com/disability/types/invisible/>
- [29] J. Wissel and L. Feingold, "'Non-apparent disability' vs. 'Hidden' or 'Invisible disability' – which term is correct?," *Disability: In Monthly Digital Accessibility Highlights*, 2022. <https://disabilityin.org/mental-health/non-apparent-disability-vs-hidden-or-invisible-disability-which-term-is-correct/>
- [30] G. Thompson, "Accommodating invisible disabilities in the workplace," *Accessibility for Ontarians with Disabilities Act*, 2018. <https://aoda.ca/accommodating-invisible-disabilities-in-the-workplace-2> (accessed Dec. 21, 2021).
- [31] S. K. Kattari, M. Olzman, and M. D. Hanna, "'You Look Fine!': Ableist Experiences by People With Invisible Disabilities," *Affilia*, vol. 33, no. 4, pp. 477–492, Nov. 2018, doi: 10.1177/0886109918778073.
- [32] R. J. Orlando, "Gimp anthropology: Non-apparent disabilities and navigating the social," Rice University, Houston, Texas, 2012. [Online]. Available: <https://www.proquest.com/dissertations-theses/gimp-anthropology-non-apparent-disabilities/docview/1266049298/se-2?accountid=14503>

- [33] The Disability Unit, “Living with Non-Visible Disabilities,” *GOV.UK*, 2020. <https://disabilityunit.blog.gov.uk/2020/12/17/living-with-non-visible-disabilities/>
- [34] *Americans with Disabilities Act of 1990*. 1990.
- [35] M. Oliver, “If I had a hammer: The social model in action.,” in *The social model of dis/ability - Theory and research*, C. Barnes, Ed. Leeds: The Disability Press, 2004, pp. 18–31.
- [36] D. Goodley, *Disability’ studies: An interdisciplinary introduction*. London: SAGE Publications, 2011.
- [37] N. Erevelles, *Disability and Difference in Global Contexts: Towards a Transformative Body Politic*, vol. null. 2012.
- [38] R. McRuer, *Crip theory: Cultural signs of queerness and disability*. New York: New York: New York University Press, 2006.
- [39] F. LeFrançois, R. Menzies, and G. Reaume, *Mad Matters: A Critical Reader in Canadian Mad Studies*, vol. null. 2013.
- [40] M. Shildrick, *Dangerous discourses of disability, subjectivity and sexuality*. London England: Palgrave Macmillian, 2009.
- [41] R. E. Black, L. A. Weinberg, and M. G. Brodwin, “Universal design for learning and instruction: Perspectives of students with disabilities in higher education,” *Except. Educ. Int.*, vol. 25, no. 4, pp. 1–26, 2015, doi: 10.5206/eei.v25i2.7723.
- [42] D. Milton, N. Martin, and P. Melham, *Chapter 12 Beyond reasonable adjustment: autistic-friendly spaces and Universal Design*. Hove: Pavilion Publishing and Media, 2016. [Online]. Available: <https://openresearch.lsbu.ac.uk/item/8715v>
- [43] K. L. Sherwood and S. K. Kattari, “Reducing Ableism in Social Work Education Through Universal Design for Learning and Policy,” *J. Soc. Work Educ.*, 2021, doi: 10.1080/10437797.2021.1997686.
- [44] H. Pearson and B. Dickens, “(Re)framing qualitative research as a prickly artichoke: Peeling back the layers of structural ableism within the institutional research process,” in *Centering Diverse Bodies in Critical Qualitative Inquiry*, 1st ed., J. N. Lester and E. A. Nusbaum, Eds. London, England: Routledge, 2021.
- [45] S. Grimes, J. Scevak, E. Southgate, and R. Buchanan, “Non-disclosing students with disabilities or learning challenges: characteristics and size of a hidden population,” *Aust. Educ. Res.*, vol. 44, no. 4, pp. 425–441, 2017, doi: 10.1007/s13384-017-0242-y.
- [46] S. Grimes, “Student Suggestions for Improving Learning at University for Those with Learning Challenges/Disability,” in *Strategies for Supporting Inclusion and Diversity in the Academy: Higher Education, Aspiration and Inequality*, G. Crimmins, Ed. Cham: Springer International Publishing, 2020, pp. 329–352. doi: 10.1007/978-3-030-43593-6_17.
- [47] M. L. Sanchez-Pena, N. Ramirez, X. R. Xu, and D. B. Samuel, “Work in Progress: Measuring Stigma of Mental Health Conditions and Its Impact in Help-seeking Behaviors Among Engineering Students,” presented at the 2021 ASEE Virtual Annual Conference, 2021. [Online]. Available: <https://peer.asee.org/38181>
- [48] J. R. Karpicz, “‘Just My Being Here is Self-Advocacy’: Exploring the Self-Advocacy Experiences of Disabled Graduate Students of Color.,” *JCSCORE*, vol. 6, no. 1, pp. 137–163, 2020.
- [49] M. Mingus, *Femmes of Color 2011, Keynote by Mia Mingus*, (Aug. 2011). [Keynote Address]. Available: <https://leavingevidence.wordpress.com/2011/08/22/movingtoward-the-ugly-a-politic-beyond-desirability/>

- [50] E. Seymour and A.-B. Hunter, Eds., *Talking about Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education*, 1st ed. Springer, 2019. [Online]. Available: 10.1007/978-3-030-25304-2
- [51] F. Fovet, "Chapter 9: Using universal design for learning as a lens to rethink graduate education pedagogical practices," in *Reshaping Graduate Education Through Innovation and Experiential Learning*, T. S. Jenkins, Ed. IGI Global, 2021.
- [52] A. Khan, "Improving STEM Graduate Students' Mental Health and Wellbeing. The Organizational Improvement Plan at Western University, 192," 2021. [Online]. Available: <https://ir.lib.uwo.ca/oip/192>
- [53] C. Hockings, "Inclusive learning and teaching in higher education: a synthesis of research," York: Higher Education Academy, 2010. [Online]. Available: <https://www.advance-he.ac.uk/knowledge-hub/inclusive-learning-and-teaching-higher-education-synthesis-research>
- [54] J. M. Ardeljan, "Navigating Graduate School: It's All About the Process (opinion)," *Inside Higher Ed.*, 2021. <https://www.insidehighered.com/advice/2021/10/18/how-navigate-unwritten-rules-graduate-school-opinion> (accessed Feb. 18, 2022).
- [55] "Hidden Curriculum," *The Glossary of Education Reform*, 2015. <https://www.edglossary.org/hidden-curriculum/> (accessed Feb. 18, 2022).
- [56] I. Villanueva *et al.*, "What Does Hidden Curriculum in Engineering Look Like and How Can It Be Explored," presented at the 2018 ASEE Annual Conference & Exposition, Salt Lake City, UT, 2018. doi: 10.18260/1-2--31234.
- [57] D. Fidelak and K. Rodier, "Incorporating Academic Strategy Instruction in Assignment Design to Remove Barriers to Writing Assignments in Philosophy," in *Handbook of Research on Applying Universal Design for Learning Across Disciplines: Concepts, Case Studies, and Practical Implementation*, F. Fovet, Ed. 2021, p. 18. [Online]. Available: 10.4018/978-1-7998-7106-4
- [58] J. Pensky, C. Richardson, A. Serrano, G. Gorski, A. N. Price, and M. Zimmer, "Disrupt and demystify the unwritten rules of graduate school," *Nat. Geosci.*, vol. 14, no. 8, pp. 538–539, Aug. 2021, doi: 10.1038/s41561-021-00799-w.
- [59] Ohio Center for Autism and Low Incidence, "History of UDL A Brief Overview," *Learn about UDL*. https://www.ocali.org/project/learn_about_udl/page/udl_history (accessed Feb. 02, 2022).
- [60] National Disability Authority, "What is Universal Design?," *The Center for Excellence in Universal Design*, 2020. <https://universaldesign.ie/what-is-universal-design/> (accessed Feb. 02, 2022).
- [61] CAST, "About Universal Design for Learning," 2020. http://www.cast.org/our-work/about-udl.html#.X01_z-hKiUl (accessed Dec. 11, 2020).
- [62] K. D. Roberts, H. J. Park, S. Brown, and B. Cook, "Universal Design for Instruction in Postsecondary Education: A Systematic Review of Empirically Based Articles," *J. Postsecond. Educ. Disabil.*, vol. 24, no. 1, pp. 5–15, 2011.
- [63] J. McGinty, "Accessibility and Inclusion in Higher Education: An Inquiry of Faculty Perceptions and Experiences," Dissertation, Colorado State University, Fort Collins, CO, 2016.
- [64] S. A. Stolz, "Phenomenology and phenomenography in educational research: A critique," *Educ. Philos. Theory*, vol. 52, no. 10, pp. 1077–1096, Aug. 2020, doi: 10.1080/00131857.2020.1724088.

- [65] K. Jarrett and R. Light, "The experience of teaching using a game based approach: Teachers as learners, collaborators and catalysts.," *Eur. Phys. Educ. Rev.*, vol. 25, no. 2, pp. 565–580, 2019.
- [66] N. Kellam, K. Sweeney, and J. Walther, "Narrative Analysis in Engineering Education Research: Exploring Ways of Constructing Narratives to Have Resonance with the Reader and Critical Research Implications," presented at the 2015 ASEE Annual Conference & Exposition, Seattle, Washington, 2015. doi: 10.18260/p.24521.
- [67] J. W. Creswell, *Research Design*, 4th ed. Thousand Oaks, CA: SAGE Publications, 2014.
- [68] S. Tracy, *Qualitative Research Methods: Collecting Evidence, Crafting Analysis, Communicating Impact*. West Sussex, United Kingdom: Blackwell LTD, 2013. [Online]. Available: [https://ucblibraries.skillport.com/skillportfe/main.action?assetid=RW\\$16699:_ss_book:143097#summary/BOOKS/RW\\$16699:_ss_book:143097](https://ucblibraries.skillport.com/skillportfe/main.action?assetid=RW$16699:_ss_book:143097#summary/BOOKS/RW$16699:_ss_book:143097)
- [69] L. Harvey, "Beyond member-checking: a dialogic approach to the research interview," *Int. J. Res. Method Educ.*, vol. 38, no. 1, pp. 23–38, 2015, doi: 10.1080/1743727X.2014.914487.
- [70] S. J. Tracy, "Qualitative Quality: Eight 'Big-Tent' Criteria for Excellent Qualitative Research," *Qual. Inq.*, vol. 16, no. 10, pp. 837–851, Dec. 2010, doi: 10.1177/1077800410383121.
- [71] H. Rubin and I. Rubin, *Qualitative interviewing: the art of hearing data*. CA: SAGE Publications, 2012.
- [72] J. Saldana, *The coding manual for qualitative researchers*, 3rd ed. Thousand Oaks, CA: SAGE Publications, 2016.
- [73] J. Lofland, D. A. Snow, L. Anderson, and L. Lofland, *Analyzing Social Settings: A Guide to Qualitative Observation and Analysis*. Cengage Learning, 2006.
- [74] The Trustees of Indiana University, "Institution Lookup," *The Carnegie Classification of Institutions of Higher Education*, 2021. <https://carnegieclassifications.iu.edu/lookup/lookup.php> (accessed Jan. 15, 2022).
- [75] S. C. Dwyer and J. L. Buckle, "The Space Between: On Being an Insider-Outsider in Qualitative Research. International Journal of Qualitative Methods," pp. 54–63, 2009, doi: 10.1177/160940690900800105.
- [76] D. Bridges, "'Nothing About Us Without Us': The Ethics of Outsider Research," in *Philosophy in Educational Research: Epistemology, Ethics, Politics and Quality*, D. Bridges, Ed. Cham, Switzerland: Springer International Publishing, 2017, pp. 341–361. doi: 10.1007/978-3-319-49212-4_20.
- [77] D. C. Beardmore, "Navigating the academy in the absence of graduate disability accommodation policies," New Orleans, Louisiana, 2022, p. Paper ID #35572.
- [78] A. Lillywhite and G. Wolbring, "Undergraduate Disabled Students as Knowledge Producers including Researchers: A Missed Topic in Academic Literature," *Educ. Sci.*, vol. 9, no. 4, p. 259, 2019, doi: 10.3390/educsci9040259.
- [79] D. Jansen, K. Petry, E. Ceulemans, S. van der Oord, I. Noens, and D. Baeyens, "Functioning and participation problems of students with ADHD in higher education: which reasonable accommodations are effective?," *Eur. J. Spec. Needs Educ.*, vol. 32, no. 1, pp. 35–53, Jan. 2017, doi: 10.1080/08856257.2016.1254965.
- [80] M. A. Gernsbacher, "Video Captions Benefit Everyone," *Policy Insights Behav. Brain Sci.*, vol. 2, no. 1, pp. 195–202, Oct. 2015, doi: 10.1177/2372732215602130.

- [81] B. Turner, “Best speech-to-text software in 2022: Free, paid and online voice recognition apps and services,” *techradar.pro*, 2022. <https://www.techradar.com/news/best-speech-to-text-app> (accessed May 13, 2022).
- [82] J. Povey, “The Open Captioning Accessibility War, and a Solution,” 2020. <https://jenniferrpovey.medium.com/the-closed-captioning-accessibility-war-and-a-solution-e760db3f4a02> (accessed May 13, 2022).
- [83] M. Darra and E.-M. Kanellopoulou, “The Implementation of the Differentiated Instruction in Higher Education: A Research Review,” *Int. J. Educ.*, vol. 11, p. 151, Sep. 2019, doi: 10.5296/ije.v11i3.15307.
- [84] T. Santangelo and C. A. Tomlinson, “The application of differentiated instruction in postsecondary environments: Benefits, challenges, and future directions,” *Int. J. Teach. Learn. High. Educ.*, vol. 20, no. 3, pp. 307–323, 2009.
- [85] Universal Design Center, “Flyers & Infographics Accessibility (A11y),” California State University Northridge, 2022. Accessed: May 13, 2022. [Online]. Available: https://www.csun.edu/sites/default/files/flyers_infographics.pdf
- [86] S. F. Gilson and M. R. Kitchin, “Guidelines for Creating Accessible Printed Posters.” 2007. Accessed: May 14, 2022. [Online]. Available: https://www.aucd.org/docs/annual_mtg_2008/accessibility_posters_gilson2007.pdf
- [87] Microsoft, “Make your PowerPoint presentations accessible to people with disabilities,” *Office Support*, 2022. <https://support.microsoft.com/en-us/office/make-your-powerpoint-presentations-accessible-to-people-with-disabilities-6f7772b2-2f33-4bd2-8ca7-dae3b2b3ef25> (accessed May 14, 2022).
- [88] K. Pun, “Dos and don’ts on designing for accessibility,” *Accessibility in government*, 2016. <https://accessibility.blog.gov.uk/2016/09/02/dos-and-donts-on-designing-for-accessibility/> (accessed May 14, 2022).
- [89] Microsoft, “Rules for the Accessibility Checker,” *Office Support*, 2022. <https://support.microsoft.com/en-us/office/rules-for-the-accessibility-checker-651e08f2-0fc3-4e10-aaca-74b4a67101c1> (accessed Apr. 13, 2022).
- [90] Adobe, “Create and verify PDF accessibility (Acrobat Pro),” *Acrobat User Guide*, 2022. <https://helpx.adobe.com/acrobat/using/create-verify-pdf-accessibility.html> (accessed Apr. 14, 2022).
- [91] Y. Pearson, A. P. Gulley, C. Phillips, L. Prickett, L. Smith, and M. Ragland, “Process-Driven Math: Impacts, Innovations, and Insights for Prospective Investigators,” *Virtual*, 2022.
- [92] “The Logan Project,” *Auburn University At Montgomery*, 2019. <https://www.aum.edu/academics/academic-support/warhawk-academic-success-center/learning-center/logan-project/> (accessed Feb. 14, 2022).
- [93] M. Memon, “The science behind the pomodoro technique and how it helps supercharge your productivity,” *Focus booster*, 2019. <https://www.focusboosterapp.com/blog/the-science-behind-the-pomodoro-technique/> (accessed Feb. 18, 2022).
- [94] J. Shalini Collins and S. V. Olesik, “The Important Role of Chemistry Department Chairs and Recommendations for Actions They Can Enact to Advance Black Student Success,” *J. Chem. Educ.*, vol. 98, no. 7, pp. 2209–2220, 2021, doi: 10.1021/acs.jchemed.0c01329.
- [95] C. Hockings, S. Cooke, and M. Bowl, “Learning and teaching for social diversity and difference in higher education,” Economic and Social Research Council, Colchester, Essex, RES-139-25-0222, 2008. [Online]. Available: 10.5255/UKDA-SN-850016

- [96] M. Koro-Ljungberg, “‘Democracy to come’: a personal narrative of pedagogical practices and ‘Othering’ within a context of higher education and research training,” *Teach. High. Educ.*, vol. 12, no. 5–6, pp. 735–747, 2007, doi: 10.1080/13562510701596331.
- [97] N. Zepke and L. Leach, “Improving student outcomes in higher education: New Zealand teachers’ views on teaching students from diverse backgrounds,” *Teach. High. Educ.*, vol. 12, no. 5–6, pp. 655–668, 2007, doi: 10.1080/13562510701596190.
- [98] J. Shaw, B. Brain, K. Bridger, J. Foreman, and I. Reid, “Embedding widening participation and promoting student diversity: What can be learned from a business case approach?,” York: Higher Education Academy, 2007.
- [99] E. J. Hutcheon and G. Wolbring, “Voices of ‘disabled’ post secondary students: Examining higher education ‘disability’ policy using an ableism lens.,” *J. Divers. High. Educ.*, vol. 5, no. 1, pp. 39–49, 2012, doi: <https://doi.org/10.1037/a0027002>.