Understanding the Relationships Between Disability, Engineering, and the Design of Engineering Course Websites Through Disabled Engineering Students' Perspectives

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Academic Abstract

This dissertation examines the culture and climate of disabled people and the disability community within society and the engineering field and the experience of disabled students in higher education. The theoretical lenses utilized is the Technology Acceptance Model which emphasizes the importance of end user's perspectives, and the Social Model of Disability which sees the world and society as disabling rather than the imposition of disability on a person. The perception of disability in engineering is examined through the use of a systematic literature review within Chapter 3 by comparing general engineering academic literature and engineering education literature housed within the American Society of Engineering Education national database. Chapter 4 of this dissertation quantitatively examines the digital accessibility landscape of learning management systems utilized within engineering and engineering related courses that first and second year engineering students are required to take. Finally, Chapter 5 utilized a mixed method approach to examine disabled and non-disabled engineering students' perspectives on the usability of their Learning Management System within their engineering courses. The second part of this research study utilizes individual design interviews to have students redesign their Canvas experiences such that it minimizes digital accessibility barriers. Chapter 6 details tangible digital accessibility recommendations for developers, designers, and instructors/content managers. These recommendations are based on the results within the previous chapters of this dissertation.

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General Abstract

This dissertation examines the culture and climate of disabled people and the disability community within society and the engineering field and the experience of disabled students in higher education. The research presented is understood by looking at disability as not a detriment to the individual and is imposed by society. Chapter 3 talks about how disabled people are and are not included within the engineering field. It compares a more general engineering academic literature with engineering education academic literature from American Society of Engineering Education national proceedings. The second study researches the accessibility of engineering and engineering related course websites from a higher education institution. This research shows the most common digital accessibility errors that are found along with the types of web pages that have the most accessibility errors. Finally, the third study researches the digital accessibility barriers encountered by disabled and nondisabled engineering students. These results are broken down by the specific disability that was disclosed by the participant. Chapter 6 details tangible digital accessibility recommendations for developers, designers, and instructors/content managers. These recommendations are based on the results within the previous chapters of this dissertation.

Dedication

To Chandler, my partner, love, and best friend.

Also, to my family Mom (Kathy), Dad (Charles), sisters (Kathryn and Maggie), Grandma (Jean), and Great Uncle (Stanley). You have made me who I am today.

To my furry family, Uhura (Bora), Kai, and Kira. Your endless love and relaxing snuggles have helped me through many long nights and early mornings.

Finally, to my added family, Trish, Chuck, Matt, Nikki, Riley, and Jackson. Your support and encouragement truly helped me to the finish line.

In loving memory of my Grandma (Mary) and Grandpa (Charles).

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Lastly, thank you to my committee for taking on my dissertation topic and helping me through this dissertation process. You all have worked so hard to help me succeed. Thank you.

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Chapter 1. Introduction

This dissertation focuses on understanding barriers and design needs for undergraduate engineering students, in particular the barriers and needs uniquely experienced by students with disabilities. This research has three main goals: 1) explore the perception of disability and disabled people within engineering, 2) understand the current accessibility landscape of engineering and engineering related Canvas course websites, and 3) understanding the unique barriers for disabled students in engineering when accessing their online educational content and identifying ideas to mitigate some of the challenges. This research utilizes participatory design, a design tactic that allows end users to be integral throughout the design of a product, which is vital in giving a voice to underrepresented and stigmatized members of society in particular.

Within this dissertation, the first chapter provides a high-level overview of the background literature, research questions, theoretical framework, methods, and broader impacts of my proposed dissertation research. The discussion in the second chapter describes the literature on: 1) the call for more diverse engineers, 2) the history and current climate pertaining to disabilities in the United States, 3) the push for digitally mediated education, and 4) the theoretical framework that guides this research. The third chapter consists of a systematic literature review describing the portrayal of disability and disabled people within the field of engineering. Chapter 4 details a quantitative research study that explores the accessibility errors on course webpages utilized in first and second year engineering and engineering related digitally mediated courses. Chapter 5 describes a mixed methods research study seeking to understand disabled and nondisabled design needs for Canvas through the utilization of a survey and design interviews. Finally, Chapter 6 provides an overall discussion for the entire dissertation and gives detailed recommendations based on the research provided within the dissertation.

Calls for More Diverse Engineers

The federal government, industry, and academia have all called for an increase in the number of science and engineering graduates at the bachelor's level. It is estimated that the technology field, which encompasses computer science, engineering, and information technology, needs to replace 2.3 million positions between 2012 and 2022, including 1.2 million positions in the computer occupations and 544,300 engineers (Sargent, 2013). Moreover, there has been a push to have a more demographically representative and equitable engineering workforce. Thus, not only do these reports indicate that we need to be graduating more engineers, but the cohorts of engineers that graduate also should be more diverse.

Relative to diverse teams, solutions produced by teams comprised of individuals who have homogeneous backgrounds and experiences will be of lower quality and creativity, even if the homogeneous team is comprised of high-ability problem-solvers (Hong, 2004). Thus, one justification of greater diversity in engineering supports the notion that more diverse engineering workplaces can produce the highest quality solutions to our world's biggest problems. Another justification in the diversity-related literature suggests that the inclusion of individuals from underrepresented populations in engineering, such as disabled individuals, is necessary from the viewpoint of equity and social justice. The systematic exclusion of disabled individuals, even if it is unconscious, provides a landscape for inequitable education and opportunity (Hong, 2004).

"Diversity" includes many different characteristics and is historically defined as "individual differences" (Harrison and Sin, 2006), however debate still persists regarding the characteristics that should be encompassed within "individual differences." Two broad categories of individual differences currently exist: 1) demographic diversity, including socio-economic status, race, ethnicity, geographic region, and gender, and 2) diversity of thought, including past experiences and atypical thinking because of disability and/or neurodivergance. The ideas of demographic diversity and diversity of thought are considered intertwined and, in many cases, dependent and reliant on each other.

Particularly within the field of engineering, perspectives encompassed by the diversity of thought and thought processes category, often perpetuated by a multitude of different disabilities, has the potential to provide innovative thinking. This aspect of diversity can be quite challenging to incorporate into research and practice, however, as the tracking and documentation of people identifying with learning and cognitive disabilities is minimal. Further, people with these disability types are hesitant to identify with them because of the stigma that society has exhibited toward people with high intelligence and learning or cognitive disabilities; in one national survey, for example, 43% of people believe that a learning disability correlates with a lower IQ (Cortiella & Horowitz, 2014). There have been some shifts over time in the willingness of members of this population to register officially as having a disability within higher education institutions, however, as the percentage grew from 6% in the 1995-1996 academic year (U.S. Department of Education, 1999) to 11.1% in the 2011-2012 academic year (U.S. Department of Education, 2015). The actual percentage of students with disabilities is estimated to be even higher, as approximately 20% of the school-aged population in the United States is estimated to have a disability (Cortiella & Horowitz, 2014). The reported numbers and estimated numbers vary for numerous reasons including lack of parental knowledge of disability, lack of ability for diagnosis, fluid nature of disability, and lack of perceived need to report disability. The estimated

20% number would be consistent with the reported disabled population within the United States, but even that estimate is likely to be low because of underreporting based on many of the same reasons as to why the school-aged population is underreported (Cortiella & Horowitz, 2014).

Defining Disability

Broadly, disability is defined as the inability to perform, think, or act in a manner that is typical or common (Pugach and Saidl, 1996). Disability can be further characterized into two overlapping groups: physical and cognitive disabilities. There is much debate as to what cognitive disabilities entail (Pugach and Saidl, 1996; Wasserman, Asch, Blustein, and Putnam, 2017). Some researchers state learning disabilities and disabilities solely manifesting within the mind fall in this category (Friedman et al., 2007; Wasseran et al., 2017), whereas others believe that emotional and behavioral disabilities belong within this category as well (Disabled World, 2016). Recently, the concept of disability has expanded to include not only physically and cognitively apparent disabilities, but disabilities that are invisible both physically and within everyday life, such as anxiety, Obsessive Compulsive Disorder (OCD), Attention Deficit Disorder (ADD), and Autism Spectrum Disorder (ASD) (American Association of Intellectual and Developmental Disabilities, 2011). This expansion of the traditional definition of disability allows for a more inclusive and expansive representation of disabilities.

There are two main theoretical frameworks for understanding the idea of disability as a whole: the social model of disability and the medical model of disability (see Figures 1 and 2). Whereas the social model of disabilities is based on what society deems normal, the medical definition is constructed from medical diagnosis. The social model of disability relies on people identifying their disabilities and differences without the aid of medical diagnosis (Pugach & Seidl, 1996); in contrast, the medical model is in reference to a norm, and straying from that norm is labeled as bad, disabling, and something to be cured. My research depends on the lens of the social model of disability to embody the importance of disabled peoples' voices.

Figure 1: Social Model of Disability ("Social Model of Disability", 2017)

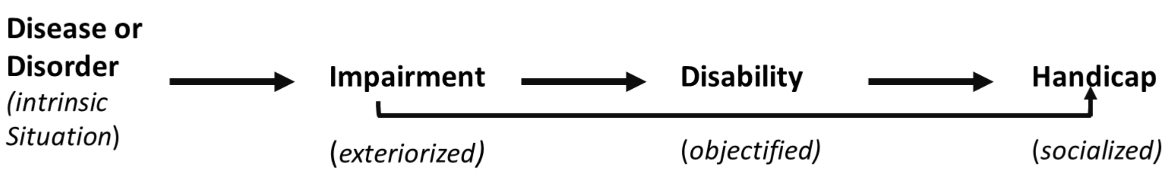


Figure 2: One of the traditionally medical classification of disability (World Health Organization, 1980).

Push for Digital Education and Implications for Students with Disabilities

Since 2014 digitally mediated courses have become prominent. Currently, 99% of all colleges use some sort of learning management system (Dahlstrom, Brooks & Jacqueline Bichsel, 2014). Further, the business need and, proportionally, the market share growth for learning management systems have grown exponentially, as shown in Figure 3, because of the heavy collegiate utilization of learning management systems to facilitate digitally mediated education. This digital growth in education can partially be equated to the general and ever growing social acceptance of technology.

Despite heavy reliance and investment in learning management systems, in a large scale study including 213 institutions and more than 75,000 students, nearly 50% of students, disabled and nondisabled, asked for "better features to better enable interaction and communication." This finding is seen in Figure 4 along with other student recommendations for learning management systems (Dahlstrom, Brooks & Bichsel, 2014). Although many students need to access an online LMS, research and student responses state academia is "lagging behind" in their online institutional support for disabled people, especially those who have cognitive and learning disabilities (Straumsheim, 2017). Some research is starting to be done on design for inclusive virtual environments, but designs still have not been fully formed, assessed, or validated. Many large national studies on higher education digital learning environments only briefly mention disabilities or fail to mention any data on either physical or cognitive disabilities.

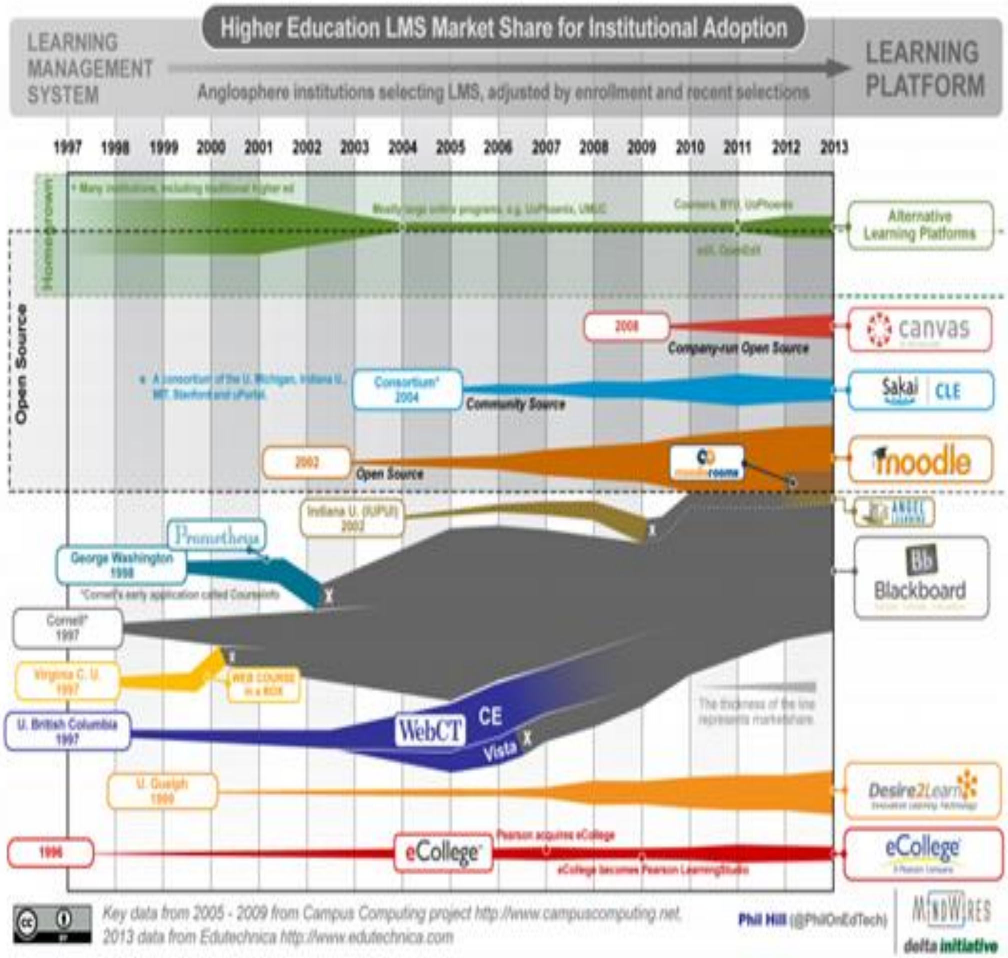


Figure 3: Higher education LMS market share 2013 (Dahlstrom et al, 2014)

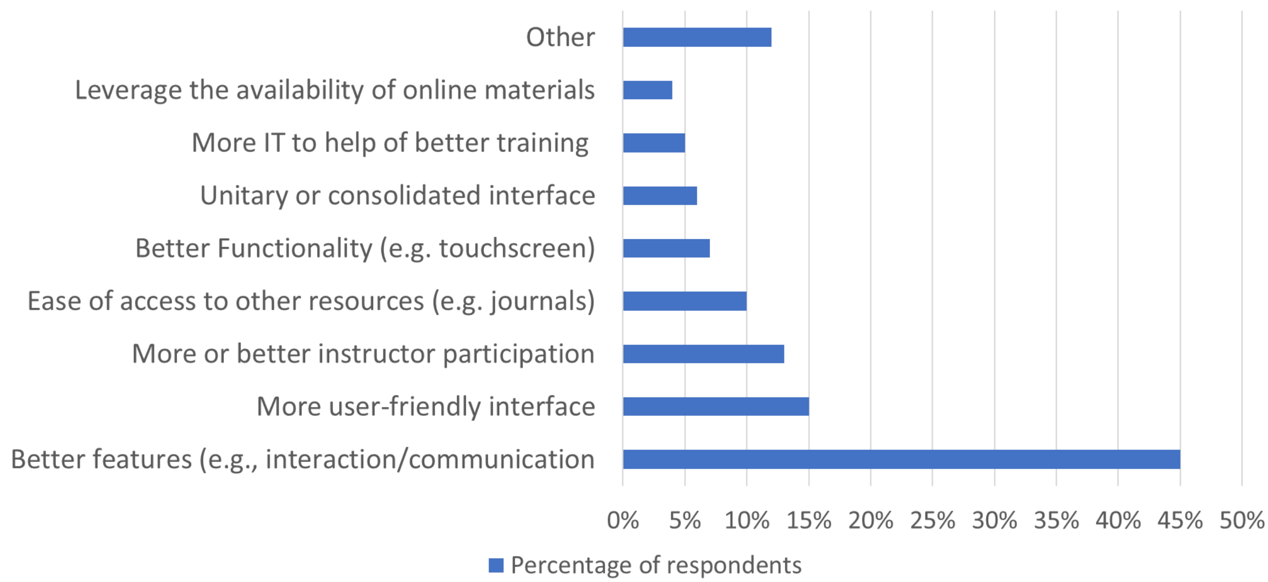


Figure 4: Student recommendations for improving the LMS if building it from scratch (Dahlstrom et. al, 2014)

Because engineering is a technological field, the incorporation of software and digital entities within the classroom environment is needed for improved innovation, and relative to other fields, technology in the classroom is more commonplace. However, it can be difficult for engineering as a whole to diversify when not all underrepresented groups can access equitably the learning materials presented in courses. Within the context of my research interest, it is vital for disabled engineering students to be able to access their digital educational content with the same ease as typically abled engineering students. Moreover, this problem is exacerbated by a lack of training for engineering faculty and lack of knowledge about the needs of cognitively disabled future engineers. Further, cognitively disabled engineering students may be limited in their abilities to access their digitally mediated education, thus providing a less inclusive and less equitable environment for those students.

Theoretical Framework

The research within this dissertation is informed by the Technology Acceptance Model (TAM) (see Figure 5 (Lederer, Maupin, Sena, & Zhuang, 2000)), which has been utilized within human computer interaction and user interface design research studies. The model fundamentally strives to incorporate users' perspectives of the utility of the technology. The Technology Acceptance Model provides no mention or contextualization for factors external to the user and the final technological system. For example, there are no mentions of legal, political, environmental, financial, or bureaucratic elements within the model. Additionally, nowhere in the Lederer et al. (2000) model does it mention accessibility; however, the main focus of the model is the *user interaction* with the technology and *user experience* because of the interaction with the technology. For my research, it is important to gain information from the perspective of the user rather than getting information external to the user, such as software constraints, recommendations and standards, and accessibility law. For this reason, the TAM model is useful in this research because of its embodiment of a user-centric framework, which some models focused on design for disabilities do not feature as prominently. This framework helps guide my study at a high level by ensuring, through all stages of the study, that the questions, data, procedures, and analyses are focused on understanding the technology through the lens of the user.

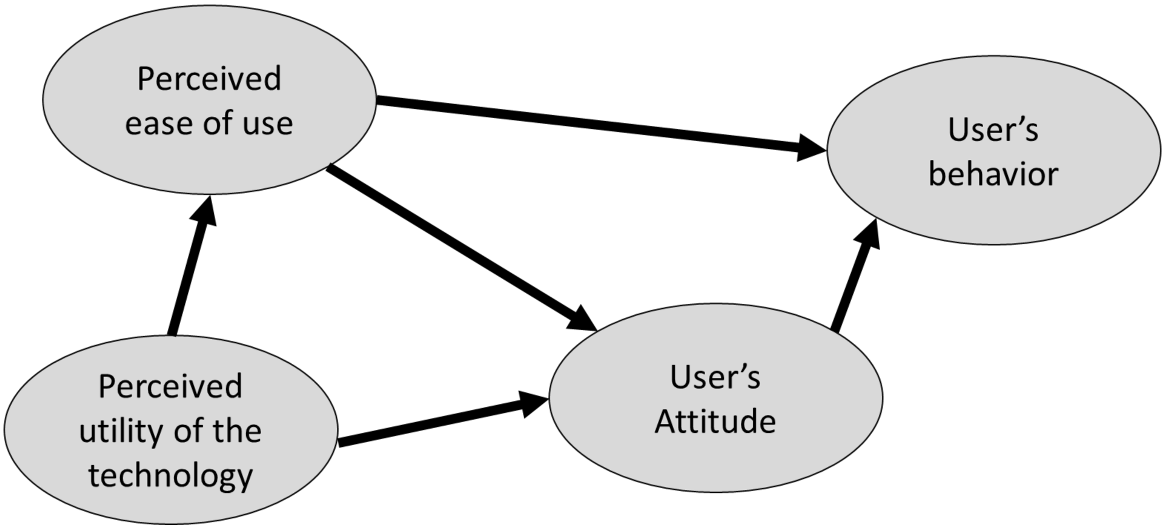


Figure 5: The Technology Acceptance Model (Lederer, Maupin, Sena, & Zhuang, 2000).

Research Studies and Research Questions

My dissertation is organized into three separate, but related, studies. Within Chapter 3, I investigate the perceptions of disability and disabled individuals within general engineering academic writing and within American Society of Engineering Education (ASEE) academic writing. An overarching question that encapsulates the research and results presented within Chapter 3 is: "What are the perceptions and climates of disabled people within engineering based on academic engineering literature and literature published with the American Society of Engineering Education (ASEE)?'.

Chapter 4 quantitatively explores the accessibility, based on the Web Content Accessibility Standards 2.0 (WCAG), of first and second year engineering and engineering related Canvas course websites for courses that were taught in person. A general overarching question that encompasses the specific research questions and results presented within Chapter 4 is: “How accessible are Canvas course websites, and what determines the inaccessibility of the course websites?”

Chapter 5 is a mixed methods research study where both survey and design interviews were used to help understand Canvas barriers and brainstorm ideas to lessen Canvas barriers as presented by disabled engineering students. The overall framing question that can embody the research presented within Chapter 5 is: “How would disabled and nondisabled engineering students redesign their Canvas course websites based on their accessibility needs?”.

Research Implications

This research helps inform recommendations that are understandable and actionable for web-based education developers as well as instructors who use learning management systems. Currently, the standards published and recommended provide little direction on what specifically is necessary to fulfill the recommendations and suggestions as to how to achieve it. This lack of structure fails to provide developers and instructors with direction and salient points that are actionable. My research highlights design and implementation differences that are necessary for accessibility and access of digital education for different individuals.

Chapter 2. Literature Review

This chapter details the pertinent literature pertaining to my dissertation topic. The first section explains the current and historical landscape of disability within the United States. The following section explains the perception of disability in society and within the engineering field more specifically. The chapter then expands upon the idea for why there have been calls for more diverse engineers and how disability is a crucial component of diversity and inclusion within higher education. Next, a section outlines literature on the shift to digitally mediated education within higher education. Finally, the last section describes how different theoretical frameworks have been used to study this space, why I selected the Technology Acceptancy Model to inform this project, and how that framework has been used in prior research studies.

Current and Historical Landscape of Disability in the United States

Disability is an important aspect of inclusion within engineering from a social justice standpoint (Thomas, 2015). Despite the inclusion of disability within diversity and civil rights laws, there has been minimal positive effects for the disabled community within the past 15 years (Thomas, 2015). Since the 1950s, there has been a social justice movement within the United States that helped encourage the formation and the passing of the Civil Rights Act, particularly focused around race-based discrimination. The Civil Rights Act failed to provide protections against discrimination with respect to disability, however, which is still the case. Being mostly excluded from that legislation was and still remains a large blow to the disabled community, and this exclusion legally divides different aspects of civil rights activism. The first piece of legal protection for the disabled community was the Architectural Barriers Act that only handles traditional physical barriers, such as stairways. Within the 1970s, the Rehabilitation Act was put into place to help disabled veterans (Goss, 2016). This act was, once again, only focused on physical disabilities despite the growing number of disabilities of different types being acknowledged formally, which is consistent with how disabilities typically are treated in conversations pertaining to diversity (Kitchin, 2000). Intellectually and psychiatrically disabled individuals traditionally were forcefully institutionalized; the deinstitutionalization and legal protection of these disabled individuals only began to happen in the United States after the 1970s, a decade after the Civil Rights Act. Further, the massive disabilities legislation granting social and educational rights, the Americans with Disabilities Act, was not passed until 1990. Thus, the inclusion of disability within civil rights and diversity conversations is a relatively new phenomenon (Thomas, 2015).

Context of Disability Legislation in the United States

Historically, disabilities have been presented with negative connotations within the United States. Eastern State Hospital, located in Williamsburg, Virginia, was established in 1768 under the name "Public Hospital for Persons of Insane and Disordered Minds" and its first patients were admitted in 1773 (Williams, 1920). However, the first law for a *state* run asylum was not passed until 1842, leading to the building of many state run institutions in the 1850s and 1860s. Although state run mental help was now available, the huge divide between private and state run institutions was vast, leading to cruel and inhumane treatment of patients. Social unrest and pressure came around the 1940s when Eleanor Roosevelt stressed the importance of the Civilian Public Service and the need to reform mental institutions. However, the rise in the number of institutions still increased into the 1950s.

The 1950s brought about the deinstitutionalization of mental institutions, however the deinstitutionalization of institutions for behavioral difficulties did not occur until 15 years later. Significant change with regards to disability law occurred during two presidencies when social pressure climaxed and when the individuals in office had family members with cognitive disabilities. In general, the deinstitutionalization of mental disorder disallowed institutions that dealt solely with individuals in vegetative state or in a mental capacity that does not allow independent or semi-independent living. In contrast, the institutionalization for behavioral difficulties ranged from institutionalizing non-disabled individuals with troublesome difficulties to autistic individuals to violent and “uncontrollable” individuals. Overall, the institutionalization of individuals ranged from high impact disabilities that require individuals to utilize intensive aid, such as individuals in a coma or on the high end of Autism Spectrum Disorder, to nondisabled people that are simply difficult for their families to handle.

Eventually, John F. Kennedy pushed the Community Mental Health Act in 1963 ("The Community Mental Health Act of 1963 - Young Minds Advocacy", 2017) after the botched lobotomy of his sister, Rose, this piece of legislation disallowed the permanent and long-term institutionalization of disabled individuals. A later piece of legislation, the Rehabilitation Act, Section 504 of the Civil Rights Act passed in 1973, attempted to create an equitable environment for veterans returning from the Vietnam War and laid the groundwork for George H. Walker Bush to sign the Americans with Disabilities Act decades later in 1990 ("Introduction To The ADA", 2017), which was a powerful law that allowed and mandated “reasonable” accommodations for individuals with protected disabilities in “major aspects” of living, including schooling and higher education. These laws were monumental and helped transform the legal landscape in the United States with regards to disability.

With President Bush signing the Americans with Disabilities Act in 1991 and the other disability inclusive laws, disabled individuals were given the rights to be employed fairly and access physical environments in a “more reasonable and comfortable manner” as long as the expectations were “reasonable” for the accommodating organizations. For example, new buildings have to be constructed with accessible bathrooms, doorways, ramps, and elevators, and employers are no longer able to deny health benefits to disabled individuals. However, the 1991 law falls short on defining digital and technological accessibility (Straumsheim, 2017). Social pressure and much petitioning led to the revision of the ADA in 2008 that expanded accessibility requirements to include digital interfaces utilized by the public to have compliance with the Web Content Accessibility Guidelines (WCAG).

The WCAG was created to help ensure access for disabled individuals within the expanding technological world, and the original version included details regarding the specific elements needed for accommodating some disabilities within the ever evolving digital landscape, such as captioning for videos and alternative text for images. In January 2017, the U.S. Access Board approved a final rule to update Section 508 of the Rehabilitation Act of 1973, thus allowing for updates to verbiage and to include new information pertaining to current common technologies and ruled that the WCAG 2.0 guidelines are the “industry standard” for website accessibility. Additional elements added to the WCAG further improved the digital landscape for individuals with low vision and screen reading softwares for blind/low vision individuals. As a net result of all of these changes and updates to laws, websites are now more stringently required to design for disabled people to meet different levels of compliance with the law (Yanchulis, 2017).

Despite the massive civil rights wins for the disability community through these pieces of legislation, the WCAG still lacks guidance on *how* standards should be met, as illustrated in the following quote from Reid and Snow-Weaver (2008, p 110):

> “In order to leave room for innovative solutions, WCAG 2.0 does not prescribe exactly how the conditions are to be met in the normative standard. It does, however, provide informative guidance on currently known methods for meeting the success criteria.”

Additionally, the WCAG guidelines give little to no guidance as to how to create accessible and inclusive digital environments, especially digital learning environments, for individuals with specific cognitive and behavioral disabilities. My research helps begin to understand the needs of disabled engineering students within the online learning environment. This information provides a clearer picture of how to achieve an accessible digital environment.

Depiction of Engineering and Disability Within Pop Culture

Beyond the legal landscape, the social depiction of disability and of disability within engineering is vital to understand and explore. To remove barriers within engineering for disabled students, it is necessary to understand the complexity of the societal view of engineering and disability, which I review in this section. It is important to understand the differences between the societal depictions of engineers, disability, and disability within engineering to understand the experience of disabled engineers within engineering.

Depiction of Engineers

The depiction of engineers within pop culture and media remains heavily reliant on constructed stereotypes of engineers. Through an analysis of popular television shows and films, engineers are portrayed as nerdy, male, smart, awkward, and secluded, although there are some notable exceptions (e.g., Iron Man’s Tony Stark). A summary of these attributes can be found within Table 1 (Long, Steinke, Applegate, Knight, Lapinski, Johnson & Ghosh, 2010). As summarized by Long et. al (2010 p. 17), the perpetuated stereotype of engineers shown on popular modern television shows is as follows:

"The typical scientist character in these programs was an unmarried Caucasian man who did not have children, held a high-status science position, and was likely to be portrayed as being intelligent."

Table 1: Attributes of engineers and scientists in media (Long, M., Steinke, J., Applegate, B., Knight Lapinski, M., Johnson, M. J., & Ghosh, S. (2010).

- Scientist character
- Scene identification
  - Live-action, narrative
  - Animated
  - Education/demonstration
- Demographic attributes
  - Age
  - Biological sex
  - Marital status
  - Race/ethnicity
  - Scientific job status
- Feminine attributes
  - caring
  - Dependent
  - Romantic
- Masculine attributes
  - Athletic
  - Dominant
  - Independent
- Scientist attributes
  - Nerdy/geeky
  - Alone in scene
- Wishful identification attributes
  - Caring
  - Intelligent
  - Respect
  - Violent

Shows like Big Bang Theory, IT Crowd, Bill Nye, and Dilbert (see Figure 6 as an example) perpetuate the idea that the vast majority of engineers are male, white, and socially awkward with the "redeeming" quality of being "smart." In many circumstances, these individuals are used as comic relief (Long et. al, 2010). Disconcertingly, many of the characteristics stereotyped to engineers are corollary to symptoms of behavioral disabilities, such as Autism Spectrum Disorder.

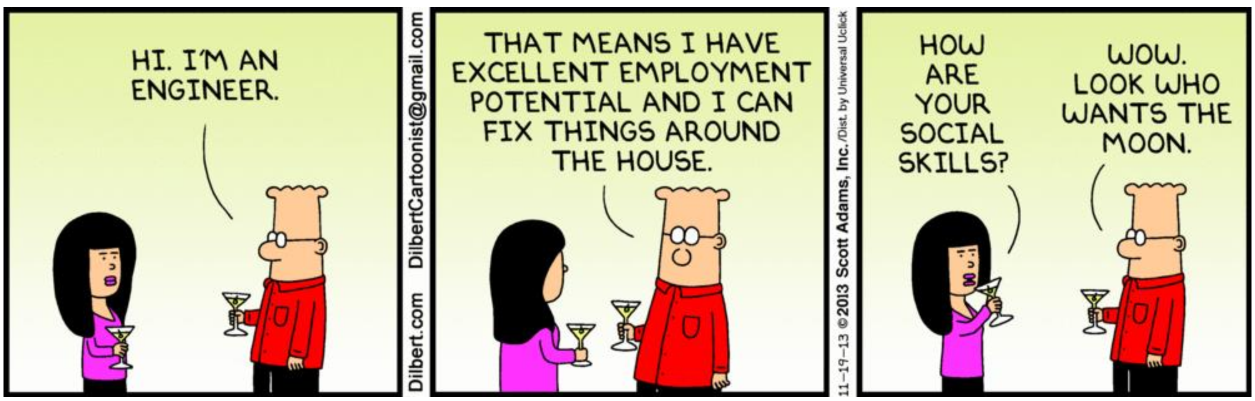


Figure 6: The perception of engineers in comical form as depicted by Dilbert Dilbert.com Copyright 2013

Depiction of Disabilities

For numerous underrepresented minorities and underheard groups, the media encourages and reinforces negative perceptions with descriptions based on misinformation and stereotypes (Elliott & Byrd, 1982). This depiction of disabilities is perpetuated even without having to include disabled individuals within the film, media, or even the physical and digital social environment, as articulated by the quote from Ben-Moshe (Haller, Dorries & Rahn, 2006):

> "When we use terms like 'retarded,' 'lame,' or 'blind' – even if we are referring to acts or ideas and not to people at all – we perpetuate the stigma associated with disability. By using a label, which is commonly associated with disabled people to denote deficiency, a lack, or an ill-conceived notion, we reproduce the oppression of people with disabilities." (Ben-Moshe, 2005, pp. 108–109)

Beyond discriminatory and stigmatizing language that is commonplace within pop culture, the depiction of disabled individuals in film and media range from horror flicks about "crazy serial killers," to inspirational sports and "overcoming differences" inspirational films, to articles depicting physically disabled white men (and rarely women), to intellectually disabled white males for comedic value, to socially awkward men who "save the day by being smart," to the pitiful disabled person, to the "unlikely" romance, and to commentary on "mentally disturbed" mass shooters (Safran, 1998; Thomas & Smith, 2003; Haller et. al, 2006). More often than not, physical and psychiatric disabilities are depicted within rated R movies, with the disabled individual portrayed as "crazy" and having a difficulty to overcome. The emphasized and popularized views of most disabilities tend to intersect with engineering as a negative or comical perception. Indeed, the aspects of "an engineer" intersect with the perception of "disability" where both are painted in a negative manner or a joke. This depiction leaves both disability and engineering cast in a poor light.

Perception of Disability and the Need to Differentiate Between Disabilities

My proposed research uses the social model of disability and encompasses physical, cognitive, psychiatric, and behavioral disabilities. This section describes the risks and stigma associated with identifying with different types of disabilities in both society as a whole, the academic space, and within the disabled community. Further, this section details the difficulties with describing all disabled individuals as simply "disabled" rather than addressing the differences between disabilities.

Risk of Identifying With a Disability

There is significant risk identifying with any type of disability in society, the academic space, and even within disability communities (Saetermoe, Scattone & Kim, 2001; Fine & Asch, 1988). This risk is perpetuated through society as a whole and remains especially strong within the educational and academic space, as it brings with it a social stigma strongly connected to how the media portrays disability. A 2011 study out of the University of Glasgow found that individuals associate disability with fraud and abuse of government systems. Additionally, this study found a noted increase in the perception of disabled people being "burdens," whereas minimal articles described the day-to-day lives of disabled individuals without turning them into inspirational news stories (Briant, Watson, & Philo, 2011). This stigma presents a significant risk for disabled individuals to disclose their disability in society, academia, and the disabled community. However, the risk and stigma associated with identifying a specific disability changes based on the disability and the setting in which the disability is disclosed.

Different disabilities provide different risks in different aspects of society. Within academia, for example, intellectually disabled individuals are faced with disbelief and ideas of "tricking" the system (Babic, 2010; Byrne, 2000). This is especially true for people with non-apparent disabilities in society as a whole (Babic, 2010; Byrne, 2000). This societal stigma and its effects are denoted in the article "Are We Not Human?" (Parsons, Bond, & Nixon, 2015) where researchers found that disabled individuals and their families will even refuse governmental support and treatment because of the stigma attached to "being disabled" and how this stigma affects the disabled individual's family (Parsons et. al, 2015).

Disabled individuals thus are hesitant to disclose non apparent disabilities within the workplace, even after the employee has secured a paying job. Three main aspects affect coworker acceptance of disability and accommodation when a disabled individual identifies with a disability: attitude towards the disabled coworker, perceived fairness of accommodations, and discriminatory employment judgments (McLaughlin, Bell & Stringer, 2004). A summary of a theoretical model illustrating this relationship between disability, employee type, and acceptance is depicted in Figure 7. This figure shows that different disability types may encounter different societal and environmental stigmas that impact co-workers' acceptance of the disabled employee. Further, employee characteristics, such as race and gender, can also impact co-workers' acceptance of the disabled or nondisabled employee. This judgement from coworkers and others presents risks for disabled individuals to be open about their disability within the workplace (McLaughlin et al., 2004).

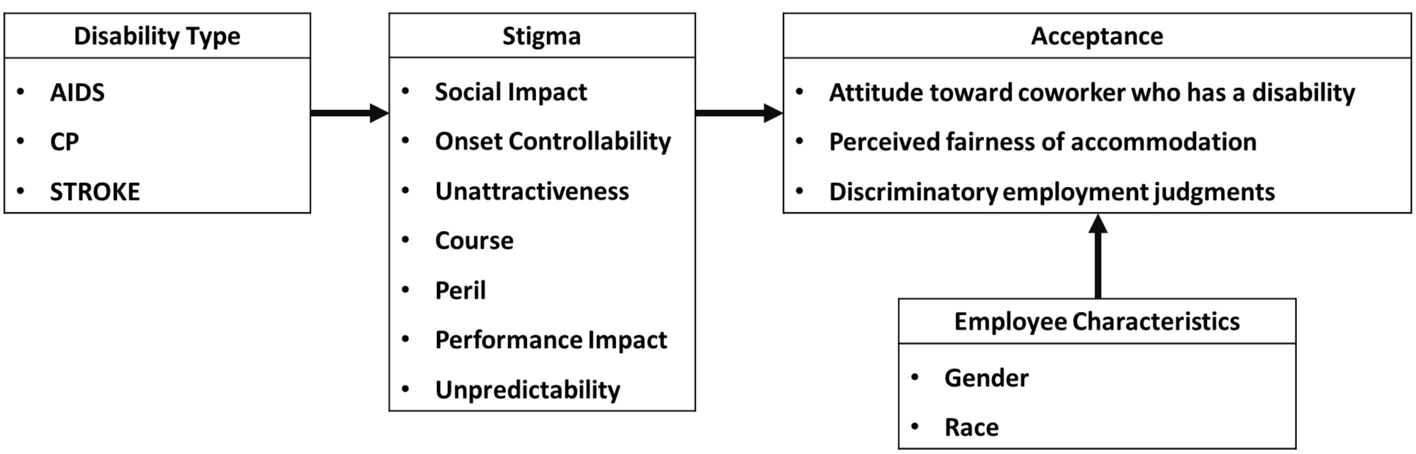


Figure 7: Illustration of Relations Between Disability Type, Stigma, Employee Characteristics, and Acceptance; (McLaughlin, Bell, & Stringer, 2004)

The risk of identifying as disabled in academia is starker, especially with the invisible intellectual and psychiatric disabilities of students and faculty (Cooney, Jahoda, Gumley, & Knott, 2006; Martin, 2010; Collins, & Mowbray, 2005). Many students and faculty members go to considerable lengths to attempt to keep their disability hidden for fear of discrimination and "loss of social status" (Martin, 2010). However, passing of abled bodied and the idea being able to hide your disability is an experience apparently disabled individuals typically cannot experience. The ability to hide your disability allows for less outright societal stigma but also discourages students and faculty from seeking the medical help they need and not have access needs met by their university or employer (Martin, 2010; Collins et al., 2005). The difference in stigma and support shows the necessity to differentiate between different disabilities when attempting to design products or solutions that alleviate access barriers.

Within the disabled community there are divides and stigmas between types of disabilities (Snow, 2016). Typically, this hierarchy is based on the disabled person's ability to act socially within an "acceptable" manner. Amputees are accepted and inspirationalized, individuals with non-apparent disabilities are able to manage within social norms but stigmatized when accommodations are needed, apparent intellectual disabilities are pitied and feared, and psychiatric disabilities are demonized. This hierarchy of disabilities is depicted in the following quote:

> "During one of my presentations about attitudes, "Sabrina" shared the following about her twin sister, "Kristina," who uses a wheelchair: "People talk about Kris like she's not even there," she exclaimed. "I mean, she's not *retarded* -- she just uses a chair!" The unspoken message seemed to indicate it would be acceptable for

> Kristina to be presumed incompetent if she *did* have a cognitive disability, but it was *not okay* since she "just" had a physical disability. Was Sabrina aware she was promoting the Disability Hierarchy?" (Snow, 2016 p. 1)

The mindset portrayed within this quote by Sabrina is common within the disability community and starts to show the need for the differentiation between different disabilities.

Need For Differentiation of Disability

Because of the different risks and the persistent but changing stigmas in identifying with being disabled within different aspects of society, differentiated measures and approaches are needed to make meaningful change.

Different Needs, Different Difficulties

One of the problematic aspects of grouping all disabilities under the same umbrella is the idea of different, and sometimes conflicting, access needs (PADSA - Conflicting Access Needs, 2016). Different disabilities have different accommodating access needs, and while sometimes these access needs overlap, sometimes they conflict with one another. A strong example of this is the following scenario: low lighting needed for a person with sensory processing disorder, and bright light needed for other individuals who may have low vision. Within this example, both low light and bright light will have difficulty existing simultaneously. If the two disabilities and access needs were grouped together under the same broad umbrella of "disability," the more prevalent disability would show greater need for accommodations than the less prominent disability (PADSA - Conflicting Access Needs, 2016).

Additionally, grouping all disabilities under the same umbrella enforces the hierarchy of disability where access needs that are perceived as "more important" and "more necessary" take precedence over less apparent and less blatantly necessary access needs. Beyond perpetuating a disability hierarchy, this mindset encourages an environment where all access needs and all disabilities are not accommodated, and there becomes a need to "prove" how disabled the individual is to receive accommodations (Snow, 2016).

Groupings of Disabilities

With the wide variety of disabilities with which individuals may identify, there is a necessity to classify and group different types of disabilities. This section describes different methods of grouping disabilities, including traditional methods, and more unique and recent methods to grouping disabilities.

Typical Grouping of Disabilities

Traditionally, disability has been classified into four main categories: physical disabilities, intellectual disabilities, behavioral disabilities, and psychiatric disabilities. Other literature describes classifications of disability as: visual, hearing, motor, and cognitive. Once again, all cognitive disabilities are treated as one grouping without distinguishing between different types of disabilities, the different needs those individuals may have, and the different insights those differently disabled individuals many bring to design and understanding access (Crow, 2008). More recently, the definition of disability has expanded to include: mobility disabilities, hearing and deafness impairments, visual disabilities, developmental disabilities, mental health disabilities, cognitive disabilities, and health-related disabilities (Mackelprang, & Salsgiver, 2016). By having more grouping categories, researchers can begin to understand the differences between disabilities that previously may have been within the same grouping strata. Researchers have typically clustered different disabilities according to some of the traditional methods above. An example of this grouping can be found in Figure 8 where the clustering variables are “severity of disability”, “level of social stigma”, “Sex”, and “race/ethnicity”.

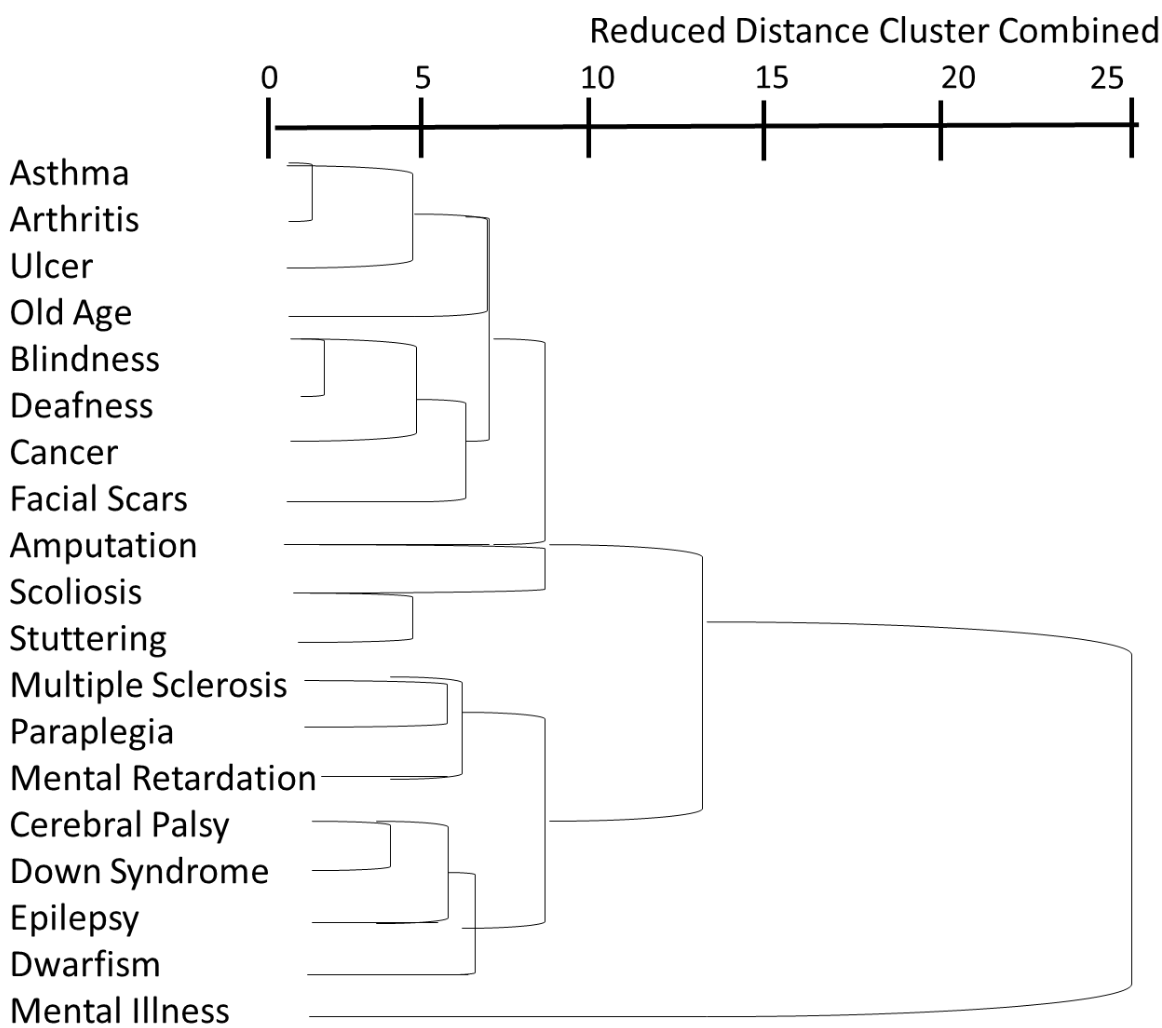


Figure 8: A hierarchical analysis of 19 items measuring disability stigma for all ethnic groups

Saetermoe, Scattone, & Kim, 2001

Nontraditional Groupings of Disabilities

Nontraditional groupings of disabilities include: apparent vs. non apparent or visible vs. invisible, symptom based, and deficit based. In 2001 The World Health Organization (WHO) published the International Classification of Functioning, Disability and Health (ICF) that classifies disabilities based on disability type, symptoms, and some of the deficits the disabled body encounters. This classification includes:

- Activity
- Participation
- Body Structures
- Body Functions
- Personal Factors
- Health Conditions
- Activity Limitations
- Functional Limitations
- Environmental Factors
- Participation Restrictions

Although this type of grouping for disability is uncommon, the inclusion of factors other than traditional disability types provides the flexibility for more types of disabilities to be contained within each category and even be within multiple categories. Flexibility allows the researchers to understand more granular differences between different disabilities. Additionally, this flexibility allows for overlap between different disabilities and will enable researchers to understand how different disabilities interact with each other. Even with the different ways of grouping disabilities, grouping disabilities together still presents difficulties when trying to understand specific differences between disabilities and even within the same disability. Different disabilities within the same category or group or even the same disability can present differently than their peers and need specific accessibility features to ensure the most inclusive experience of them. Grouping disabilities together neutralizes these differences and can dilute the voice of the disabled participant.

Disability as a Part of Diversity and Inclusion in Higher Education

Engineering is a field in which innovation and new and differing ideas are of utmost importance to moving the field forward (Hong, 2004; National Academy of Engineering, 2004). Relative to diverse teams, the solutions produced by teams comprised of individuals who have homogeneous backgrounds and experiences will typically be of lower quality and creativity, even if the homogeneous team is comprised of high-ability problem-solvers (Hong, 2004). Thus, this research supports the notion that the new wave of engineers should be characterized by high diversity who are able to produce the highest quality solutions to our world's biggest problems. Beyond inclusion from purely an equality and social justice perspective, the inclusion of disabled individuals as engineers will make for more diverse, creative, and innovative designs, solutions, and products (Hong, 2004). Despite the ADA being passed 27 years ago and accessibility being legally mandated, many physical and digital environments remain inaccessible, however. This is especially true for digital environments and small, local businesses (Jaeger, 2012; Lazar and Jaeger, 2011; Olalere and Lazar, 2011; Yu and Parmanto, 2011; Areheart and Stein, 2015; Jaeger, 2013; Stein et al., 2014; Wentz and Lazar, 2011). These inaccessible environments prevent the inclusion of disabled students within engineering learning environments, such as labs, and disabled engineers in certain workplace environments.

Disability in Education

All types of disabled individuals are underrepresented within higher education, with 27% of the population within the United States being disabled; 59% of disabled youth graduate high school, and only 11.1% of all undergraduates report having a disability. This figure includes all disabled students who went to trade schools or certificate programs (Wolanin & Steele, 2004). More specifically, students with intellectual and psychiatric disabilities and disabled students in engineering and science related fields (Wolanin et al., 2004) are even more underrepresented because of the lack of K-12 preparation, with 56% of disabled students not completing the pre-requisite math or science curriculum. Within higher education, only 4% of disabled students went into engineering compared to the 5% of non-disabled students who selected engineering (NSF, 2017).

These observations contrast with the societal narrative. Although engineering seems to be a "safe haven" for autistic individuals because of the perceived lack of social interaction of the field, the numbers do not support that misconception. 34% of the autistic collegiate population enrolled within STEM, compared to 23% of the general population, yet the disabled students were most likely to enroll within science or computer science, and only 6% of autistic students enrolled within engineering (Wei, Jennifer, Shattuck, McCracken, & Blackorby, 2013). Although the percentage of autistic students and otherly disabled individuals in 4 year colleges and universities has indeed increased from 6% in 1995 to 9% in 2012, the five year rate for obtaining a bachelor's degree for disabled students still remains incredibly low at 28% compared to the national average of 54% (Knight, 2016; Wei et. al, 2013; Wolanin et al, 2004).

K-12

Since the passing of the ADA and the inclusion of "special education" students within the typical classroom, the high school graduation rate of disabled students has risen to an average of 78%, up from 61%. However, K-12 initiatives for engaging students within engineering are seldom targeted or inclusive of disabled students. The main focus of engineering outreach programs in K-12 education as it relates to disabilities still remains around designing for disabled individuals without the specific inclusion of disabled students (National Research Council, 2009). Within the past twenty years, there has been a push to recruit women and underrepresented racial minorities to engineering majors through the use of targeted outreach programs. Partially because of these efforts and the call for more diverse engineers, researchers, academics, K-12 teachers, administration, and the United States government has encouraged initiatives to inject engineering within the K-12 curriculum. Although there are debates about the authenticity of the engineering work within these classrooms, the inclusion of this engineering curriculum along with the inclusion of disabled individuals within the typical classroom has led disabled K-12 students to be exposure to engineering material. However, engineering interaction for disabled students remains just happenstance rather than something intentional, and that distinction is vital. Disabled students are not being targeted for K-12 engineering exposure, unlike other underrepresented populations in engineering; rather, any exposure to engineering within K-12 is typically by accident.

Higher Education

The existence of the ADA has increased the inclusion of disabled students to 56% of disabled students attending 4 year postsecondary institutions, making up only 7.6% of the undergraduate college population attending a traditional 4 year undergraduate institution (NSF, 2017). The population reporting a disability is 19%, with estimations that as many as 15% of disabilities go unreported, thus making the percent of disabled students going to postsecondary 4 year institutions underrepresented. These data can be found within Table 2 that shows comparisons between different institution types, disabled students, and non-disabled students. Further, the bachelor's graduation rate of disabled students is only 27% as compared to 37% for the remaining population. This percentage is even higher for students with learning disabilities with 53% of those students having post graduate education with no degree versus the 40% of nondisabled students who attend postsecondary education and receiving no degree.

Table 2: Percentage distribution of 1988 eighth graders who completed high school according to highest postsecondary education degree attained as of 2000, by disability status and type, and type of first institution attended (U.S. Department of Education, 1988)

	SOME PSE, NO DEGREE	CERTIFICATE OR LICENSE	ASSOCIATE'S DEGREE	BACHELOR'S DEGREE	MASTER'S DEGREE OR EQUIVALENT	DOCTORAL OR PROFESSIONAL DEGREE
TOTAL	40.6	10.4	8.8	35.6	3.8	0.7
Does not have a disability	**39.9**	**9.7**	**8.9**	**37.0**	**3.9**	**0.7**
Has a disability	**46.0**	**15.1**	**8.1**	**26.7**	**3.6**	**0.5**
Visual impairment	25.4	28.7	5.9	34.7	5.3	0.0
Hearing impairment	46.5	21.4	4.9	27.2	0.0	0.0
Orthopedic impairment	43.7	6.9	3.8	43.7	2.0	0.0
Learning disability	53.2	14.1	9.4	21.6	1.3	0.4
Speech impairment	36.7	12.8	9.2	33.5	6.6	1.1
Other health related disability	43.0	14.8	7.3	27.9	6.4	0.6
Public, 4-year or above						
Does not have a disability	30.3	3.3	4.5	55.3	5.6	0.9
Has a disability	31.0	2.8	1.1	61.5	3.5	0.0
Private, non-profit, 4-year plus						
Does not have a disability	20.6	2.2	2.9	63.7	8.8	1.8
Has a disability	21.9	1.6	3.9	53.1	15.3	4.1
Public, 2-year						
Does not have a disability	58.5	12.5	14.2	13.9	0.8	0.1
Has a disability	61.1	14.2	10.0	12.6	2.1	0.0
Other institutions						
Does not have a disability	38.7	39.1	17.3	4.9	0.1	0.0
Has a disability	39.8	43.8	15.5	1.0	0.0	0.0

NOTE: Percentages will not sum to 100 because of rounding.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988, Fourth Follow-up (NELS:88/00), Data Analysis System.

Additionally, minimal research has been conducted to hold up the belief that engineering is a "safe haven" for autistic and other disabled individuals. While the STEM participation rate of young adults with an Autism Spectrum Disorder appeared to be high, their postsecondary enrollment rate was the third lowest of all the disability categories (Wei, Jennifer, Shattuck, McCracken, & Blackorby, 2013)

Graduate School and Beyond

Disabled engineering graduates holding a doctoral degree within the labor force, as seen within Figure 9, only amount to 4.5% of all individuals with a doctoral degree in engineering. This percentage is markedly lower than the disabled population, disabled population of engineering students, and even the disabled population enrolled in any undergraduate major. From this information, it can be extrapolated that at most only 4.5% of PhD engineering researchers have the experience of being disabled and leading research from the perspective of being disabled if we are to believe the documented numbers of disabled people. Thus, the vast majority of research within the engineering field is led by engineering doctorate-holders from the perspective of nondisabled individuals.

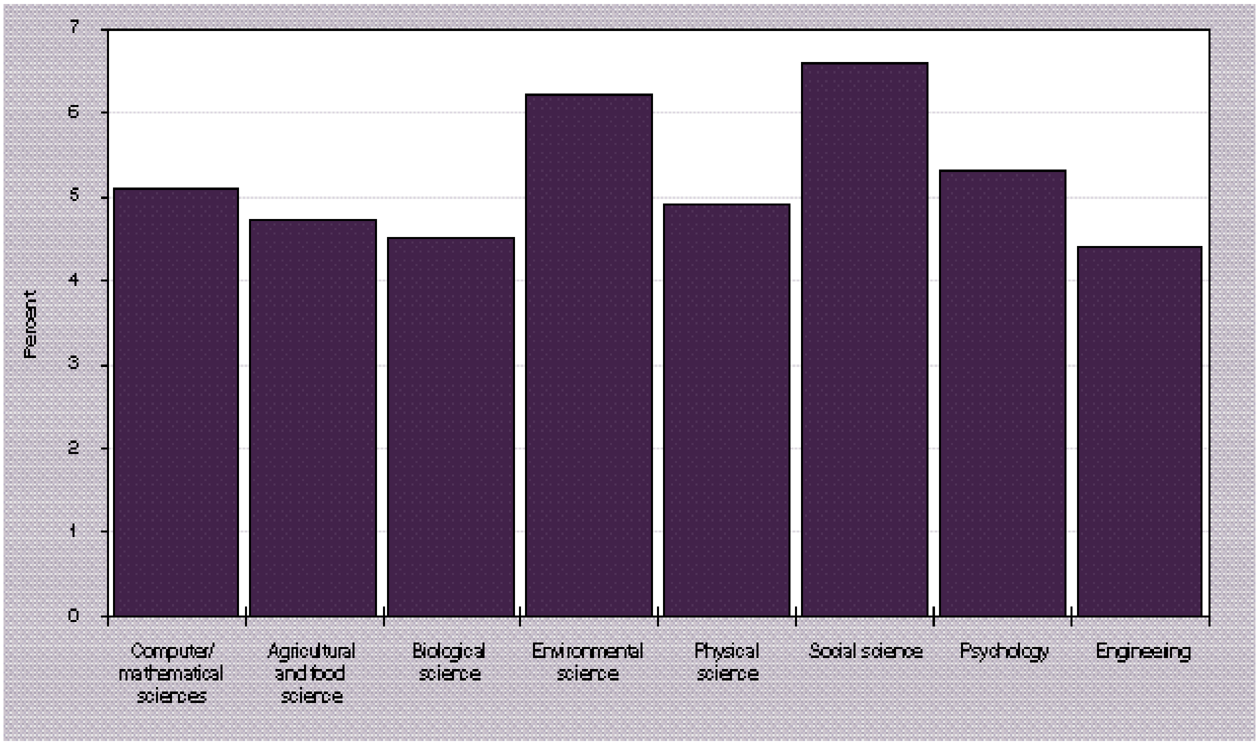


Figure 9: Persons with disabilities as a percentage of doctoral scientists and engineers in the labor force, by field of doctorate: 1993 (NSF, 2009)

In addition to considering who participates in graduate education, prior researchers have also investigated how disability has been integrated into curriculum. Rather than include the disabled perspective as researchers, engineering graduate level courses are focused on the aspect of rehabilitation and assistive technology (Lenker, 1998; Helal, Mokhtari, & Abdulrazak, 2008). Additionally, the graduate curriculum for rehabilitation engineering and assistive technologies remains diverse and inconsistent. For example, many programs do not require their students to have interaction with disabled people to obtain their degree (e.g., Helal et al., 2008). Further, these programs focus on "curing" and "fixing" disabled people and perpetuates the stigma that disability is something that is negative and in need of curing and fixing.

The majority of the time, products for disabled individuals do not take input from the disabled individuals themselves (Kitchin, 2000). Disabled individuals expressed the need for more emancipatory and empowering research strategies that include the voice of disabled individuals. The lack of disabled individuals being intimately involved within research and engineering product development is partially because of the lack of disabled engineers within the workforce (Kitchin, 2000). Additionally, on the rare occasion that an engineer identifies with having a disability, they are tokenized and pigeonholed into representing all disabilities (Kitchin, 2000). The experience and side effects of an engineer identifying as disabled is similar to the experiences of other underrepresented and minority groups within industry and academia (Wingfield & Wingfield, 2014).

The Current Accessibility of Digital Education Spaces

With the passing of the ADA in 1991, digital spaces such as websites were vaguely protected and required to be accessible for disabled individuals. However, these protections did not specifically address websites and other technological advances that are within the digital realm and are constantly changing and adapting, such as cell phones and smart phones.

The 2010 ADA web design focuses strongly on the access needed for people with physical disabilities, specifically blindness and deafness, with mandated captioning for videos and text accessible to screen readers. The percentage of websites that are inaccessible has fallen from 97% of sites in 2005, according to a survey conducted in the UK by The Royal National Institute of the Blind, AbilityNet, Dublin City University and Socitm Insight and the Royal National Institute of the Deaf, to 70% of websites in a survey in 2008, with websites being taken from a sample of the same population (2005). While this rise in web accessibility is promising, a majority of websites were still inaccessible, and while several companies are taking notice of web accessibility, there is no record of companies providing investigative research on what designs are needed; rather, the focus has been on becoming compliant with the ADA. This effect was exasperated in late 2012 with the amendment for Section 508 and the revamping of digital and web compliance.

In September 2012, the ADA came out with the Section 508 Report to the President and Congress: Accessibility of Federal Electronic and Information Technology, which provided laws to regulate the design and execute digital design of items based on the 211 survey results on the state of information technology and access for the disabled (ada.gov, 2018). This report utilizes the very limited Web Content Accessibility Guidelines 1.0 (WCAG 1.0) and provides amendments to these guidelines (ada.gov, 2018). In the amended Section 208 Report, Section 4 is solely dedicated to web compliance. While this section was a large leap for the disabled community by providing legal regulations including detailed information on requirements for technological and digital accessibility, it tends to fall short in the aspect of actual website design. The elements the report focuses on are the digital pieces embedded into the website, such as videos and documents, rather than the design of the website itself. Further, Section 508 heavily relies on the outdated and limited regulations provided by WCAG to the extent that compliance agencies for web design focus more on WCAG compliance rather than the updated Section 508 compliance. Both are still extremely limited in scope, however, barely touching on the needs of people with non-physical disabilities, such as learning disabilities. Like many other design standards, digital and otherwise, both the WCAG and Section 508 focus only on the perceived needs of dyslexics and believe they may have covered the realm of cognitive and intellectual disabilities sufficiently. Individuals still struggle with the implementation of the limited design standards outlined through this amendment. Currently, the business of becoming ADA compliant online has grown, leaving the conversation focused around how they remain compliant of web accessibility rather than how to be more inclusive using innovative web accessibility.

Beyond these general limitations within the digital accessibility space, university websites consistently fail to meet accessibility guidelines. In 2014, only 35% of university homepages, for example, passed the A standard for the WCAG (Solovieva, & Bock, 2014). This finding has led to many lawsuits targeting large higher education institutions, such as Pennsylvania State University, California State University in Los Angeles, San Jose State, and the Law School Admissions Council.

Although the concepts of accessibility and disability are not new, cutting edge technologies are rapidly emerging and being adapted within many social environments. With new technology always being produced, it is difficult to constantly and consistently ensure that all products and spaces are accessible to all communities leaving numerous products and spaces inaccessible to the disabled community. Digital education and learning spaces have progressed in technological advancements and complexity but, as a whole, fail to address accessibility difficulties for the disabled communities. This digital inaccessibility is especially true within higher education, especially higher education fields that particularly and intentionally incorporate new technology, such as engineering.

Theoretical Model

This section reviews two different theoretical models in detail: the Seale (2006) model and the Lederer et al. (2000) Technology Acceptance Model. The Seale (2006) model is a theoretical model that is situated within accessibility in higher education. At first this model seems to be a perfect guiding model for my research; however, this section details the use and critique of the Seale (2006) model and provides an argument as to why the Lederer et al. (2000) Technology Acceptance Model is more suited as the model to frame my research.

The Use and Critique of Seale (2006) in Literature

This section details a brief overview of the Seale (2006) theoretical model, a literature review of articles and research using the Seale (2006) theoretical model, and a critique of Seale (2006) as presented by researchers in the literature. Although Seale (2006) is a relatively new theoretical model, it has been utilized within two theses and 13 additional research papers. More often, the text surrounding and contextualizing the model is cited within new research papers rather than the new research citing the embedded theoretical model within the paper.

Seale (2006) Theoretical Model Overview

Seale's (2006) theoretical model, shown in Figure 10, is broken into four major aspects: stakeholders, drivers, mediators, and outcomes. Through this model, Seale depicts the complexity of the environment and people involved in creating accessible e-learning. The stakeholders include professionals, administrators, disabled students, and faculty. Drivers include legislation, universal guidelines, and universal standards that are mediated by factors such as different views of accessibility, disability, environment, responsibility, compliance, and integration. From there, stakeholders develop goals, responses, and different milestones to reach the main outcome of a partially or optimally accessible e-learning experience.

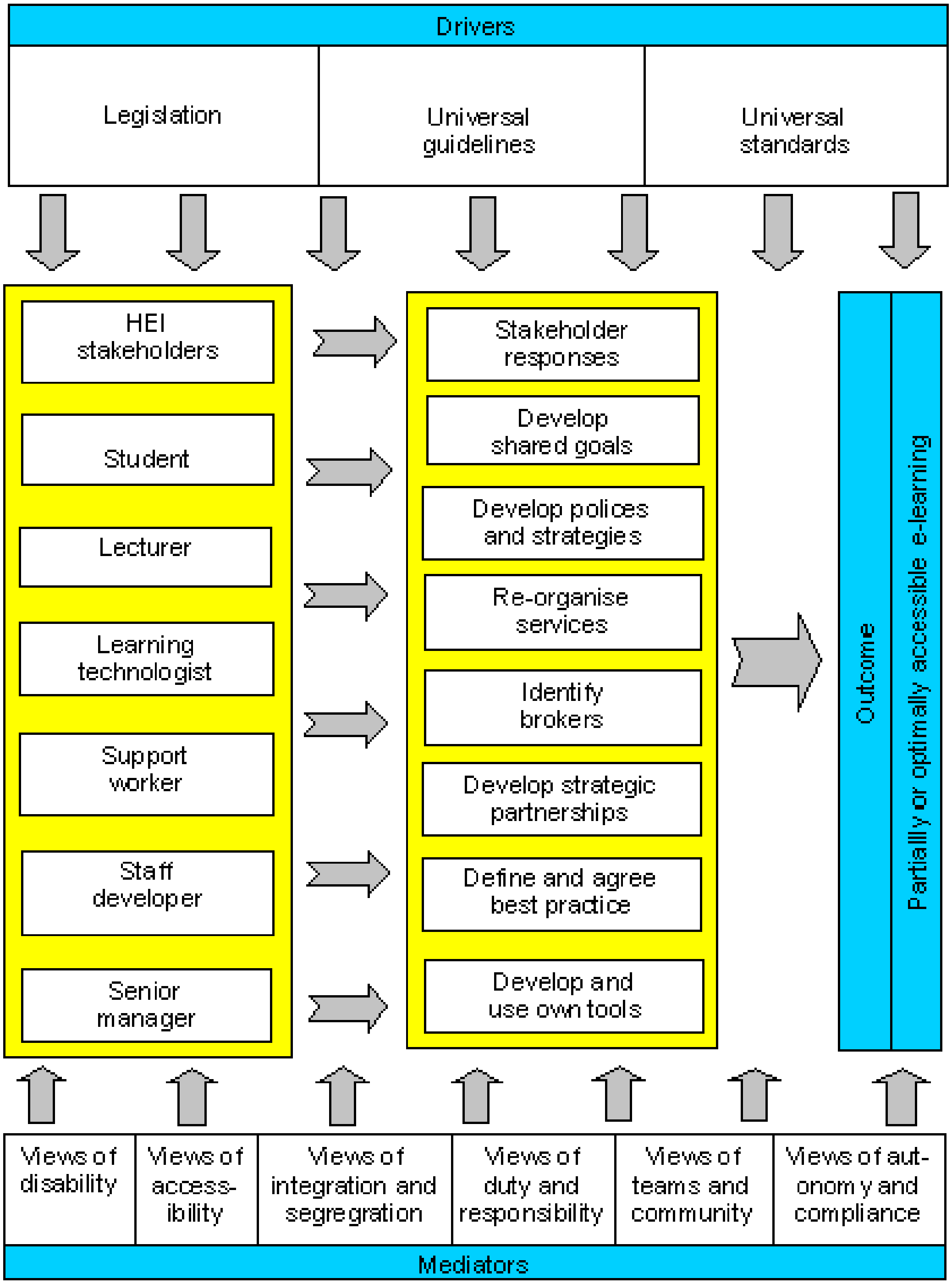


Figure 10: The Seale (2006) theoretical model

There were 37 articles that cited Seale (2006). Out of those articles, seven were written in a non-English language. Of the remaining articles, 23 simply mentioned the surrounding information (e.g., something from the literature review) rather than the model embedded within the article and did not use the theoretical model to help inform their research. Most commonly, researchers noted the importance of involving users and the complexity of the accessible e-learning environment and research space.

Seven articles used some aspects of the theoretical model to inform aspects of their research. In one study, Brobst (2012) utilized qualitative and quantitative methods to investigate accessibility within higher education with research aspects including: Side-by-side policy analysis, Web content review, Automated testing, and Expert testing.

The other study by Maisak (2015) took elements of the Seale model but presented a critique of the model along with reasoning as to why the researcher ultimately selected a different approach for studying accessible e learning. Within the study, the researcher used a mixed methods approach using both a survey and face-to-face interviews with practitioners and students. This allowed the researchers to understand the landscape of accessible e-learning while also thoroughly understanding the perspectives of the practitioners and students. The Seale (2006) model did not provide the flexibility that the research required. Since this model is so detailed, it was difficult for the researcher to correlate the Seale (2006) model to their context.

The other research studies that utilized the Seale (2006) model typically provided no critique of the model and utilized a mixed methods approach including a survey and either observations or interviews with differing stakeholders. It should be noted that only three of the studies analyzed and emphasized participation including interviews with disabled students.

A surprising discovery that came out of this literature review was that almost 70% of the research articles citing this model failed to have disabled individuals participate within their research. This is particularly surprising observation because the theoretical model was originally based on disability. The lack of quantitative studies and studies that include a disabled population speak to a gap within the research articles utilizing the Seale (2006) theoretical model.

Lederer, Maupin, Sena, & Zhuang, (2000). The technology acceptance model

The Lederer et al. (2000) Technology Acceptance Model is comparatively a simplistic model (see Figure 11) when compared to the Seale (2006) model. The technology acceptance model provides no contextualization for factors external to the user and the final technological system. Nowhere in the Lederer et al. (2000) model does it mention accessibility, however the main focus of this model is the user interaction with the technology and user experience because of the interaction with the technology. Similar to the Seale (2006) model, there are arrows denoting a series of events. Through additional exploration of the Lederer et al. (2000) model, an expanded TAM model incorporating accessibility was formed by Brobst (2012). However, much like the Seale (2006) model, the Brobst (2012) expanded model allows for little flexibility and was primarily suited for the dissertation research for which it was created. Table 3 summarizes each of the four different facets of the TAM framework.

Table 3: Defining the main general constructs of the original TAM (Holden, & Karsh, 2010; Legris, Ingham, & Collerette, 2003)

TAM Constructs	
Perceived Usefulness	(1) using (application) increases my productivity; (2) using (application) increases my job performance; (3) using (application) enhances my effectiveness on the job; and (4) overall, I find the (application) useful in my job
Perceived Ease of Use	(1) learning to operate (the application) is easy for me; (2) I find it easy to get the (application) to do what I want to do; (3) the (application) is rigid and inflexible to interact with; and (4) overall, I find the (application) easy to use
User's Attitude	Perceived usefulness, perceived ease of use
User's Behavior	User's attitude

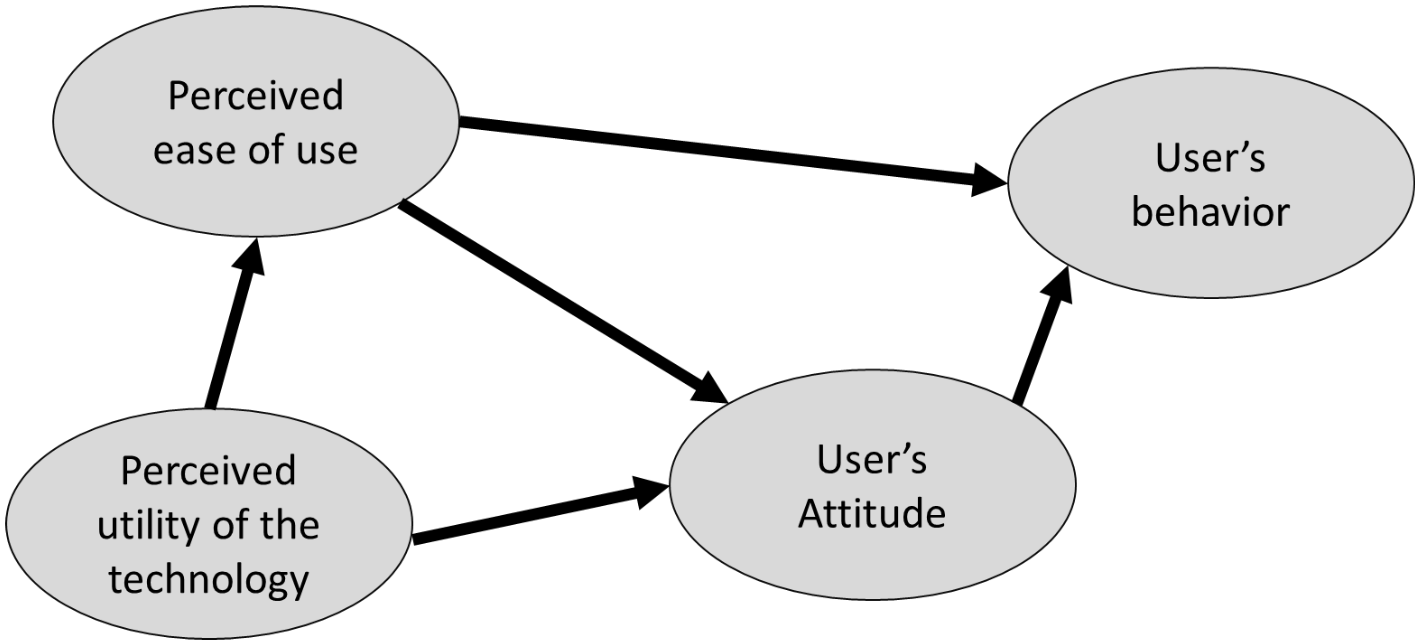


Figure 11: The Technology Acceptance Model (Lederer et al, 2000)

Lederer et al. (2000) is cited by 1,751 different research articles. To narrow this pool of research articles, I further investigated papers using the key words "education" and "disability," which narrowed the pool to 22 articles. Surprisingly, only one of the remaining articles utilized higher education institutes, faculty, students, or disabled students as their population. An in-depth summary of these articles and their methodologies, populations, and contexts is provided in Table 4.

Table 4: Summary of articles that used the Lederer et al (2000)

	Model used?	**Methods**	**Disabled Participants**	**Context**	**Year**
Jaeger, P., & Matteson, M.	Yes	User testing, analysis, testing of websites, automated testing, and survey of federal web developers	yes	Governmental websites tested for accessibility	2006, 2009
Brobst, J. L.	Yes, adapted	Side-by-side policy analysis, Web content review, Automated testing, and Expert testing	no	Website accessibility within healthcare	2012
Alexander, M. .	Yes	Survey, quant	no	motivation of minorities to adopt and learn new, innovative technologies	2008
Brown, B. L.	Yes	Survey, quant	Somewhat, veterans	Veterans' feelings towards ebenefits portal	2018
Pagani, M.	Somewhat	NA	no	Accessibility, Usability, and Functionality in T-Government Services	2010
Sharma, S. K., & Gupta, J. N.	yes	Builds a framework	no	e-commerce	2003
JUNG, E., & KIM, E.	no	quant	no	Mentoring services for kids	2013
Smith, T. J.	Yes, adapted	Mixed, field study observations and tallies	Somewhat, elderly	Internet for older adults in senior orgs	2007
McCloskey, D. W.	Yes, adapted	survey	Somewhat, elderly	Online older customers	2006
Niaz, H., & Hanif, M.	Yes	literature review, workshop and survey including questionnaire and interview	yes	Impairment rehab in Hospital	2010

Ducey, A. J., & Coovert, M. D.	Yes	Lit review, survey quant	no	Healthcare	2016
Gao, S., Krogstie, J., & Siau, K.	Yes	Quant, user survey	No, but students	Mobil, expanding the model	2014
Kim, K. O.	Yes	Qual, interviews	Somewhat, elderly	Elderly with new technology	2013
Parry, D. T.	No	Quant	no	Computer algorithms to find important medical info	2005
Zheng, Y.	Yes, adapted	Quant, survey, Likert	no	Building a model to promote mobile donations	2016
Iqbal, S.	No	Mixed, telephone surveys and interviews	no	Engineering management in health care in Pakistan	2016
Ghazizadeh, M.	No	Quant, survey, observation	Somewhat, elderly	Tech use in older adults	2014
Witecki, G.	No	quant	Somewhat, elderly	Touchscreen in older adults	2017
Schuster, L.	Yes, adapted	Mixed, qualitative evaluation, quant test, qual eval	no	Social marketing	2013
Bentley, R. S.	Yes, adapted	Mixed, case study	no	Air Force intranet web sites	2006

Out of the 22 relevant articles, two articles appeared multiple times in different formats, which left 20 unique and relevant articles. Out of the 20 articles, 14 were dissertation pieces with the most recent dissertation being published in 2017. The recent and frequent use of this theoretical model points to its relevance and importance within the emerging research in the Human Computer Interaction and technology fields. As seen in Table 4, only eight articles included disabled participants, and of those eight only two specifically mentioned the inclusion of disabled participants; five of those populations referred to elderly or older adults, many who tend to be disabled, and one referred to their participants as veterans, also many whom are disabled. These research studies only utilized populations that have higher numbers of disabled individuals rather than specifically targeting disabled individuals for their population. This means that if there were any disabled individuals within their populations, such an occurrence was happenstance. Additionally, the methods of most of the studies were quantitative in nature, however a mixed methods approach was used within the majority of dissertations and theses within the literature review.

The review of the Lederer (2000) TAM model shows that there is a lack of research within the higher education space using this model, especially true for studies focused on the disabled population. Although there were no studies that utilized the TAM for disabled students in a traditional education setting, five of the studies utilized the TAM for online situations, and one used the TAM to understand accessibility for disabled users on governmental websites (Jaeger & Matteson, 2006, 2009). This study found that there were significant barriers for disabled individuals as they accessed different websites, which presented the participants with difficulties accessing certain governmental resources.

Furthermore, this review demonstrates that the most common methodological approach in large, comprehensive research studies is a mixed methods approach. Thus, my proposed study will apply this model in a new context (i.e., digital accessibility of the higher education disabled population) while using a familiar approach (i.e., mixed methods design).

For my research, the TAM works well as an organizing theoretical model. This model allows me to understand participants' perceptions about the utility and usability of Canvas and, by doing so, I will be able to embrace the social model of disability and understand how the "disabling world/environment" contributes to access difficulties for particular students.

Chapter 3

Mini Study: Systematic Literature Review

Introduction

An entire branch of research within engineering education focuses on minoritized and underrepresented groups. Typically, studies focus on ways to expand participation in engineering of women, members of underrepresented racial groups, and, more recently, the LGBTQ+ community. However, other minoritized groups in engineering have been researched to a lesser degree, including veterans and disabled individuals (https://mind.asee.org/, 2019, Svyantek, 2016).

Traditionally, the engineering field has been comprised of mainly white, middle class, typically functioning men (Long, Steinke, Applegate, Knight Lapinski, Johnson, & Ghosh, 2010). Through the historic integration of the civil rights movement in society starting within the 1970s, the picture of engineering has slowly begun to change to include more racially diverse people along with women (Thomas, & Smith, 2003). However, these populations remain underrepresented within the engineering field (Hong et. al, 2004; Clough, 2004). Only recently has there been pushes within the engineering field to expand the diversity of the engineering field actively to include the LGBTQ+ population and the disability community (Thomas et. al, 2003). Throughout the history of engineering, the disabled community has traditionally remained as a "population" for engineers to study, "help," and "fix" rather than a population that should be recognized for their individuality and included as engineers within the field (Pope, & Brandt Jr., 1997). Although the efforts for a broader scope of diverse inclusion in engineering remain, characterizing meaningful participation for a wide variety of disabled individuals still is relatively unexplored (Hong et. al, 2004; Clough, 2004).

My research systematically reviews the literature about disabled individuals' involvement in engineering. It focuses on understanding the manner in which disability, the disabled community, and the disabled population is perceived, accepted, included, and integrated into the engineering scholastic field. Within this literature review, disability is classified in four different groupings: physical, intellectual/cognitive, behavioral, and psychiatric. Additionally, the focus of each study is classified into different groups including: disabled student participant, disabled engineer participant, consultant, and engineered product for disabled individuals. Further, I provide descriptive statistics of key words pertaining to stigmatized and non-inclusive words describing the disabled community and disabled individuals. Finally, I identify themes that characterize participation of disabled individuals in the engineering field, such as describing disabled people as the population of a research study versus describing disabled people as active participants within a research study.

Methods

I followed an approach that systematically reviewed the literature. A systematic literature review is an exploratory research methodology that seeks to answer specific research questions by identifying, critically evaluating, and integrating the findings of all relevant, high-quality individual studies addressing one or more research questions (Baumeister & Leary, 1997; Bem, 1995; Cooper, 2003; Borrego, Foster, & Froyd, 2014).

The guiding research questions of this systematic literature review are:

- How does the general academic engineering literature describe disabled people?
- How does the academic engineering education literature from the American Society of Engineering Education (ASEE) discuss disability?

These research questions were formed following the literature review preformed within Chapter 2 of this dissertation. Chapter 2 reviews literature to understand the general public perception of disabled people, the basic perception of disabled people in engineering, and the public perception of engineers. Although the literature review presented in Chapter 2 began to unpack these topics, this systematic literature review explores these topics further by thoroughly understanding how disability is talked about within both general engineering academic literature and engineering education literature from ASEE.

Inclusion Criteria and Cataloging

I identified key words through the exploration of the disability literature outside of the engineering space (see Chapter 2). Particular interest was paid to verbiage surrounding disabled participants and disabled researchers and to verbiage surrounding products, technology, or interventions for disabled individuals. These key words were chosen by looking at societal disability research and important aspects of disability, theoretically, especially as it pertains to engineering and engineering literature. Table 5 shows the key words utilized within this systematic literature review. The key words in the table with asterisks (*) by them are main key words that were utilized within the first layer of gathering articles from Google Scholar and the ASEE paper database.

Table 5: Key words searched for within the literature review

Key words

Disability*	**Engineering***
Accessibility*	
Accessibility	Participation
Stigmatized words (stupid, lame, retarded, special, etc)	Child
Teen	College
K-12	Elderly
Education	Population
Design	Technology

The main key words (i.e., disability, accessibility, and engineering), were used to search the Google scholar and the ASEE database for potential articles to include within the literature review. These databases were searched separately, and all of the ASEE articles found within Google scholar were labeled as ASEE articles. Distinctions were made between the general engineering academic literature and the academic engineering education literature published in the American Society of Engineering Education (ASEE) by specifically indicating articles published in ASEE. These distinctions were made to discern the differences between how generalized academic engineering literature and academic engineering education literature within ASEE talk about and perceive disabled people, students, participants, and researchers.

I limited the time frame for published literature to 2013-2018 to capture the most recent literature on disability related to the engineering field and engineering education research. Within Google Scholar and the ASEE national conference database, the key words disability, accessibility, and engineering were used to search for articles. Each of these words was entered separately into Google Scholar. Using a web scraper programmed within Python, I collected all of the articles on Google Scholar and stored them in a file. Once an article was identified using the key words, the citation was placed within an Excel spread sheet, the article was scanned for suitability, and all of the key words were searched within the articles using the search function. The suitability of the article was classified by its focus on traditional engineering research and traditional engineering education research. General engineering academic research is defined as research that:

> "expands the engineering knowledge base; contributes ot the exploration and application of specific areas of technology; provides systematic contexts and infrastructure for the diffusion and transfer of engineering and technological information; and provides training for most of the future leaders in engineering across the spectrum of research, developments, design, and other engineering functions." (Schowalter, 1995, p. 18).

Engineering education research in general and within the American Society of Engineering Education is defined as research falling into five categories: Engineering Epistemologies, Engineering Learning Mechanisms, Engineering Learning Systems, Engineering Diversity and Inclusiveness, and Engineering Assessment (NEERC, 2006). Studies that utilized the word “engineer” with no relation to traditional engineering research or engineering education research, such as “The Nurse as Engineer — the Theory of Knowledge in Research in the Care Sector,” were excluded in addition to articles that used “disabled” as a verb, such as “the machine was disabled to conserve energy.” This process resulted in the tabulation of 1,329 articles from Google Scholar, with 827 articles meeting the criteria and recorded into Excel. Similarly, through searching the ASEE national database, 596 articles were found with none of the articles needing to be eliminated. Only non-redundant research papers were recorded within this secondary search of the ASEE national database. The number of occurrences for each of the key words was recorded within the Excel sheet after reading the article briefly to understand the surrounding context in the article to ensure the proper documentation of the key words and the proper collection of the data. The distinction between disabled participation versus disabled population needed more nuance than a simple key word search. To distinguish between a disabled individual being an active participant within the study rather than a population that research was done “on”, each article that pinged for the keywords “participant” or “population” were further inspected. The text surrounding these key words was read and if the research included the active participation of disabled individuals, it was marked as “disabled participant”. If the research did not include disabled people as active members of the research the article was marked as “disabled population”. This distinction was made to begin to understand the active inclusion of disabled people’s perspectives within disability research in engineering. Once the data were collected, the Excel sheets were imported into Minitab to obtain descriptive statistics for both data sets. From there, the results from both of the data sets were compared to understand ASEE academic culture as it compares to the traditional academic engineering research culture.

Limitations

This systematic literature has limitations. Some of the engineering education data was parsed out of the Google Scholar data set by eliminating data from ASEE and putting that within a separate dataset. There are other engineering education journals and conference papers that were not included within the ASEE data set This research began as a work in progress paper published with ASEE, and so I excluded articles from other Engineering Education outlets such as the *International Journal of Engineering Education*, the *European Journal of Engineering Education*, First Year Engineering Education conference proceedings, and Frontiers in Education conference proceedings. The exclusion of other streams of engineering education data within this data set limits the generalizability of the results to the ASEE community rather than the entire engineering education research community. Additionally, this research does not limit based on specific journals or databases within Google Scholar. Although specific exclusion techniques were utilized to eliminate articles, no strict boundaries were put into place around specific journals, databases, or professional societies. Finally, since some of the keywords, especially “disabled participants” and “disabled population”, were not as quantitatively clear cut, there is room within these categories for interpretation and differences within results. While this study does remain repeatable, there may be some differences within these categories based on researcher interpretation. This systematic literature review is meant to serve as a starting point toward understanding of the perception of disability within specific fields in engineering and other organizations within other engineering education communities.

Results

Through the Google scholar search, 1,329 relevant papers were identified using the key words “engineering,” “accessibility,” and “disability.” Out of these papers, over 800 articles talked about technology as it relates to disability. Emotional disabilities were the least common focus of the articles, whereas the most common disability type included in the articles focused on physical disabilities. Commonly, the target population was disabled individuals without the active participation of the disability community or disabled people. Over 100 articles used words that are stigmatized within the disability community such as retarded, stupid, and lame. Each one of the articles utilizing stigmatized words were examined to ensure no quotes were surrounding the word(s) indicating a potential acknowledgement of the stigma attached to the word. None of the articles included within this category utilized the words with an acknowledgement of the stigma attached to the word(s). A summary of the frequency of general engineering academic research articles incorporating the presented variables is presented within Figure 12.

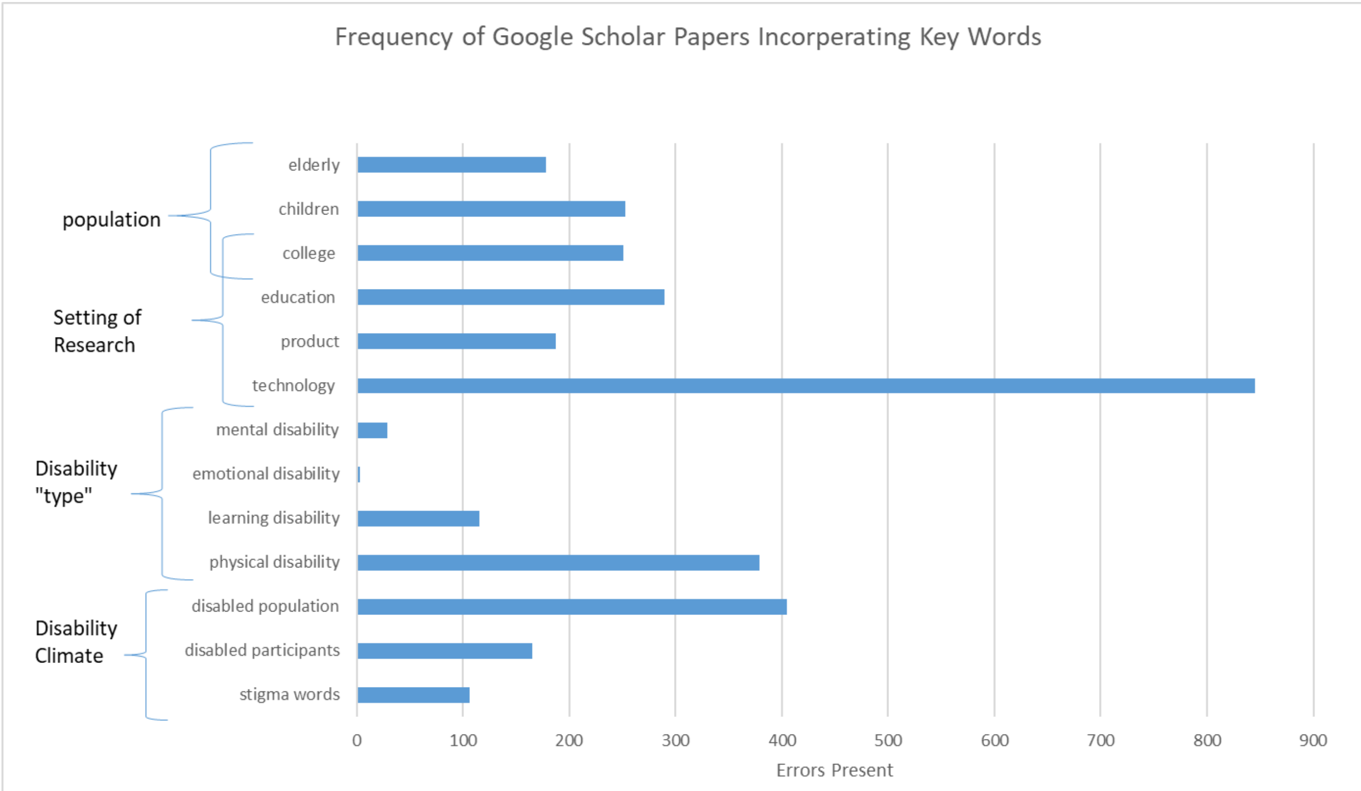


Figure 12: Frequency of Google Scholar Articles Incorporating the Presented Key Words

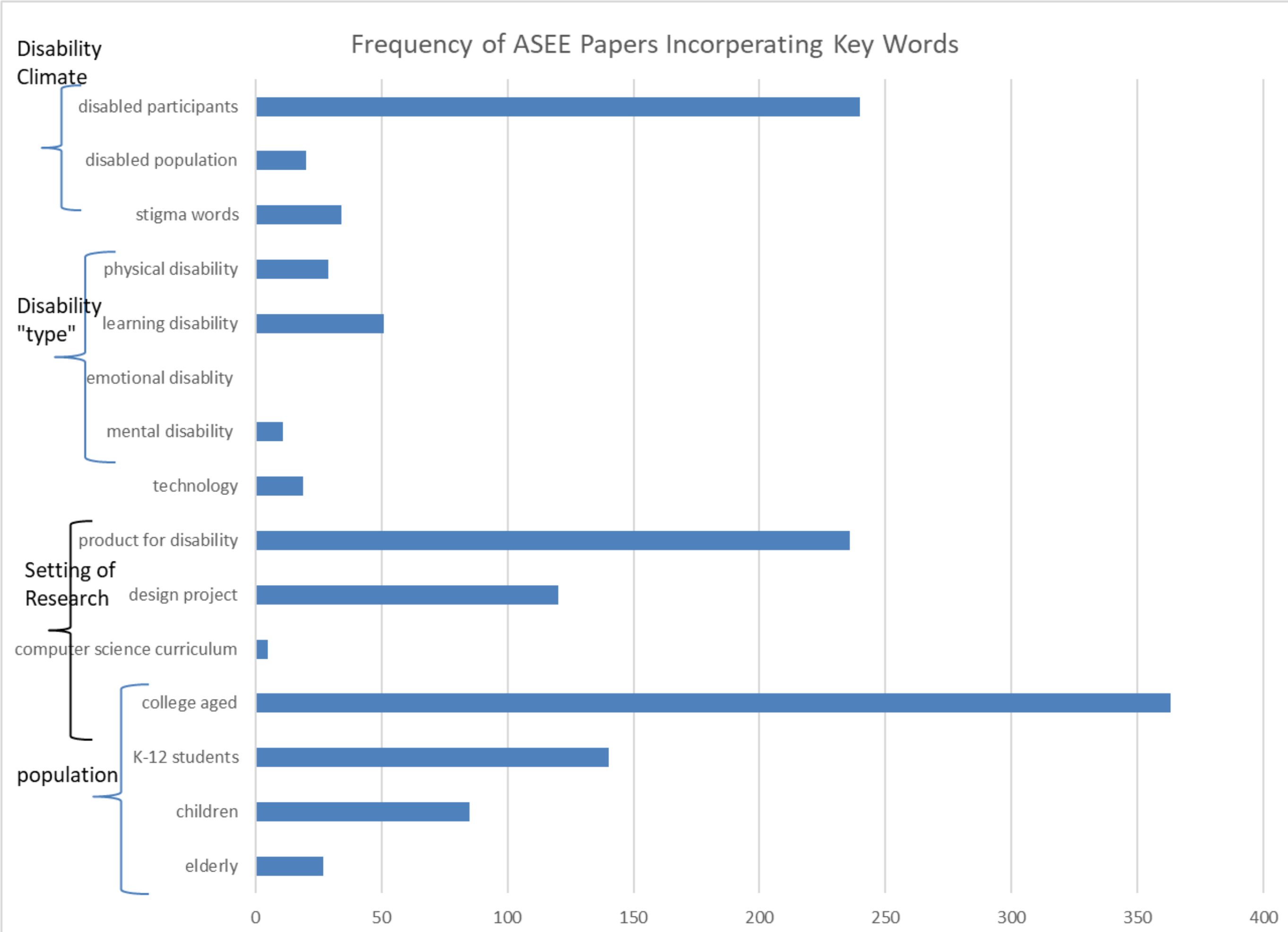


Figure 13: Frequency of ASEE Papers Incorporating Stated Key

Through searching within the academic engineering education literature as depicted by ASEE literature, 596 papers were identified using the key words “engineering” and “disability”. Out of these papers, 363 focused around engineering within a college setting. Similar to the results in the general academic engineering research from Google Scholar, the least represented disability type was emotional disabilities. However, unlike the general academic engineering research data, the most common disability type was learning disabilities. A more detailed and in-depth summary of the frequency of all of the variables incorporated within the academic engineering education literature as depicted by the ASEE literature can be found within Figure 2.

Figure 14 and Figure 15 show the percentages for each grouping so to normalize the results of the general engineering academic research and engineering education academic literature as presented by ASEE. Through the comparison it can be observed that the literature within engineering education in ASEE refers to disabled people as active participants within the research a great deal more than general engineering academic literature, which refers to disabled people as a population that does not actively participate within the presented research.

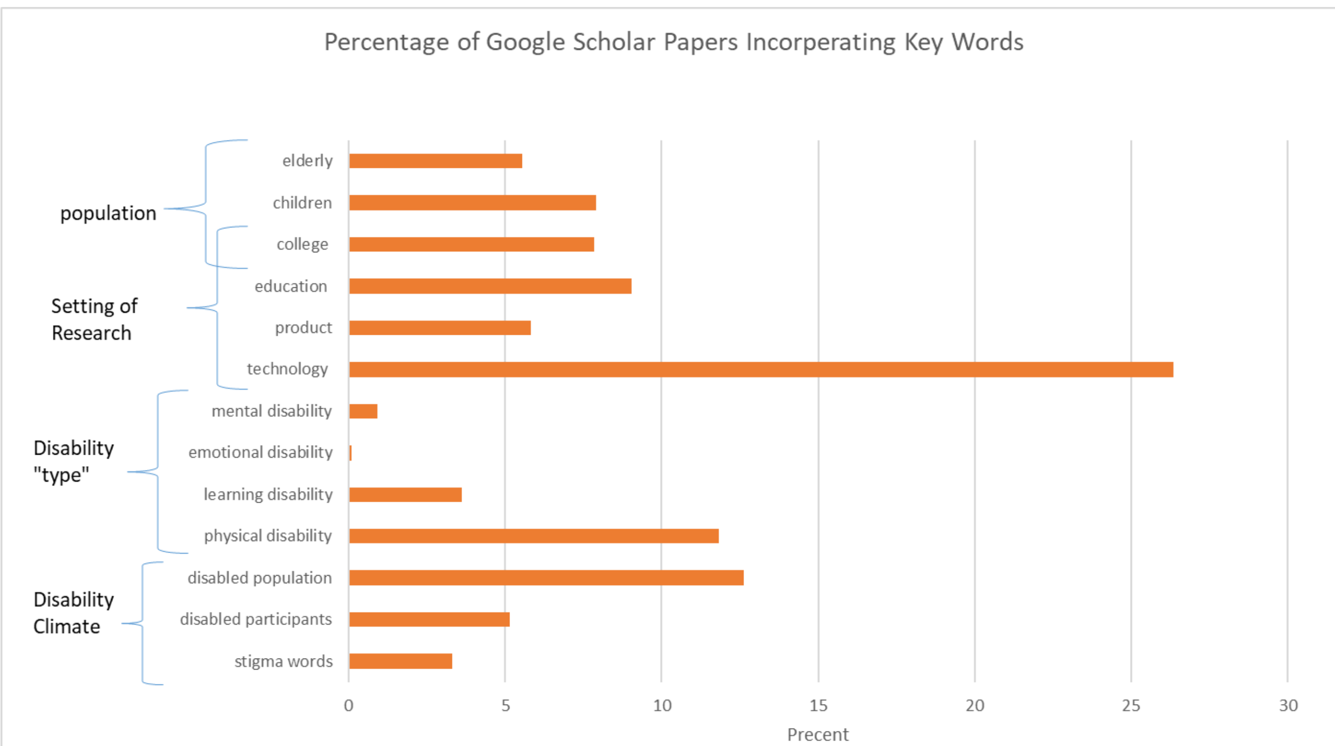


Figure 14: Percent of papers incorporating key words

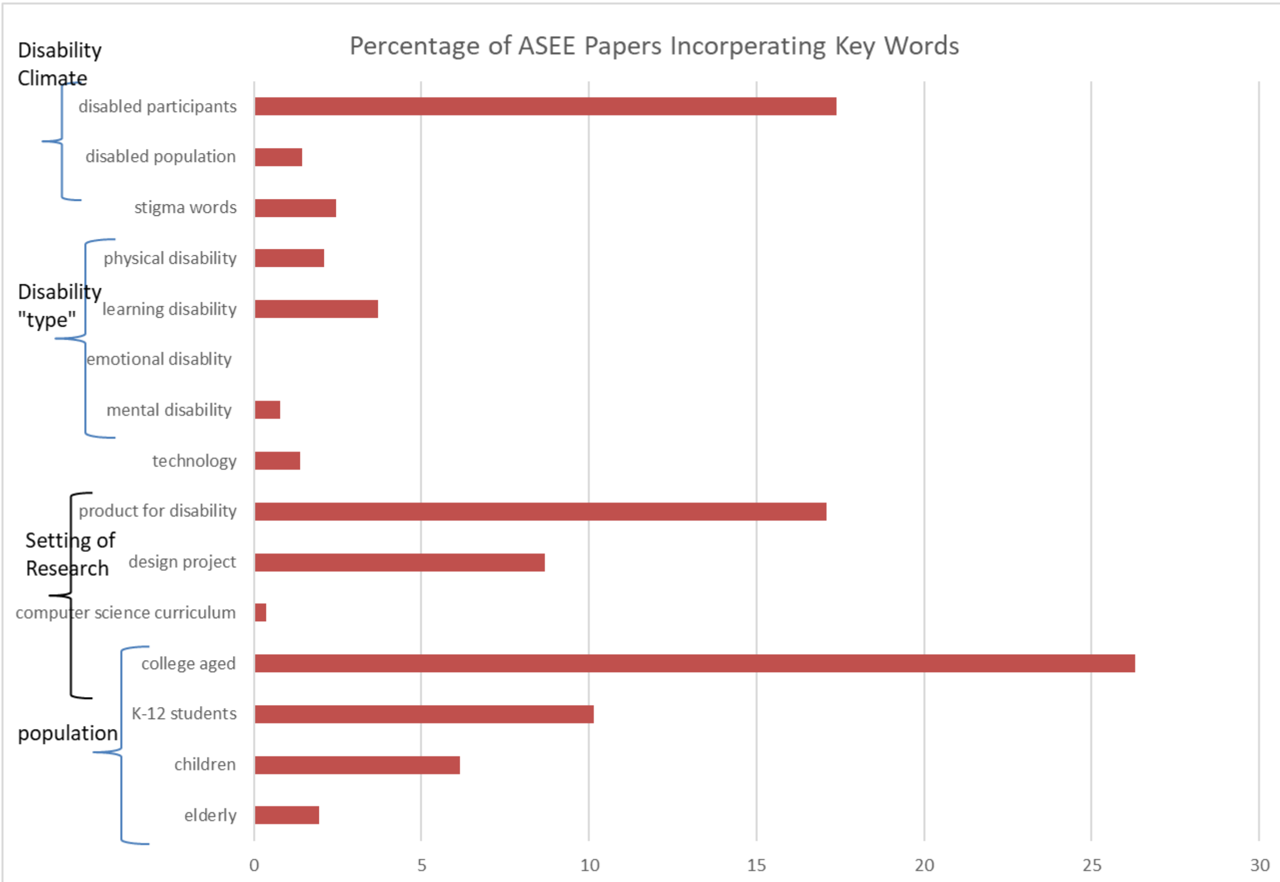


Figure 15: Percent of paper incorporating key words

Discussion

The data and the results provided support the idea that the inclusion of the disabled population and disabled community in a meaningful manner in engineering remains an emerging area as seen by the lack of active disabled participation within engineering education research as presented by ASEE and general engineering research. It is expected that the lack of inclusion of disabled people within engineering education literature is because of the lack of disabled students within engineering, especially at the undergraduate collegiate level (U.S. Department of

Education, 1988). Additionally, the lack of inclusion of disabled people within engineering education literature could be because of the lack of targeted recruitment and targeted retention strategies for disabled students within engineering for collegiate work. Disability is not federally included within the underrepresented minority designation, despite it fitting well into that category, so it tends to be left out of the broadening participation in engineering conversation.

It is expected that the lack of disabled participation in the general engineering academic literature stems from the unwillingness of disabled people to disclose their disability even within the general public and the lack of disability awareness, acceptance, and education within engineering (McLaughlin, Bell & Stringer, 2004). Typically, within the literature, the traditional engineering work pertaining to disability focuses on the production of products by nondisabled engineers, even if the product is for disabled people. Through the exploration of the data it became apparent that traditional engineering still tends to view the disabled people as a population and creates products to "fix" them rather than being perceived as a population that has a unique perspective and should be included and educated as an equal engineering partner. A common example of engineering without consulting and including disabled people is the promotion of exoskeletons for individuals who utilize wheelchairs. The vast majority of people who have difficulty walking are not suitable candidates for exoskeletons, and these devices are exorbitantly expensive and not covered by insurance (Gijzen, 2017). Rather, most mobility impaired people would rather have no stairs present than the ability to, sometimes very painfully, walk up the stairs. The concept of participatory design, where the target population of the product is included within the development and design of a product, would help involve disabled people in a meaningful way while creating more useful and productive technology for disabled individuals (Cochran, Marshall, Garcia-Downing, Kendall, Cook, McCubbin, & Gover, 2008).

The narrative of "design for disabled students" and "design for disabled individuals" rings loudly through this data set perpetuating the "othering" ideology of the disabled population. Within the othering ideology, researchers come from the mindset of "us" versus "them," "engineers" versus "the disabled," "the included population" versus "the excluded target population." This narrative subtly speaks to the exclusion of the disabled population within engineering both as active participants in research and product development, practicing engineers, and engineering students. This point is emphasized within the argument of including disabled people within engineering design and the engineering of products through the utilization of participatory design and encouraging production of disabled engineering students and engineers.

Despite the greater focus on the disabled individuals within the engineering education academic literature in ASEE, both the engineering education academic literature in ASEE and the general engineering academic literature tend to frame their research with the medical model of disability rather than then the social model of disability. The social model of disability shifts the onus of accessibility onto society rather than placing the burden on the disabled person themselves.

The disability research that *does* typically happen within both general engineering academic research and engineering education research in ASEE tends to be *on* disabled individuals primarily and focuses on physical disabilities of K-12 student-aged population and the "elderly" population. Primarily the research on "elderly" populations is hesitant to call them disabled, even when they are dealing with a disability such as hearing loss or difficulty with mobility. These research interventions do not typically include the input of the elderly disabled population but still attempt to “solve” some of their perceived problems. This approach is similar within the research on the K-12 aged population. The literature leaves a meaningful gap in the research on disability and engineering research within higher education in ASEE and general engineering research for college aged disabled individuals. This gap in the literature on disabled individuals is similar within literature in other fields such as human development and psychology.

Furthermore, the low representation of engineering research related to mental, emotional, and learning disabilities within the engineering education and traditional engineering literatures denotes a gap in data collected about this particular subset of the disabled population. Specifically, at the postsecondary level, this gap is generally consistent within other disability literature (Trammell, 2009). Young adults typically are left out of the disability literature perhaps because disabled young adults have received coping mechanisms as children (if they have been disabled since a young age) and, thus, are assumed to be able to cope with their disability to the best of their ability (Trammell, 2009). This gap was particularly noticeable within the results found within the general engineering academic research. The largest discrepancy between the two sets of literature was the representation of learning disabilities within the articles. The engineering education academic literature presented within ASEE showed a larger percentage of literature on learning disabilities than the general engineering academic literature. This could be explained by the innate focus on education and learning that is present within the ASEE research.

Conclusion

Through the exploration of the recent scholarly literature on the intersection of engineering education, engineering research, and the disabled population, it is evident that there is a need for more research including the perspectives of disabled individuals in both engineering education and engineering practice. Additionally, there are less data about invisible disabilities and their intersection with the engineering field and engineering education. This review suggests that there is a specific need for future research on the inclusion of disabled students, individuals, and industry works within the engineering field. Finally, this research presents the idea that the depiction of disability within engineering has the potential to expand to include disabilities beyond physical disabilities. Much of the literature in both the traditional engineering academic research and traditional engineering education research presented within the ASEE national database is framed, even subconsciously, around the medical model of disability rather than the social model of disability. These models help frame how the research and the researchers think about disability as a whole. While the medical model of disability understands disability as formalized medical diagnosis imposed on someone where disability is an innately negative aspect that needs to be "fixed," the social model of disability frames disability as something that society imposes on people because of its inaccessibility. Framing disability with the social model of disability allows engineering research and engineering in general to be more inviting to disabled people and inclusive techniques such as participatory design.

Chapter 4

Websites: Understanding the Accessibility Landscape of Courses using Canvas as a Learning Management System

Introduction

Universities across the globe are using Learning Management Systems (LMSs) extensively. These online venues offer instructors a common interface in which to post items such as course syllabi, announcements, assignments, and grades. For students, it gives a single place on the internet where they, in theory, can access features of all of their courses. The interface typically allows instructors to complete activities relatively easily. However, the common interface does not mean that all content is created—or made accessible—equally.

In many cases, faculty members post content with little to no consideration of students with disabilities (Gladhart, 2010). For example, graphs which use a color scheme for plots of different data may be indistinguishable to students who are colorblind. Little consideration may be given to students who may utilize a screen reader. In most cases, overlooking students' accessibility needs is unintentional and simply the result of a lack of training. Instructors are largely unfamiliar with the accessibility standards (Spingola, 2018) and, therefore, content is created and posted to websites that is out of compliance. Further, the LMS structure itself is often out of compliance, which means that an instructor who posts content in compliance may find themselves with a web page that is out of compliance simply because of the framework of the LMS (Spingola, 2018).

Over the past decade, digitally mediated courses have become more prominent. Currently, 99% of all colleges use some sort of learning management system (Gladhart, 2010). Further, the business need and, proportionally, the market share growth for learning management systems have grown exponentially because of the heavy collegiate utilization of learning management systems to facilitate digitally mediated education.

Despite heavy reliance and investment in learning management systems, nearly 50% of students, including nondisabled and disabled, ask for "better features to better enable interaction and communication" (Gladhart, 2010). Although many students need to access online LMS dashboards, research and student responses state academia is "lagging behind" in their online institutional support for disabled people, especially those who have cognitive and learning disabilities (Dahlstrom, Brooks, and Bichsel, 2014). Although some research has started on the aspects needed to design for inclusive virtual environments, these have not been fully formed, assessed or validated. Most large national studies on higher education digital learning environments only briefly mention disabilities or fail to mention any data on disabilities, whether physical or cognitive.

The Web Content Accessibility Guidelines (WCAG) were created by the World Wide Web Consortium (W3C), the body that sets the main international standards for the World Wide Web. The WCAG 2.0 guidelines are designed for all Internet pages, including academia, industry, and commercial sites, and many countries require compliance. The guidelines are categorized into three levels of compliance: A (basic accessibility compliance), AA (medium level of accessibility compliance), and AAA (highest level of accessibility compliance outlined in the WCAG). Note that 'conformance' to a level of the standard is defined for a complete Web page, and features of that page outside of the designer's control may prevent compliance at a higher level; this scenario could be the case within pages posted in the framework of an LMS. Instructors cannot control certain aspects of their LMS site.

My study explores this compliance issue by examining the frequency of errors as defined by the WCAG 2.0 standards within course web pages (Web Content Accessibility Guidelines, 2019). Focusing on the current level of accessibility of course webpages for courses taken by early engineering students, my study identifies common pitfalls inherent in digital learning platforms and identifies interventions that can ensure a higher level of accessibility and inclusion within the online portion of the engineering classroom. Since this form of learning is relatively new and constantly evolving, there is room for improvement in many areas of this digital learning system, especially with respect to accessibility. There has been little improvement in these systems on assisting or helping students with disabilities, and content added by faculty members or instructors utilizing the learning management systems as a course website framework is also lacking in incorporating features required for accessibility.

My study unpacks a few of the elements that may contribute to inaccessible course webpages: 1) the type of page that is embedded within the system, and 2) characteristics of the course instructor, who can make decisions about the course design. I address the following research questions in part one of this study, which focuses on a multi-section course for first year and transfer engineers:

- What is the relationship between the type of webpage and the number of accessibility errors on a webpage?

- What is the relationship between the individual instructor who created the content for a course site and the number of accessibility errors?

The second part of this study seeks to understand the accessibility landscape of digitally mediated courses throughout a suite of foundational gateway courses for engineering students at the undergraduate level across multiple departments. This part of the study tries to understand the accessibility of the structure of Canvas as it is utilized by different courses, instructors, and departments. Research questions guiding this part of the study include:

- How do different courses differ in the number of accessibility errors on course webpages?
- Are there differences between different course page types with respect to accessibility errors?
- Which accessibility errors are the most common?

Addressing both sets of research questions will connect with research knowledge that has been completed individually within the computer science, learning management systems, and accessibility fields. The Web Content Accessibility Guidelines (WCAG), a world-wide standard, was used to access the accessibility of multiple sections of introductory engineering course websites. Further research into the accessibility of common learning management systems supported the idea that certain prevalent accessibility faults were innate to the learning management system itself and were unable to be modified by the instructor of the course. This initial literature finding informed the analysis in my study (Spingola, 2018).

To address the first set of research questions, I conducted a series of three experiments. The first observational experiment was an exploratory complete randomized design investigating the number of WCAG level AAA errors found per page by type of page and by instructor. The second and third observational experiments were nested designs exploring errors per page dependent on instructor and type of page, respectively. The second set of research questions was addressed in a similar manner, with a series of three experiments: 1) a complete randomized design investigating the number of WCAG level AAA errors found per page by type of page and by course code, 2) a nested ANOVA nesting pages under courses as opposed to instructors, and 3) a multiple regression to understand the top two variables that explain the most variation contributing to total AAA accessibility errors.

Results of these analyses were used to develop a workshop and guide focused on accessibility information that is pertinent when instructors creating an engineering course website. Workshop attendees were given a quick tips and tricks sheet on how to implement these suggestions into their engineering course websites to enhance accessibility of their online digital materials.

Data and Methods

This study is broken into two different parts. For part 1, I analyzed course websites within the First Year Engineering courses. In Part 2, I analyzed a broader set of course websites that encompassed foundational courses that were required within the engineering curriculum. These courses are housed in different departments, and my study included the following departments: Chemistry, Mechanical Engineering, Engineering Education, Physics, and Engineering Science and Mechanics.

Contexts of the Courses

For the first part of this study, all First Year Engineering faculty and instructors were contacted by email with a request for participation. This correspondence was completed after requesting and gaining approval from the Assistant Department Head for Undergraduate Studies in Engineering Education, the department that manages the First Year Engineering Courses. All individuals who were teaching the First Year Engineering Courses at the time, in Spring of 2018, were emailed and asked to grant me optional access to the content of their Canvas course. Instructors had the right to grant access or not and could revoke this access at any time throughout the study. At the time, the following groups of individuals were responsible for teaching the First Year Engineering Courses: teaching-intensive faculty members, research-intensive tenure-track faculty members, and Graduate Teaching Assistants (i.e., graduate students) who had varying levels of teaching experience with this particular course. Additional demographic information about each individual teaching this course was collected, however it is not relevant within this study. 11 members of the teaching team participated out of a possible 30 instructors; there was less Graduated Teaching Assistant representation in the sample than in the population, proportionally.

The second part of this study included faculty members who taught first and second year courses for engineering students. Individuals teaching these courses included the same groups of individuals as in the first part of the study. No additional demographic information was collected from those teaching. These instructors were contacted through an existing faculty contact who had previously completed non-accessibility related research collaboratively. Instructors contacted through email via the existing faculty contact were assured that the information would remain anonymous and that they could revoke consent at any time by eliminating my access to their Canvas course website. 17 total instructors participated within part two of this study.

Both parts of this study were conducted at a large, research–intensive institution known for its highly ranked College of Engineering. At this institution, there is a common first year engineering program that is required for all engineering students within their first year at the institution before they are able to declare an engineering discipline as their major. At this institution, the learning management system universally provided to instructors is Canvas. Some professors use other course website platforms or create their own course website without the aid of a learning management system. None of these types of course websites were included within either part of this study.

Analyses

To understand and explore the research questions in part one, I conducted a series of three experiments. First, I characterized variable types: “page type” and “instructor.” “Page type” is guided by the specific LMS framework and included five types of pages determined by the auto-populated embedded navigation: home page, syllabus, assignments, modules, and announcements. The page types were derived from the vertical navigation within the individual Canvas course websites. “Instructor” included 6 different instructors at varying levels: tenured, tenure track, Professor of Practice, and Graduate Teaching Assistant. Figure 16 shows the Canvas layout and the navigation to the left denoting the different page types that were analyzed.

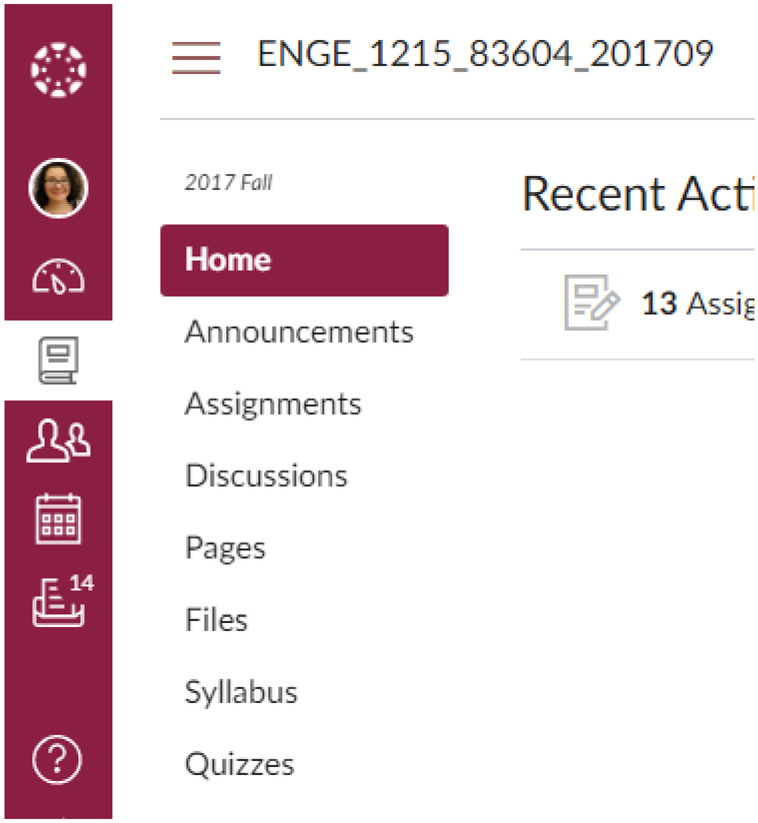


Figure 16: Navigation and page types within Canvas

The data were collected using an automated tool: a Google Chrome web browser extension named "Siteimprove." This extension automatically checks the accessibility of a particular webpage at the click of a button by looking at the computer code behind the page and how that code visually presents itself on the actual page. From there, it checks to see if there are violations to the Web Content Accessibility Guidelines (WCAG) at the A, AA, and AAA levels, with A being the least strict and AAA being the most strict and most theoretically accessible. Violations are categorized and recorded by the different categories of the WCAG under each level of compliance. All of the violations for each level of compliance were totaled per page to obtain the number of total violations per level of compliance. All data were stored in an Excel sheet. Figure 17 shows an example of the "Siteimprove" extension.

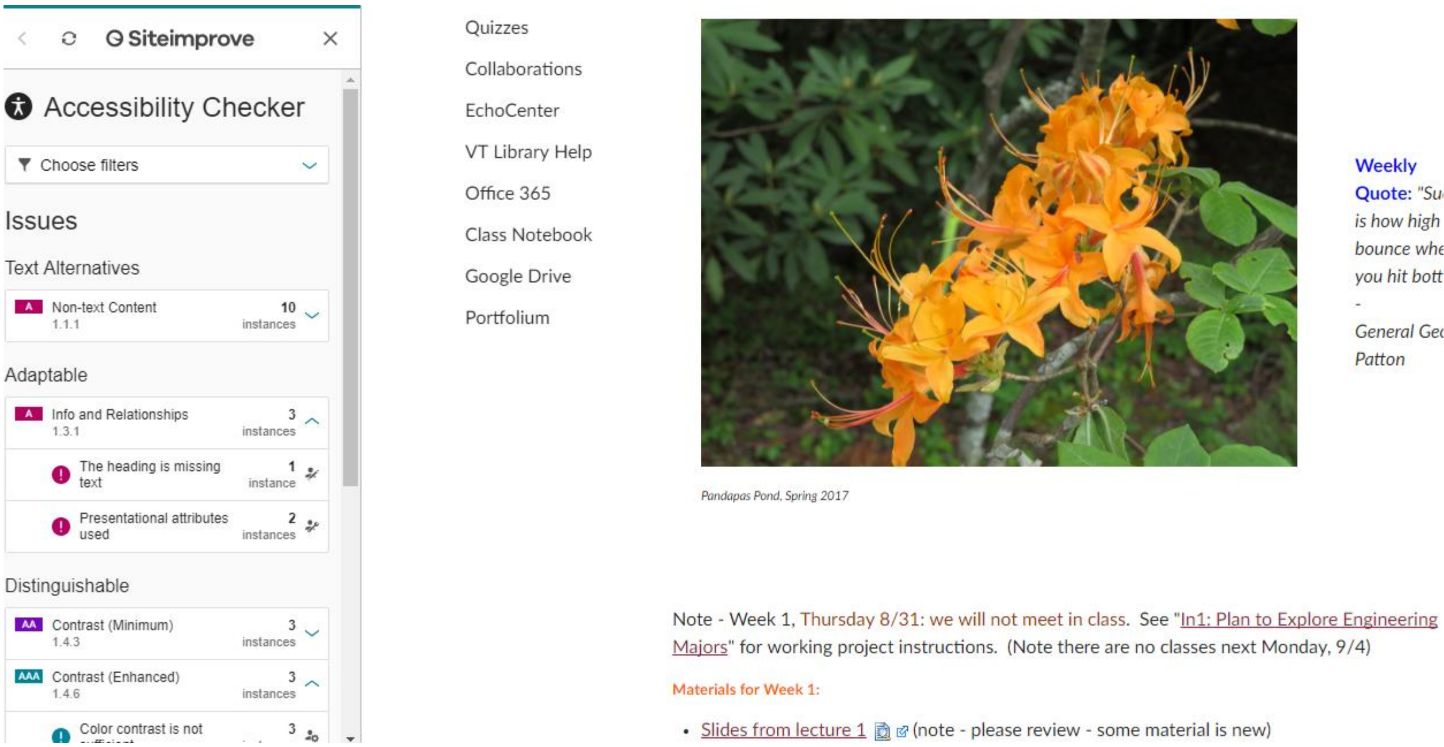


Figure 17: The Siteimprove Google Chrome Extension on an individual Canvas course website

Part 1: Observational Experimental Design 1

The first experiment was carried out to determine the accessibility of engineering course websites based on the WCAG standards legally incorporated within the Americans with Disabilities Act. The number of violations at the AAA level found on each page is the response variable. The two different variables that were included within this study were page type and instructor. The response of this experiment was the AAA total number of errors presented per page. A simple ANOVA was completed to explore the correlation between the independent variables "page type" and "instructor" and the response variable “number of AAA violations found on each page tested,” which I refer to as “errors” throughout the remainder of this text.

To understand the general trends in the data and to check assumptions, I used normal probability plots, residual vs fitted plots, and histograms. All of these visual tests show the patterns of the entire data set to ensure that the data performs in a normal manner. To ensure this, I looked for outliers and unusual patterns such as an “S” shaped or curved line. While the outliers are important to analyze and record before deletion, curving patterns in the residual vs fitted plots may indicate a need for a transformation of the data to ensure normality. Fisher’s LSD post hoc tests were thereafter utilized because there was found to be significant difference between the groups to understand where the significant differences (if any) were and to what extent.

Part 1: Observational Experimental Design 2

The second experiment utilized the same independent and response variables as the first experiment, however it utilized a nested structure for the ANOVA with the “page type” variable nested under the instructor who created the particular page. Within this design, I randomly selected three instructors to test the differences in total number of accessibility errors based on the page types the instructors created. Three instructors were randomly selected for this experiment to understand patterns within the sample with the least amount of variables possible for sound experimental design. The web pages selected were nested under each instructor, and within the entire web site, I randomly selected pages to test for accessibility errors using the AAA WCAG 2.0 standards. By nesting the pages under the instructor, I am able to see if there are differences between the page types and the instructors while showing the dependence of the created page on the instructor. Table 6 shows the structure of the variables used within this experiment. Note: there were more replicates provided than what is shown within Table 6.

Table 6: Structure of variables used in experiment 2

Instructor 1	Page type 2	Errors
	Page type 3	Errors
	Page type 5	Errors
Instructor 2	Page type 2	Errors
	Page type 3	Errors
	Page type 5	Errors
Instructor 3	Page type 2	Errors
	Page type 3	Errors
	Page type 5	Errors

Part 1: Observational Experimental Design 3

Experiment three was a duplication of experiment two with a nested ANOVA design. This experiment was conducted to determine the generalizability of the results in experiment two to the population of engineering faculty and instructors.

This observational experiment in the nested experimental design using different instructors identified whether there was consistency in results throughout the study sample. Within this design three different instructors were selected. The web pages selected were nested under each instructor, and within the entire web site randomly selected pages within page type were tested for accessibility errors using the AA WCAG 2.0 standards. Table 7 shows the structure of the variables used within this experiment

Table 7: Structure of variables used in experiment 3

Instructor 4	Page type 2	Errors
	Page type 3	Errors
	Page type 5	Errors
Instructor 5	Page type 2	Errors
	Page type 3	Errors
	Page type 5	Errors
Instructor 6	Page type 2	Errors
	Page type 3	Errors
	Page type 5	Errors

Part 2

For the second part of the study, I followed a similar three-experiment approach. In this first experiment, a simple ANOVA was completed to explore the correlation between the independent variables "page type" and "course code" and the response variable "number of AAA violations found on each page tested," which I refer to as "errors" throughout the remainder of this text. Within experiment 2, the nested ANOVA was still used as in the first part, however, instead of nesting pages under instructors, the webpages were nested under courses. The variable course code was used to understand the differences that occur within different courses rather than the difference that occur between instructors of the same course because of the small sample size of courses within each department; the statistical viability of understanding granular differences between departments is minimal. This is why course code and page type were utilized. Within experiment 3 multiple regression was utilized to understand the two variables that explained the most variation contributing to total AAA accessibility errors.

Limitations

Although Siteimprove is a viable accessibility checking tool, all automated accessibility checking tools have their limitations. These tools can produce false positives allowing for more errors than actually present and false negatives allowing for less errors than actually present. For example, when the Google Chrome extension Siteimprove is utilized on specific university pages, it will not process the images that link to PDFs of information properly. This will produce an error when that particular aspect of the page may include the proper accessibility aspects needed by reference to the WCAG. Additionally, Siteimprove does not check the accessibility of linked websites and external sources, embedded materials such as documents and videos, and other material embedded within the Canvas framework. Because of this limitation of the tool, this research *only* speaks towards the Canvas framework and instructor added elements directly to the course website. This research cannot speak for the accessibility of the embedded elements of the course websites such as embedded videos, external websites, embedded modules, and linked documents.

In addition, part two of this study is limited by the number of instructors within the sample from each of the different courses and departments. Small numbers of instructors within many of these departments within the sample limited the generalizability of the results, limited the type of analysis able to run, and limited the conclusions created from the data and analysis. Conclusions about differences between departments and instructors teaching the same courses were limited because of the small sample size within part two.

Results for Part 1

Observational Experiment 1

Overall, there were significant differences across page types and instructors (*p*-values of 0.000 and 0.001, respectively). This finding implies that there are differences between page types and instructor codes for the accessibility errors on the course web sites.

To understand the differences presented within the page type and instructor type, a Fisher Least Significant Difference (LSD) post hoc test was performed. Through this test, the page types were seen to fall within three significantly different groups. Additionally, instructor code grouped within three significantly different groups. However, the groups within instructor code are not mutually exclusive. The results of the Fisher LSD test can be seen within Table 10, the instructor codes utilized within this experiment are explained within Table 8, and the page type codes and their correlating explanations are found within Table 9.

Table 8: Description of the Instructor codes

Instructor code	Code meaning
2 and 6	Tenure track faculty
3 and 5	Graduate Teaching Assistant
1 and 4	Full time instructor

Table 9: description of the page type codes

Page type code	Code meaning
1	Home page
2	Assignments page
3	“pages” page
4	Syllabus page
5	Announcements page

Table 10: Results of Fisher LSD test

Fisher Pairwise Comparisons: page type

Grouping Information Using Fisher LSD Method and 95% Confidence

page type	N	Mean	Grouping		
4	12	159.043	A		
2	52	67.528		B	
5	40	59.186		B	
3	264	42.057			C
1	14	32.027			C

Means that do not share a letter are significantly different.

Fisher Pairwise Comparisons: instructor code

Grouping Information Using Fisher LSD Method and 95% Confidence

instructor code	N	Mean	Grouping		
2	48	86.0406	A		
6	120	76.5995	A	B	
3	26	71.7438		B	C
5	54	71.0655		B	C
4	124	69.4889		B	C
1	10	56.8698			C

Means that do not share a letter are significantly different.

Finally, the assumptions of normality and homogeneity were tested. These graphs can be seen within Figure 18. The visual tests for normality presented within Figure 18 showed relative normality and homogeneity. Within the normal probability plot there were a few outliers, however, they did not statistically affect the ANOVA results when they were eliminated (note: I re-ran analyses without these points and found similar results). The histogram of values were approximately normal and the other two plots showed a nice randomized spread of variance. The assumptions were thus checked and assumed to be relatively normal.

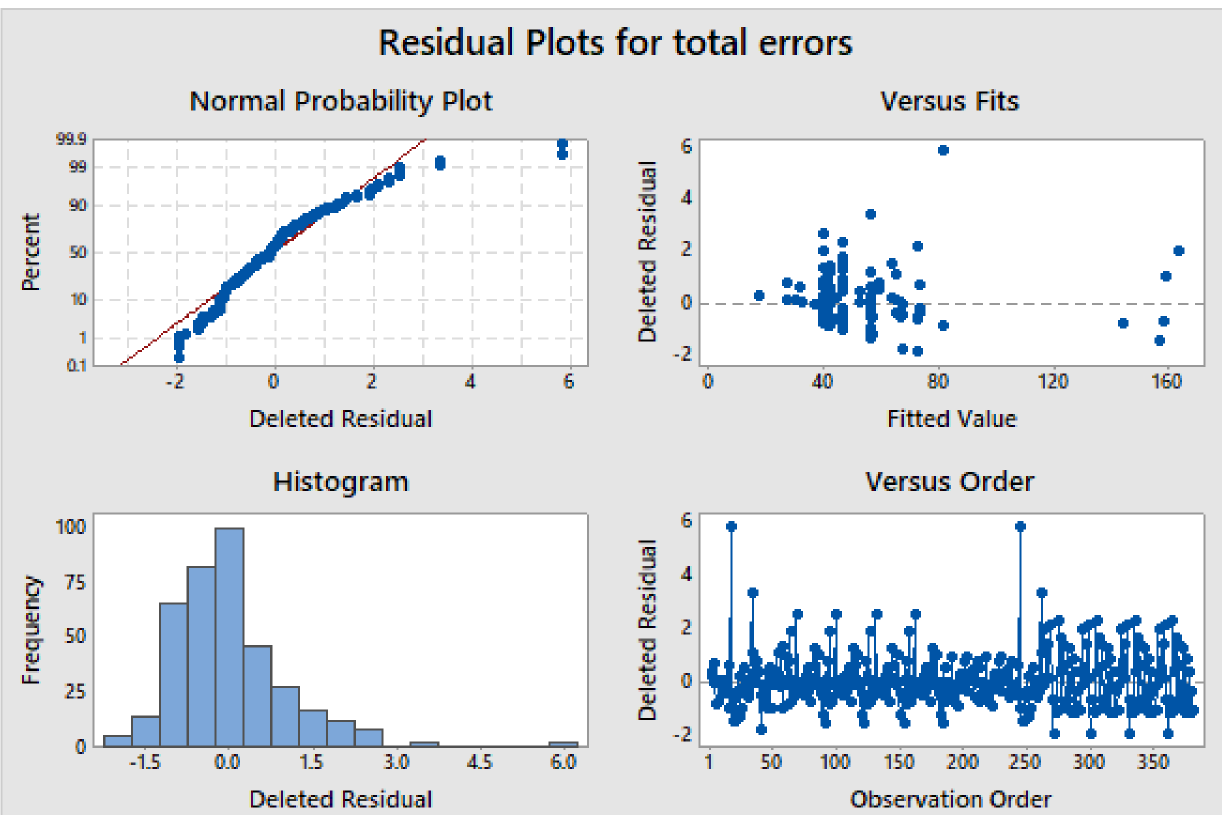


Figure 18: Results of test for normality and homogeneity

Observational Experiment 2

Looking at the normality and homogeneity plots for the second observational experiment, shown in Figure 19, there are some outliers that can be seen within the normal probability plot. Due to this, these outliers were deleted and the nested ANOVA analysis was run again along with the normality and homogeneity plots to test for normality and homogeneity. The new normality and homogeneity plots can be seen within Figure 20. These results were closer to normal than the original plots, which enabled the subsequent ANOVA.

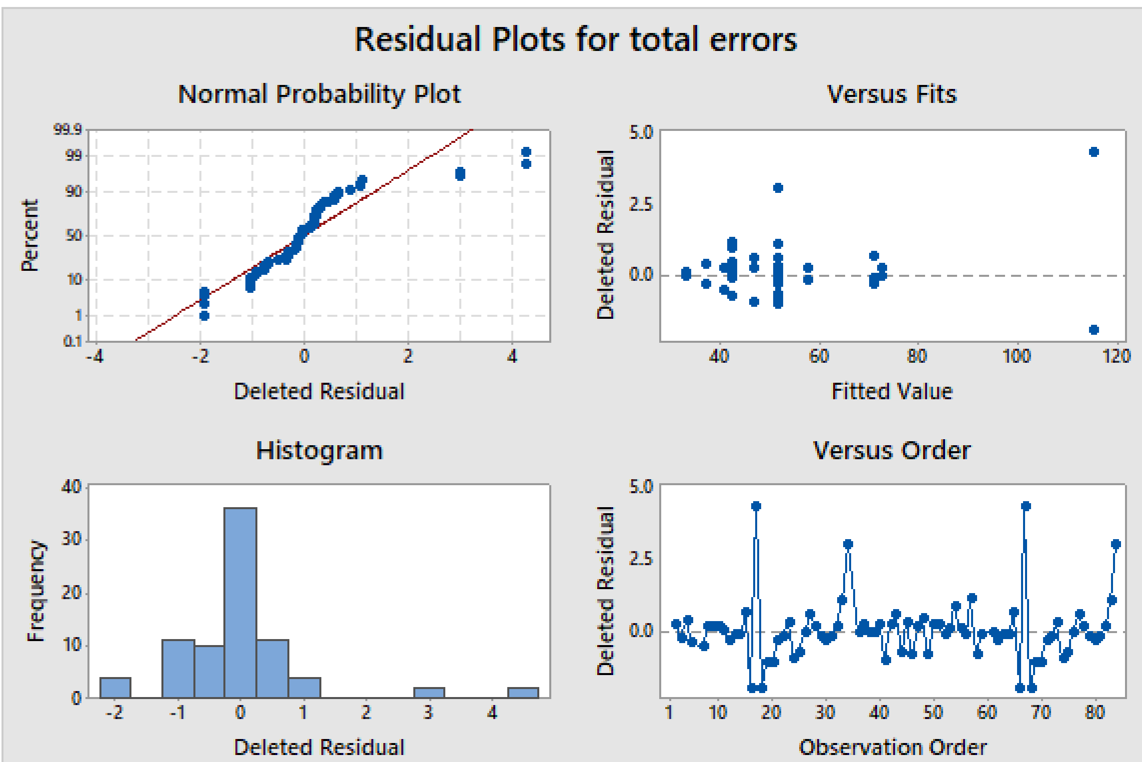


Figure 19: original normality and homogeneity plots

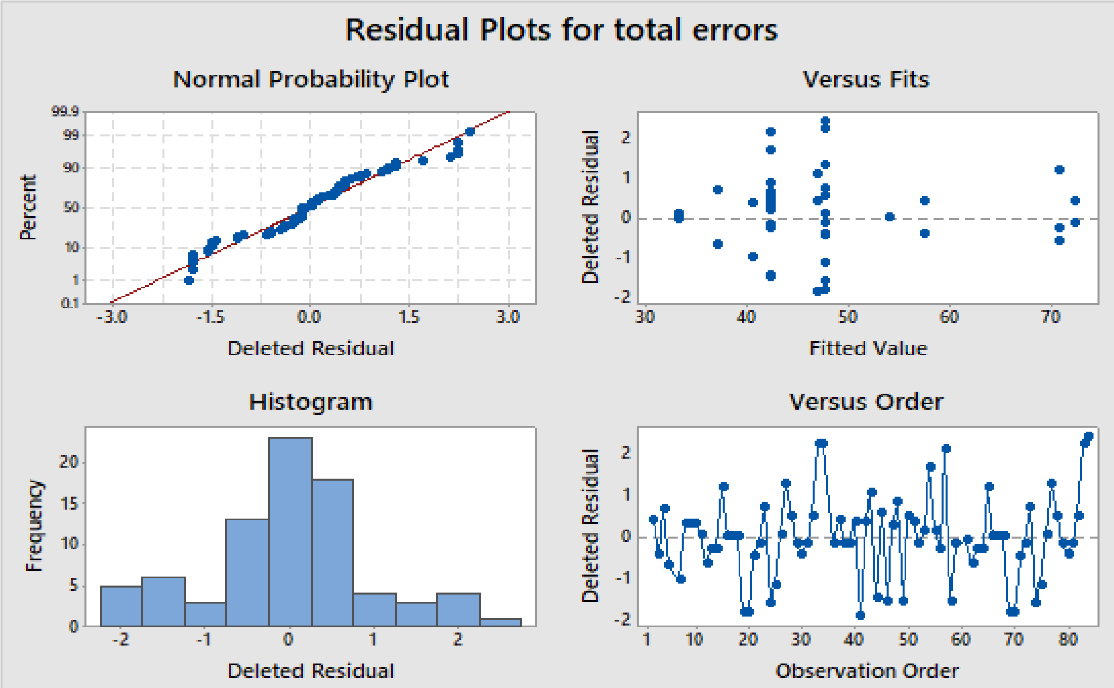


Figure 20: Normality and homogeneity plots with the outliers eliminated

Overall, there were significant differences between instructors and the nested page types, with *p*-values of 0.000 and 0.001, respectively. This finding implies that the errors associated with different instructors on different page types were significantly different from each other. To understand this finding in a more nuanced manner, a Tukey post hoc test was performed. The results of the Tukey tests of the variables can be seen within Table 13. The instructors grouped within two separate groups, and the nested page types can be seen to be grouped within four significantly different groups. In both cases these groups are not necessarily mutually exclusive. The instructor codes utilized within this experiment are explained within Table 11 and the page type codes and their correlating explanations are found within Table 12. Within the groups for the instructors, the tenure track faculty and the full-time instructors were in the same group, meaning they produced, statistically, the same amount of errors on average. This group, group A, was statistically higher in the errors they produced than group B, the Graduate Teaching

Assistants. However, there was overlap between group A and group B with the tenure track faculty falling, statistically, in both group A and group B. Practically, this means that there is a statistical difference in the number of errors produced by Graduate Teaching Assistants and Full Time Instructors, with the latter group having more errors associated with their sites.

Table 11: Description of the Instructor codes

Instructor code	**Code meaning**
1	Tenure track faculty
2	Graduate Teaching Assistant
3	Full time instructor

Table 12: description of the page type codes

Page type code	**Code meaning**
1	Home page
2	Assignments page
3	“pages” page
4	Syllabus page
5	Announcements page

Table 13: Results of Tukey post-hoc test

Tukey Pairwise Comparisons: instructor code

Grouping Information Using the Tukey Method and 95% Confidence

instructor code	N	Mean	Grouping	
3	26	75.2250	A	
1	10	56.0000	A	B
2	48	51.3203		B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: page type(instructor code)

Grouping Information Using the Tukey Method and 95% Confidence

page type(instructor code)	N	Mean	Grouping			
4(3)	1	184.000	A			
4(1)	1	122.000	A	B		
5(3)	4	72.250		B	C	D
5(2)	8	70.750		B	C	
2(1)	2	57.500		B	C	D
2(2)	6	54.000		B	C	D
3(2)	32	47.531			C	D
2(3)	4	46.750			C	D
3(3)	16	42.125				D
5(1)	4	40.500			C	D
3(1)	2	37.000			C	D
1(2)	2	33.000			C	D
1(3)	1	31.000		B	C	D
1(1)	1	23.000			C	D

Means that do not share a letter are significantly different.

The second part of Table 13 shows the page types and their groupings based on the statistical differences of their mean accessibility errors at the AAA level. Page type 4, the syllabus page, had the most errors produced out of all of the page types tested. This group, group A, is statistically higher than groups C and D exclusively and higher than group B with only one overlapping pages (i.e., the syllabus page from tenure track faculty members). The other pages included within group B, the announcement pages from Graduate Teaching Assistants and Full Time Instructors, and the assignment pages from tenured faculty and Graduate Teaching Assistants all overlapped with group C. Both of these groups, also, overlapped with the home page by full time instructors. All pages not included within group A are included within group C and D with only two exceptions. The “pages” page created by full time instructors were not included within group C, and the announcements pages created by Graduate Teaching Assistants. On average, when accounting for instructor type, the pages with the most accessibility errors on average to the least accessibility errors on average are: syllabus pages, announcements pages, assignments pages, “pages” pages, and home pages. It is important to note that all of the pages created, and thus the errors produced from those pages, are also a function of each of the individual instructors.

Observational Experiment 3

Test results for assumptions, normality and homogeneity, can be seen within the four plots in Figure 21. The normalization of the data may be questionable with some of the tail points of the data but fit within the typical tests of being less than a standard deviation from the mean, so no outliers were deleted, and the data can be analyzed without transformations or deletions. Additionally, the variance of residuals is not as homogeneous as would be ideal but, once again, it was less than a standard deviation from the mean with adequate spread, so no transformations or deletions were applied. Data shown within these graphs do not indicate enough difference from normal distributions to invalidate the ANOVA test.

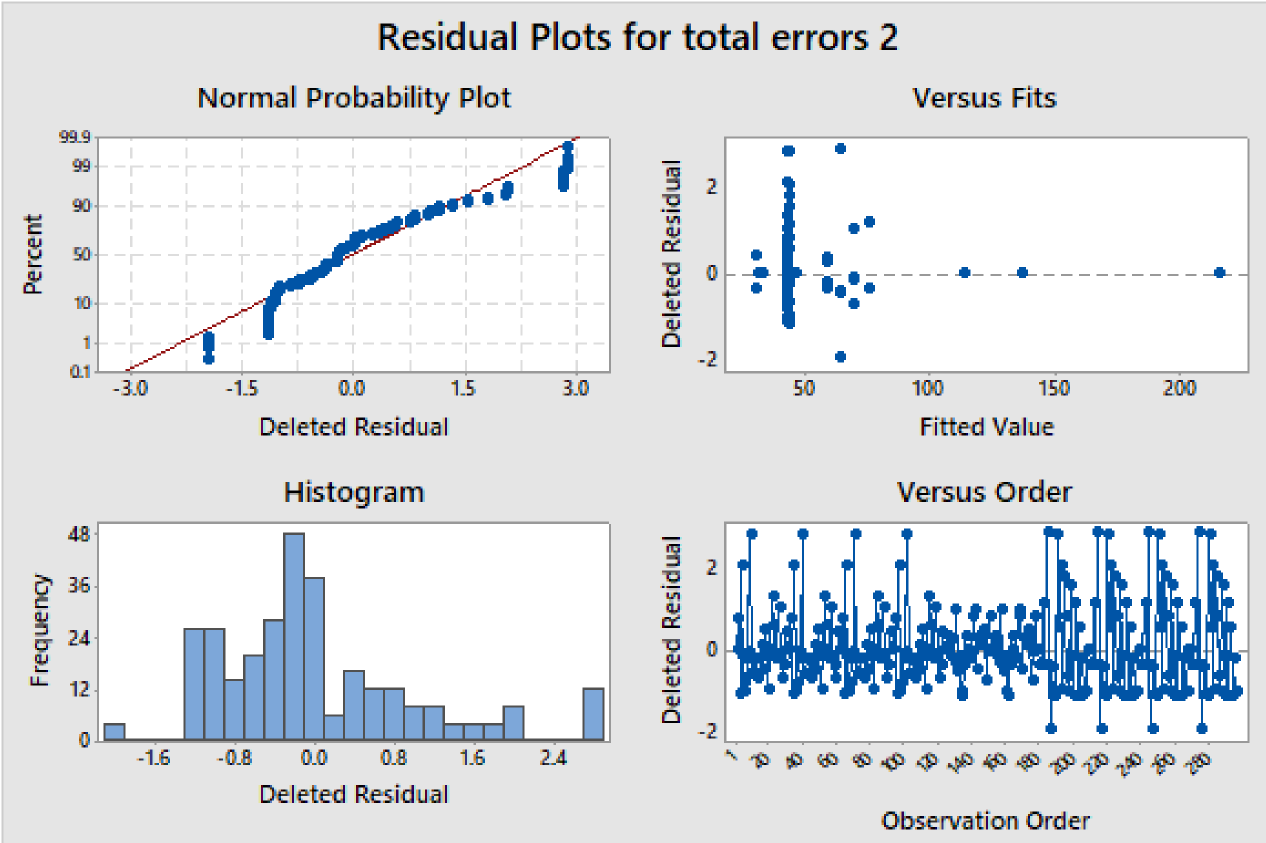


Figure 21: Test results for assumptions, normality and homogeneity

Through the ANOVA, there were significant differences for both instructor and the nested page type, with *p*-values of 0.0000. These results are very similar to the results provided within experiment 2. Table 14 shows both of these ANOVA tables with one another for comparison. The ANOVA table on top is from experiment 2, and the ANOVA table on the bottom is from the third experiment. The new ANOVA table shows that both instructor code and the page type variables are significant, with *p*-values of 0.000 for them both. This finding implies that the errors associated with different instructors on different page types were significantly different from each other. To understand this finding in a more nuanced manner, a Tukey post hoc test was performed.

Table 14: ANOVA tables

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
instructor code	2	3779	1889.4	5.50	0.006
page type(instructor code)	11	32082	2916.6	8.49	0.000
Error	70	24050	343.6		
Total	83	56193			

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
instructor code 2	2	15730	7865.0	13.07	0.000
page type 2(instructor code 2)	11	173023	15729.3	26.15	0.000
Error	284	170836	601.5		
Total	297	348606			

Since the *p*-values for both instructor and page type signified a significant difference, the Tukey post hoc test was appropriate and was performed on both the variables (i.e., instructor and the nested page type). A summary of the Tukey test can be seen in Figure 6. The Tukey test for instructor was identical to the finding for experiment 2. However, the Tukey test on the nested page type variable was somewhat different than the results produced from experiment 2's Tukey test on the nested page type. A side by side comparison of the Tukey post hoc tests on page type in both experiments 2 and 3 can be seen within Table 15.

Table 15: Results of Tukey test

Tukey Pairwise Comparisons: instructor code 2

Grouping Information Using the Tukey Method and 95% Confidence

instructor code 2	N	Mean	Grouping	
6	120	86.4500	A	
5	54	71.1250	A	B
4	124	57.4826		B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: page type 2(instructor code 2)

Grouping Information Using the Tukey Method and 95% Confidence

page type 2(instructor code 2)	N	Mean	Grouping				
4(6)	4	216.000	A				
4(5)	2	137.000		B			
4(4)	4	114.000		B	C		
5(6)	16	76.000		B	C	D	
2(4)	16	69.500			C	D	
2(6)	16	63.750				D	E
2(5)	8	58.500				D	E
1(5)	2	46.000			C	D	E
3(6)	80	43.500					E
3(5)	42	43.000					E
3(4)	92	42.913					E
1(6)	4	33.000				D	E
1(4)	4	31.000				D	E
5(4)	8	30.000					E

Means that do not share a letter are significantly different.

The instructors grouped within two separate groups, and the nested page types can be seen to be grouped within four significantly different groups. In both cases these groups are not necessarily mutually exclusive. The instructor codes utilized within this experiment are explained within Table 16, and the page type codes and their correlating explanations are found within Table 17. Within the groups for the instructors, the tenure track faculty and the full time instructors were in the same group meaning they produced, statistically, the same amount of errors on average. This group, group A, was statistically higher in the errors they produced than group B, the Graduate Teaching Assistants. However, there was overlap between group A and group B with the full time instructors falling, statistically, in both group A and group B. Practically, this means that there is a statistical difference in the number of errors produced by Graduate Teaching Assistants and Tenure track faculty.

Table 16: Description of the Instructor codes

Instructor code	Code meaning
6	Tenure track faculty
5	Full time instructor
4	Graduate Teaching Assistant

Table 17: description of the page type codes

Page type code	Code meaning
1	Home page
2	Assignments page
3	“pages” page
4	Syllabus page
5	Announcements page

Table 18: Tukey results for experiment 2 (left) and 3 (right)

page type(instructor code)	N	Mean	Grouping			
4(3)	1	184.000	A			
4(1)	1	122.000	A	B		
5(3)	4	72.250		B	C	D
5(2)	8	70.750		B	C	
2(1)	2	57.500		B	C	D
2(2)	6	54.000		B	C	D
3(2)	32	47.531			C	D
2(3)	4	46.750			C	D
3(3)	16	42.125				D
5(1)	4	40.500			C	D
3(1)	2	37.000			C	D
1(2)	2	33.000			C	D
1(3)	1	31.000		B	C	D
1(1)	1	23.000			C	D

Means that do not share a letter are significantly different.

page type 2(instructor code 2)	N	Mean	Grouping				
4(6)	4	216.000	A				
4(5)	2	137.000		B			
4(4)	4	114.000		B	C		
5(6)	16	76.000		B	C	D	
2(4)	16	69.500			C	D	
2(6)	16	63.750				D	E
2(5)	8	58.500				D	E
1(5)	2	46.000			C	D	E
3(6)	80	43.500					E
3(5)	42	43.000					E
3(4)	92	42.913					E
1(6)	4	33.000				D	E
1(4)	4	31.000				D	E
5(4)	8	30.000					E

Means that do not share a letter are significantly different.

The second part of Table 18 shows the page types and their groupings based on the statistical differences of their mean accessibility errors at the AAA level. Page type 4, the syllabus page, had the most errors produced out of all of the page types tested. This group, group A, is statistically higher than all of the other groups, including group B which contained the additional syllabus pages from the other instructor types. The other page included within group B was the announcement pages created by tenure track faculty. The other groups, C, D, and E, are not mutually exclusive. This means that the elements in multiple groups, the different page types, are statistically similar to the other elements in each group. Within this experiment, group B and C are both statistically different than group E. On average, when accounting for instructor type, the pages with the most accessibility errors to the least accessibility errors on average are: syllabus pages, announcements pages, assignments pages, “pages” pages, and home pages.

Although experiment 1 showed significant differences between page type and instructor, there was no grouping between pages that were not auto-created by the Canvas system. It is important to note that almost all of the different types of pages created by different instructor types fall within a different group. This finding means that even within different instructors and instructor types, page types still had a significant difference between one another, on average. Figure 7 shows the Tukey results for page type for experiments 2 and 3. This finding suggests that the web pages that the instructors produce have greater variability within errors relative to the instructors on their own. This particular result would not have been possible to find accurately without the use of a nested design.

Summary of Part 1

The first research question i.e., the relationship between webpage type and accessibility errors) was answered through the process of all three observational experiments. Within these experiments, it was found that the Syllabus pages, Announcements pages, and Assignment pages had the most errors, whereas the Home pages, on average, had the least amount of errors. This may be because of the large amount of detailed information and embedded information that is typically found within the Syllabus pages, Announcements pages, and Assignments pages in comparison to the Home pages. The second research question (i.e., the relationship between instructor types and accessibility errors) was also answered through the process of all three observational experiments. While experiment 1 showed a difference between the type of instructors and the number of errors they produced per page, experiments 2 and 3 emphasized that the differences in errors produced on each page type were more important than instructor type.

Statistical tests for each comparison were found to be significant. The post hoc tests denoted that there are significant differences between particular types of web pages and the instructors who produce the content for those pages. Practically, this means that there are significant differences in the number of errors produced between all of the variables tested: page types and the individual instructors. Different instructor types produce varying numbers of accessibility errors per page. Additionally, different page types that instructors utilized within their Canvas course produced different numbers of accessibility errors per page. For example, announcements pages for the courses tended to have fewer accessibility errors than the syllabus pages. This result could be troublesome especially if the instructors of the course put important information and deadlines that will need to be referenced by their students throughout the duration of the course.

This part of my study helped highlight the accessibility differences in digital education within engineering course websites for first-year engineering students. Armed with this knowledge, individuals who organize and teach training workshops for instructors can understand some of the major pitfalls instructors have when creating digital content for engineering courses. Although there are many opportunities to improve the digital accessibility of online engineering educational content, this study provides instructors with a starting point to help mitigate particular digital accessibility difficulties with in their courses with the Accessibility Guide, the Web-published Accessibility guide for LMS, and the Quick Tips and Tricks sheet found within Appendix D, Appendix E, and Appendix F. The results of these analyses were used to develop a workshop focused on providing instructors with accessibility information that is pertinent when creating an engineering course website. Additionally, engineering professors and instructors were given a quick tips and tricks sheet and were shown how to implement these suggestions into their engineering course website to maximize the impact of the work.

As a tangible deliverable from this research, I led one workshop for faculty, instructors, and graduate teaching assistants for all individuals teaching First Year Engineering courses. This workshop was an hour long, and participants were encouraged to ask their questions about accessibility especially as it pertained to their Canvas course website. About 15 individuals participated in this workshop. Additionally, a workshop was conducted at the conference Accessing Higher Ground, a conference focused on digital accessibility, where around 10 individuals participated. The workshop at the conference was similar to the instructor workshop but answered accessibility questions about the design of websites and the code under websites within an academic setting.

Results: Part Two

Part Two of this study focused on the accessibility of courses required for first and second year engineering students. These courses reside within the following departments: Chemistry, Mechanical Engineering, Engineering Education, Physics, and Engineering Science and Mechanics. Those teaching these courses, also, included: tenure-track faculty members, instructors, and Graduate Teaching Assistants.

Experimental Design 1: Generalized ANOVA

This experiment was run to understand how different courses differ in the number of accessibility errors on course webpages. Overall, there were significant differences across page types but not the different courses, with *p*-values of 0.0000 and 0.231, respectively, as seen within Table 19. This finding implies that there are differences between page types but not course code for the number of accessibility errors.

Table 19: the ANOVA for page type and course code

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
page type	8	2292776	286597	26.52	0.000
course code	7	100944	14421	1.33	0.231
Error	594	6418141	10805		
Lack-of-Fit	37	147938	3998	0.36	1.000
Pure Error	557	6270203	11257		
Total	609	8912546			

Table 20 shows the different page type code and their corresponding page type. Eight different page types were analyzed with an additional category reserved for other page types. Table 21 shows the different courses involved within this study and their corresponding course codes. Seven different courses were analyzed in this study.

Table 20: page types and their codes

Page type	id #
home	1
assignments	2
pages	3
syllabus	4
announcements	5
files	6
blank	7
quizzes	8
other	9

Table 21: Course name and their corresponding course code

Course	course id
ENGE 16442	1
ENGE 1644	8
PHYS 2305	2
ESM 2204	3
ENGE 1216	4
CHEM 1035	5
ENGE 1215	6
ESM 2304	7

To understand the differences presented within the page type and course code, a Fisher Least Significant Difference (LSD) post hoc test was performed. Through this test, the page types aggregated into five significantly different groups, with the Files pages containing the most errors along with the "Other" category of pages that grouped many different page types only utilized by few instructors or courses. Similar to the results found within Part 1, the Syllabus Pages had a large amount of errors, grouping within groups B and C. This was the page type with the highest amount of accessibility errors per page out of the page types that were tested within Part 1. The page types Pages, Quizzes, and Blank grouped together with the least amount of accessibility errors produced per page. The "Blank" category of pages consisted of many different page types that Canvas had automatically produced from the navigation in the course website but had no additional content placed on the page from the instructor or content manager. Additionally, course code grouped within two significantly different groups. Groups were not mutually exclusive in either case (e.g., a single course type could be present in multiple groups). The results of the Fisher LSD test can be seen within Table 22, which depicts the different statistically significant groups produced by page type and course code.

Table 22: Fisher LSD for Page Type and Course Code

Grouping Information Using Fisher LSD Method and 95% Confidence

page type	N	Mean	Grouping				
6	80	269.632	A				
9	23	227.983	A	B			
4	14	151.712		B	C	D	
2	249	127.350			C		
1	15	103.723			C	D	E
5	68	91.816				D	E
3	36	80.626					E
8	30	76.688					E
7	95	63.494					E

Means that do not share a letter are significantly different.

Grouping Information Using Fisher LSD Method and 95% Confidence

course code	N	Mean	Grouping	
1	195	151.137	A	
6	101	144.758	A	
3	64	143.622	A	B
8	32	132.441	A	B
7	38	130.949	A	B
4	45	124.862	A	B
5	52	119.682	A	B
2	83	113.014		B

Means that do not share a letter are significantly different.

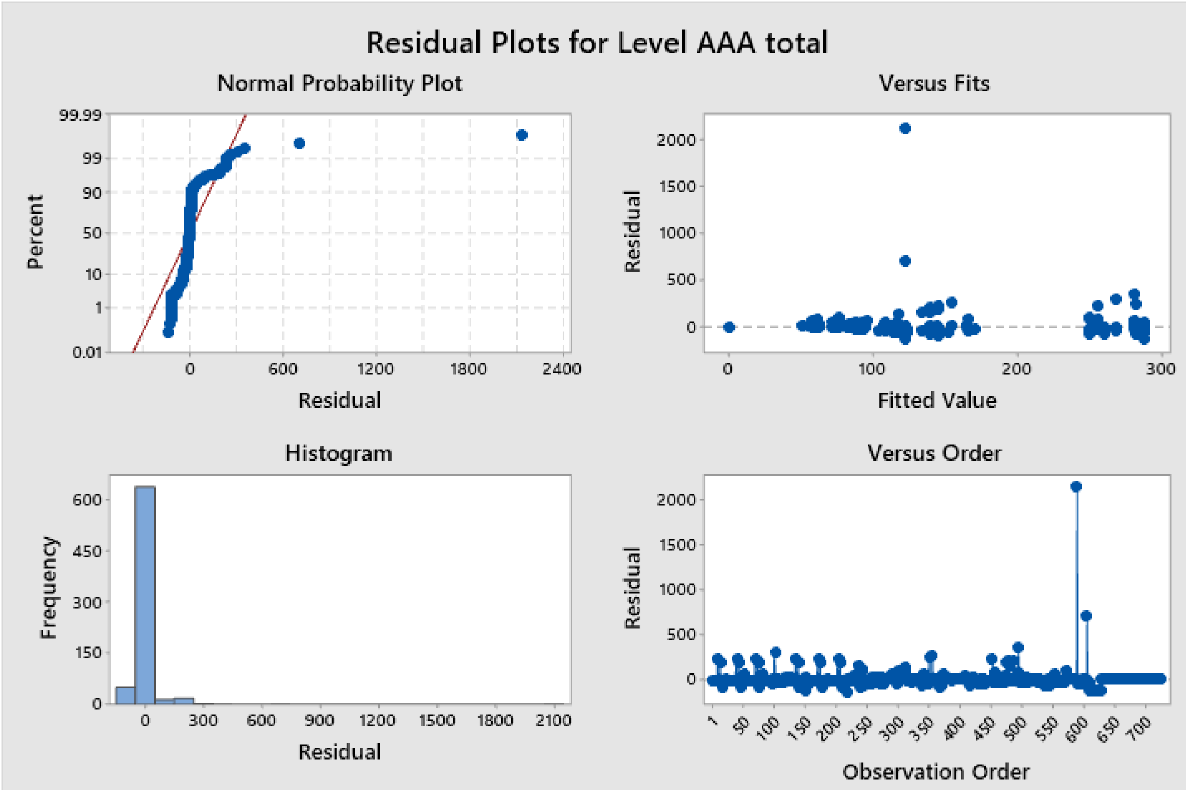


Figure 22: Test results for assumptions, normality and homogeneity

Finally, the assumptions of normality and homogeneity were tested. These graphs can be seen within Figure 22.

The normalization of the data may be questionable with some of the tail points of the data but fit within the typical tests of being less than a standard deviation from the mean, so no outliers were deleted, and the data can be analyzed without transformations or deletions. Additionally, the variance of residuals is not as homogeneous as would be ideal but, once again, it proved less than a standard deviation from the mean with adequate spread, so no transformations or deletions were applied. Most importantly, when looking at all of the plots, the data were fairly normal and homogeneous, and the overall data shown within these graphs do not indicate enough difference to invalidate the ANOVA test. Additionally, the outliers that are seen within the probability plot were eliminated, and the ANOVA test was run again. With these data removed, the ANOVA test and the follow up Fisher LSD tests had the same outcomes. Due to this, and the lack of evidence to remove the outliers, the outlier data is included within the tested data set.

Experimental Design 2: Nested ANOVA

Experiment 2 sought to determine whether there were differences between different course websites in regards to the type of accessibility errors on each type of webpage.

After running the nested ANOVA test, it was shown that the variable page type nested within course code was significant with *p*-value of 0.000 while course code independently did not have a significant *p*-value. This finding implies that the errors present in at least some of the different pages and different page types created for the unique courses were significantly different from each other. It is important to emphasize that the difference in accessibility errors produced by different page types was significant, and the differences between pages of the same type created by different courses was not significant.

Table 23: Analysis of Variance for Course cod and page type nested in course code

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
course code	7	24548	3507	0.31	0.949
page type(course code)	45	2440714	54238	4.82	0.000
Error	557	6270203	11257		
Total	609	8912546			

To understand the effects of these variables, a Fisher LSD post hoc test was performed. The results of the Fisher LSD tests of the course code and page type nested variables can be seen within Table 24. The Fisher LSD for the course code variable shows that all of the course codes fall within one grouping, A, meaning none of the courses were statistically different from each other in accessibility errors presented per page.

Table 24: Fisher LSD for Page Type and Nested Course Code

Grouping Information Using Fisher LSD Method and 95% Confidence

course code	N	Mean	Grouping
3	64	152.746	A
1	195	140.325	A
2	83	131.960	A
6	101	131.481	A
4	45	126.279	A
7	38	122.809	A
8	32	121.455	A
5	52	114.220	A

Means that do not share a letter are significantly different.

Table 24: Fisher LSD for Page Type and Nested Course Code

Grouping Information Using Fisher LSD Method and 95% Confidence

page type(course code)	N	Mean	Grouping									
6(6)	18	299.167	A									
9(3)	2	290.000	A	B	C	D						
4(2)	1	288.000	A	B	C	D	E	F	G	H	I	
6(5)	13	275.154	A	B								
6(3)	9	271.667	A	B								
6(8)	16	265.625	A	B								
6(1)	11	265.000	A	B								
6(2)	8	257.625	A	B		D						
9(7)	20	228.300		B		D					I	
6(4)	5	219.400	A	B	C	D	E				I	
4(3)	2	185.000	A	B	C	D	E	F	G	H	I	J
4(6)	2	170.500	A	B	C	D	E	F	G	H	I	J
2(1)	102	155.353			C		E	F				
1(4)	1	155.000	A	B	C	D	E	F	G	H	I	J
4(4)	1	155.000	A	B	C	D	E	F	G	H	I	J
1(3)	2	152.500	A	B	C	D	E	F	G	H	I	J
4(1)	6	151.000			C	D	E	F	G	H	I	J
2(6)	44	140.023			C		E	F	G			
2(3)	18	133.000					E	F	G	H		J
1(6)	2	130.000		B	C	D	E	F	G	H	I	J
2(4)	24	123.167					E	F	G	H		J
1(2)	1	121.000	A	B	C	D	E	F	G	H	I	J
5(3)	10	102.300						F	G	H		J
2(5)	28	101.750							G	H		J
4(8)	1	101.000	A	B	C	D	E	F	G	H	I	J
1(1)	6	101.000					E	F	G	H		J
5(5)	4	95.750					E	F	G	H		J
5(8)	4	93.250					E	F	G	H		J
5(7)	16	92.937							G	H		J
5(1)	10	92.200						F	G	H		J
5(6)	7	92.143						F	G	H		J
4(7)	1	92.000	A	B	C	D	E	F	G	H	I	J
2(2)	33	89.242								H		J
5(4)	9	88.889						F	G	H		J
5(2)	8	86.125						F	G	H		J
7(3)	10	82.300							G	H		J
3(3)	9	81.444							G	H		J
3(6)	11	80.364							G	H		J

3(2)	12	80.000						G	H		J
1(7)	1	78.000	B	C	D	E	F	G	H	I	J
7(1)	60	77.400									J
7(8)	10	77.400						G	H		J
1(5)	1	77.000	B	C	D	E	F	G	H	I	J
8(3)	2	76.500				E	F	G	H	I	J
7(6)	11	74.818						G	H		J
3(4)	4	73.500					F	G	H		J
7(5)	3	70.333				E	F	G	H		J
1(8)	1	70.000	B	C	D	E	F	G	H	I	J
7(4)	1	69.000	B	C	D	E	F	G	H	I	J
9(2)	1	68.000	B	C	D	E	F	G	H	I	J
8(2)	19	65.684									J
8(5)	3	65.333					F	G	H		J
8(6)	6	64.833						G	H		J

Means that do not share a letter are significantly different.

The results of the Fisher LSD test for the nested page type variable show 10 different groups for the 9 different page types. On average, the pages with the most errors were the files pages, and the pages with the least amount of errors was the quizzes pages. If a particular course website did not utilize a particular page type, no data entries were recorded for this page type for this course. After the files page, which was not tested within part 1 of this study, the syllabus page, on average, had the most errors, which is similar to the results found in part one of this study. This can be seen within Table 24, where the syllabus pages are all highlighted in yellow. All except one of these syllabus pages are grouped within group A. The quizzes pages, overall, presented the least amount of errors per page. These pages are highlighted in light blue in Table 24.

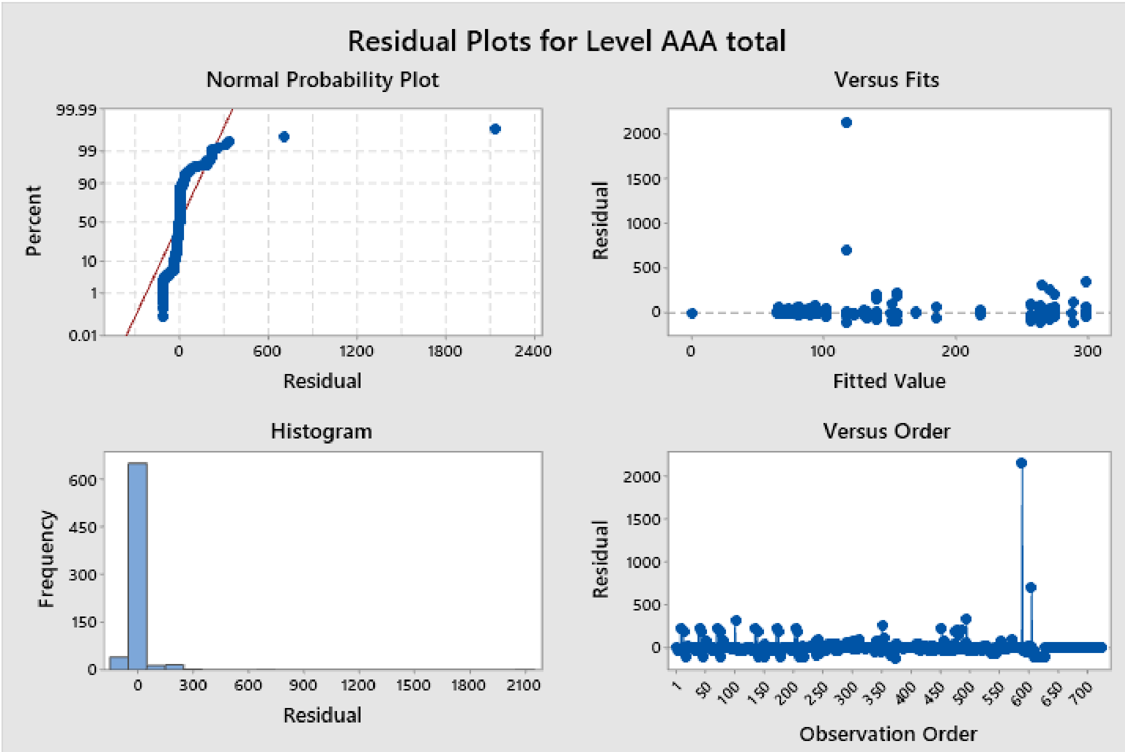


Figure 23: Assumptions plots

Finally, the assumptions of normality and homogeneity were tested. These graphs can be seen within Figure 23. The normalization of the data may be uncertain with some of the tail points of the data but fit within the typical tests of being less than a standard deviation from the mean, so no outliers were deleted and the data can be analyzed without transformations or deletions. To ensure the outliers would not have a significant effect on the results, the outliers that are seen within the probability plot were eliminated and the ANOVA test was run again. With these data removed, the ANOVA test and the follow up Fisher LSD tests had the same outcomes. Due to this, and the lack of evidence to remove the outliers, the outlier data remained included within the tested data set. Additionally, the variance of residuals is not as homogeneous as would be ideal but, once again, it proved less than a standard deviation from the mean with adequate spread so no transformations or deletions were applied.

Design 3: Regression Model

Design 3 sought to determine which accessibility errors are the most common and which of the 15 accessibility error variables explain the most variance between accessibility errors produced by the course websites in Canvas.

To understand the type of errors that are the most persistent, I ran a regression model. The regression model and the corresponding model statistics are presented in Table 25.

Table 25: Regression model including Non-Text content and Info and Relationships accessibility errors variables and the model's corresponding statistics

Regression Equation

Level AAA total = 46.65 + 0.4557 Non-text content_2 + 2.0537 Info and Relationships_2

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	46.65	2.70	17.30	0.000	
Non-text content_2	0.4557	0.0878	5.19	0.000	3.56
Info and Relationships_2	2.0537	0.0917	22.40	0.000	6.53
link purpose (in context)	-0.131	0.604	-0.22	0.828	6.81

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
42.9454	87.46%	87.40%	0.00%

The regression formula includes the variables Non-text content and Info and Relationships, both major accessibility error categories within the WCAG. Non-text content refers to images, pictures, icons, logos, symbols, and other visual elements that are unreadable to screen reading software without the presence of alternative text. Info and Relationships refers to how information is presented and linked on the webpage, through headings, footings, and other landmarks. Through an ANOVA test, both of these variables were significant with *p*-values of 0.000. An additional variable, link purpose, was originally placed within the regression formula but ultimately removed because it was not significant. Finally, the R squared value of 87.46% shows that these two variables—out of 15 variables that comprise the WCAG2.0 accessibility errors—explain 87.46% of the variance in the accessibility errors.

Part 2 Results Summary

Part two sought to understand the accessibility of first and second year engineering-related courses. The first experimental study was a generalized ANOVA that showed that the courses had no significant differences between them in accessibility errors, but the page types had significant differences. Experiment 2 further explored these results by showing the dependence of the pages on the courses through a nested ANOVA design. This test showed, once again, that the type of course did not present any significant differences in the errors they produced. However, it was shown that page types nested within the courses was significant, with the pages producing the most errors and the least errors similar to the order of pages producing the most errors and the least errors in the first experiment. Finally, the regression formula produced within design 3 showed the most common errors were the non-text content and info and relationships. The regression formula with just these two variables explained 87.46% of the variance in the accessibility errors.

Combined Results

Within both parts of these studies, there were significant differences in frequency of errors based on the page type. This finding shows that the type of page being created significantly effects the number of accessibility errors on the page, regardless of course or instructor.

Application of Results

One goal of the study was to affect change—to show instructors that there are simple changes to posted content that can bring pages closer to compliance and benefit all students. While the LMS framework may result in a series of noncompliant pages, the content that instructors develop and post can be made more accessible and can come closer to meeting WCAG guidelines. Toward this end, I developed an "Adding Web Pages to your LMS" document, which gives recommendations on institutional policies, training recommendations, and links to resources fully seen within Appendix D and Appendix E. This document was produced through the analysis of the WCAG and the results of this study.

Part of the first-year course structure at the authors' university is a series of first-year monthly colloquia, where instructors meet to discuss issues with the course. I produced a one-page summary and presented the results of the study and easy-to-implement tips to the instructional faculty at one of these colloquia. The feedback from

> **Example:**
>
> As examples of the ease of effective design, results from a study among multiple sections of an Introduction to Engineering Course found these among the most common, yet fixable, issues on course websites:
>
> - **Color contrast**: For example, a graph showing data represented by blue, green, and red lines
>   - **Solution**: Look at graphics in black and white. Select dashed lines as well as colors to distinguish data.
> - **Images**: screen readers will use alt-text to describe images
>   - **Solution**: Add relevant alt-text to all images. Note that this is typically very easy within an LMS.

the session was positive and thankful. As one might surmise, there are many steps instructors can take to make pages more accessible and bring pages closer to compliance – these tips, however, are not generally well known, so a quick set of tips to developers can be quite effective. One instructor emailed immediately after the meeting:

> "Please let your trainer know how helpful this is. I'll make changes to the way I enter URLs immediately, I need to consult the guide to figure out what I need to do to my PDFs."

Investing about 30 minutes when setting up a course website should result in a suite of pages that are more accessible.

Conclusion and Discussion

Many programs around the world are starting or have already implemented digitally mediated courses. There is still room for improvement in many areas of this digital learning system. Although published guidelines, such as the WCAG hat are directly applicable to the creation of digital content, exist, there has been little improvement on assisting college-aged students with any sort of disabilities, either through faculty training or innate website design of course websites. In part one, through running three related experiments, a complete randomized design and two nested designs, the research questions "Does the types of webpage created influence the number of accessibility errors on a webpage?" and "Does the individual instructor who created the content for the webpage influence the number of accessibility errors?" were answered. All three of the experiments and the post hoc test performed in part one found that both the type of page and the individual instructor were significant when looking at the number of accessibility errors their webpages had, but the page type tended to dominate accessibility error frequency.

Part two sought to understand the accessibility of first and second year engineering related courses. The tests presented within Part 2 showed that the type of course did not present any significant differences in the errors they produced. However, similar to Part 1, page types nested within the courses was significant. Finally, the regression formula produced within design 3 of Part 2 showed the most common and statically significant errors were the Non-Text Content and Info and Relationships. The regression formula with *just* these two variables explained 87.46% of the variance in the accessibility errors.

The findings presented within this study are important because they will allow individuals who conduct digital accessibility training for faculty, staff, and instructors to be able to focus their training and provide information that can truly make websites more accessible for disabled individuals and the general population by understanding the most problematic types of course pages and the most common errors that are found on all course webpages tested in Canvas. Future experiments can build on this knowledge and look at the particular types of errors that are the most common per page type. This will allow for more targeted training and tutorials on how to produce more accessible digital material when instructors and/or content managers are trying to create particular page types for their course, such as an accessible syllabus page. Additionally, this research is important in informing content managers and website designers as to the accessibility difficulties students may encounter when they are accessing their digital educational content. Particular note should be taken to the types of pages with the most errors such as the syllabus pages, assignment pages, files pages, and announcements pages. All four of these page types tend to be critical to the student participating within the course. Lack of accessibility within these pages can put disabled students at an educational disadvantage. Perhaps these page types are less accessible because of their reliance on autoformatted tables, images, and links to websites, documents, and files. Additionally, these page types may have more information on them. To truly understand why these pages have the most accessibility errors requires a further exploration of the specific accessibility errors produced on each of these page types.

Chapter 5

Understanding the Relationship between Disability and the Design of Engineering Course Websites Through Disabled Engineering Students' Perspectives

For this aspect of the study, I recruited first year engineering students to participate in a survey asking about participants' perceived usability of Canvas and the barriers they have to accessing the learning management system. The survey also asked questions about disability and the limitations encountered within everyday life. Next, I analytically compared how participants responded to questions about Canvas as a function of how they responded to the items related to disability. Participants also were invited to participate in design interviews focused on the Canvas barriers the participants identified in the survey. In these interviews, participants were asked to create a design that "solves" a Canvas barrier that they had previously identified within the survey.

Introduction

My research design, research questions, data collection, and data analysis necessitate an informed, meaningful, and intimate connection to disabled research participants. The Technology Acceptance Model presented by Lederer et al. (2000) embodies this connection and understanding between researcher and participant and organizes my study design and helps empower disabled people express their voices in a meaningful way. Chapters 2 and 3 review disability literature and shows that the perspectives and voices of disabled individuals often have been left out of the conversation. Using the Technology Acceptance Model as a theoretical framework encourages and allows for the perceptions and voices of disabled individuals to be heard and emphasized. A diagram of the Technology Acceptance Model can be seen within Figure 24.

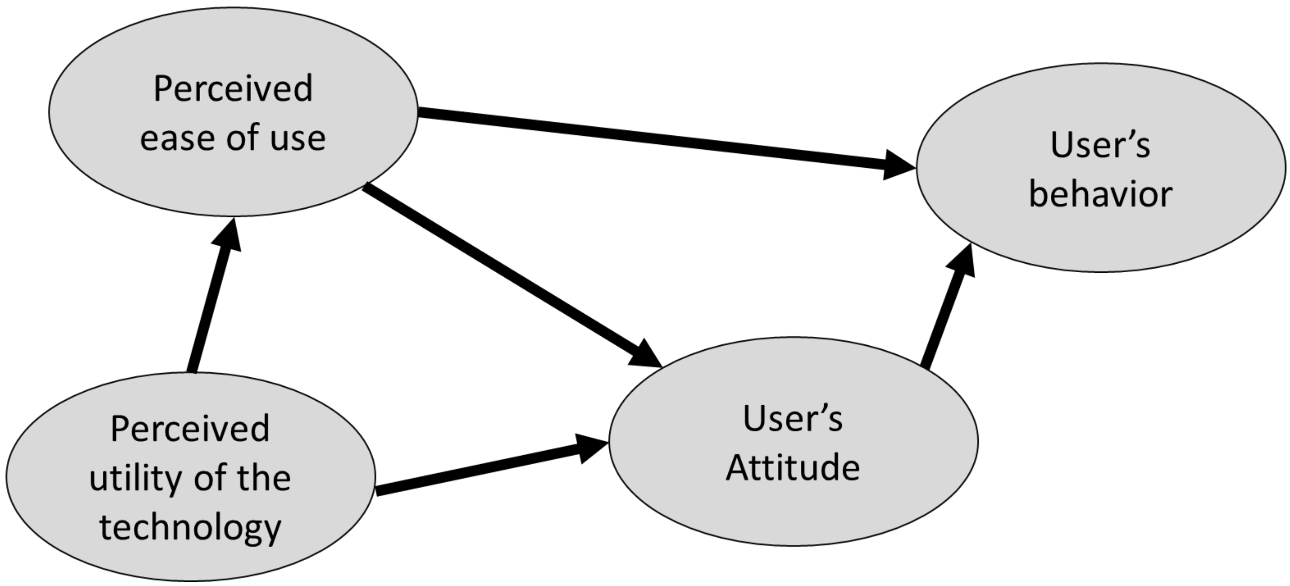


Figure 24: The Technology Acceptance Model (Lederer, Maupin, Sena, & Zhuang, 2000).

Within the Technology Acceptance Model, Brobst (2012, pg. 36) provides a description of the four guiding theoretical elements:

> “The user‘s perception of the ease of use of a given technology, combined with the perceived utility of the technology in a given context, together create a user centric attitude about the technology. The resulting attitude then influences the user’s behavior, which subsequently affects the user’s decision to employ or not employ that technology for a specific application.”

Despite its new application to disability research, this model prioritizes target users when understanding a product or interface. Gaining access to unique perspectives and lived experiences is especially important within underserved, minority, and underheard communities, such as disabled individuals (Jaeger, 2006; Jacko & Hanson, 2002; Stephanidis & Savidis, 2001).

The following research questions focus on the technological barriers experienced by both disabled and nondisabled individuals within engineering and guide this study:

Research Question 1: What are the differences and similarities in barriers encountered by disabled and non-disabled first year engineering students when they access their digitally mediated education?

Research Question 2: What barriers to accessing their digitally mediated education do first year engineering students with different disabilities encounter?

Research Question 3: What are the different design elements raised by disabled first year engineering students about their digitally mediated education?

Research question 1 embodies the idea that there may be differences between the difficulties experienced by disabled and non-disabled individuals when they access their digital learning environments. This question seeks to quantify the differences and similarities by seeking knowledge from the users themselves. Research question 1 maps to three out of the four elements in this theoretical model: perceived ease of use, perceived utility of the technology, and user's attitude.

Research question 2 attempts to understand the differences in barriers for disabled individuals when accessing their digital technology, specifically attempting to untangle the differences and similarities that occur between different disabilities. Research question 2 relates to two of the four theoretical aspects of the Technology Acceptance Model: perceived ease of use and perceived utility of the technology; it attempts to understand the perceived barriers the users encountered when accessing their digital learning management system. By understanding the difficulties that students encounter, we can understand their individual perceived utility of the different elements within the learning management system.

The third research question shifts the focus to the design of new technology through the participation of engineering students who identify with different disabilities. To understand the unique perception of this population for the design of new accessible technology, the researcher must value and understand the decisions the disabled and nondisabled participants made to create their emergent accessible technology. To do so, research question three embodies all aspects of the Technology Acceptance Model: perceived ease of use, perceived utility of the technology, user's attitude, and user's behavior by seeking to understand the disabled and nondisabled individuals' experiences and perceptions with the digital learning management system.

Data and Methods

Participants

This study included first year engineering students, over the age of 18 years old, who were enrolled in their second semester at the university. This population was selected for a number of reasons including: consistent technical background, familiarity with engineering design and the engineering design cycle, familiarity with the digital learning management system, participation in a common first year engineering educational background through the enrollment in a common first year engineering course, and a large population from which to sample. These elements of the selected population help to address some of the limitations and difficulties common to participatory design. The main limitations typical within participatory design are: lack of technological knowledge, rigor and predictive power, time, resources, money, contradictory preferences, and difficulty articulating preferences (Spinuzzi, 2005; Luck, 2003; Kensing, & Blomberg, 1998; Kensing, 1987; Ehn, 1989; Greenbaum and Kyng, 1991; Trigg et al., 1991; Mogensen, 1992, 1994; Blomberg et al., 1996; Grønbæk et al., 1997). The population included within this study address the limitations within participatory design by: having a baseline technical knowledge, having the ability to, at least somewhat, articulate their technical preferences, and having the time to participate within the interviews and survey. While predictive power and contradictory preferences are still limitations, the data collected did not have many contradictory preferences, especially within the qualitative responses and in the design interviews. Predictive power and generalization of the data and results was purposefully limited to ensure the proper inclusion of disabled voices through the methodological choice of participatory design.

Although there are notable benefits to studying first year undergraduate engineering students as the population of interest for this study, there are some limitations presented by choosing this population for this study, including: the assumed relative commonality of education for all first year engineering students, the possibility of including transfer students who would have more prior knowledge than their peers, and unequal prior experience with learning management systems from before their college experience. These limitations disturb some of the "assumed" similarities between the participants.

The limitation of different first year engineering experiences is more difficult to mitigate. However, all of the first year engineering students had the experience of participating within the First Year Engineering courses taught by the Engineering Education Department at a large research-intensive university within the Southeastern United States that has a large, well-regarded engineering college. This commonality allows for reference to a common class for the study. Although the individual learning management sites for the common engineering class may differ from each instructor teaching the course (e.g., see Chapter 4), the content of the course and the structure of the learning management system remained fairly consistent. Although I asked students about their experience with Canvas in general, having students participate within a common course that utilizes Canvas as its course website ensures that each participant has, at least, a baseline use of Canvas.

Contacting Participants and Motivation

Recruitment and participation of disabled participants within research studies has proven challenging (e.g., Simonsen & Robertson, 2012). Students were contacted through their first year engineering course with a request to participate in a survey about the usability of Canvas and their barriers, limitations, and self-identified disabilities. Survey respondents were subsequently emailed and asked to participate in an interview. This section details how I encouraged participation and recruitment of participants.

Contacting Participants

All first year engineering students were sent an email with a request to participate in this research by completing a survey. Prior to distribution, the Assistant Department Head for Undergraduate Programs for Engineering Education at Virginia Tech was contacted to approve survey distribution. After the survey was approved by the department, participants were contacted through their first year engineering classes. Although I hoped for a larger sample, only 88 First Year Engineering students responded to the survey. Thus, my discussion of results focuses more on description without having the needed statistical power. For the first part of the research design, participants completed an online survey identifying their disability or non-disability and the symptoms and barriers that they encounter when using their Learning Management Systems. Participants for the design interviews were contacted through emails provided by students on the original survey (Schuler et al, 1993). I was only able to conduct two design interviews because of a lack of response, but these richer conversations were used to triangulate qualitative responses to open-ended survey items.

Data Collection

Data were collected for part one in two main ways: 1) a survey with both closed- and open-ended questions, and 2) design interviews parsed out by the Canvas barriers that the participants and other disabled participants within the survey had identified. The survey utilized was an integration of two separate validated surveys that embody the elements of the TAM: 1) the Usability of Learning Management Systems, and 2) Model Disability Survey, Brief Version from the World Health Organization. The complete versions of the surveys can be found within appendix A. The first survey was chosen because it is a common survey for understanding usability within the specific context of learning management systems. Although this survey typically is used within a Blackboard or Moodle setting, I edited the questions to be relevant to Canvas and specifically reference Canvas and its functions, but the content and the meaning behind the questions was not changed. The second survey chosen was the Model Disability Survey, Brief Version from the World Health Organization, a validated survey pertaining to abilities and barriers. Questions were adjusted so that the survey was relevant to the first year engineering student population. An example of a question that was eliminated was the following: "How much of a problem is toileting?" because it did not fit within the context under investigation. Finally, qualitative questions that were incorporated within the original surveys and comment sections were provided for the students to present different ideas that were not encompassed within the quantitative aspect of the survey. A question at the end of the study asked the students to provide their email address if they would like to participate in a follow up interview. The second method for data collection was through 1.5 hour long interviews. The conversation guide for the design interviews can be found within Appendix B. The interview started with the participant being prompted to talk about their assigned barrier. This discussion allowed for the collection of more detailed information about the different participants' perceptions and attitudes with respect to the barrier presented. Participants answered questions from a conversation guide that helped them talk about their experiences with Canvas and the barriers they encountered. Throughout the conversation, participants were able to draw redesigns of Canvas that they imagined would relieve the different barriers they encountered when using Canvas.

This conversation guide incorporated a structure for the conversations with the participants but allowed participants to have flexibility in their answers and for the researchers to have flexibility with the questions asked. Additionally, the questions in the interview guide were formulated using standardized techniques outlined in Creswell (2017) and Turner (2010) to ensure the elimination of leading questions and to ensure the flexibility for both the researcher and the participants in their questions and responses. This data collection approach allowed for the needed flexibility to capture the participants' behaviors and perspectives vital within the TAM theoretical framework driving my research.

The data collected from each of these interviews includes: drawn images and notes from participants, notes from the researcher during the interviews, and fully transcribed recordings of the session. Participant notes and drawn images allowed the researcher to better understand the perceptions of the learning management system and the technologies that they designed. Further, observational notes recorded by the researcher allowed for an observational perspective of the participants' perceptions and their stated attitudes pertaining to the learning management system and the technology they designed.

Data Analysis

The nature of the data collection required the researcher to understand the participants without allowing the researcher's biases to overshadow the responses and voices from the disabled community and nondisabled participants. Although the quantitative aspect of the survey provides a less intimate relationship with the participants, it served to provide an understanding of the landscape before participants were encouraged to voice their difficulties with technology and whether digital aspects of websites provide barriers or lessen barriers. Qualitative data allowed the researcher to understand the complex and nuanced effect digital educational systems have on student access and the disabled perspective to understand the identified barriers and proposed solutions. The analysis of the qualitative aspect of this proposed research is driven by the theoretical Technology Acceptance Model and its focus on deeply understanding the perception and experiences of the participants. The different constructs of the TAM were used to guide the qualitative thematic coding for both the open-ended questions on the survey and the design interviews by acting as overall parent themes for the responses.

Quantitative Survey Data Analysis

Because of the low response rate for the survey, the analysis of the data was descriptive in nature utilizing count data to understand the nuances captured by the small numbers within each disability category.

Rather than grouping different disabilities together to increase the sample size and create disability categories, the responses of each disability were examined and compared to each other. The data were collected through Qualtrics and an internal report was created collecting Likert scale responses for the usability of Canvas filtering each response by disability type. This decision allows for the differing voices of specific disabilities to be heard and noted within the analysis.

Qualitative Analysis of the Surveys

The open-ended items from the survey were imported into Excel and coded in a thematic manner, especially paying particular attention to the Canvas barriers that are presented by the participants. Particular attention was paid to noting and including the Canvas barriers that were presented within the qualitative codes that were not captured within the quantitative responses. The TAM was used to frame the thematic codes by focusing on the four aspects of the TAM, perceived ease of use, perceived utility of the technology, users' attitude, and users' behavior, to understand how the themes should be phrased. Particular attention was paid to the user attitudes and the perceived ease of use of the different elements of Canvas.

Interview Data Analysis

The data from the interviews, including the notes, designs, and quotes from transcriptions, were recorded into Excel and coded in a thematic manner based around the different barriers that students encountered with Canvas. Themes found within the analysis of the qualitative elements of the survey depicting the different barriers students encountered in Canvas helped guide the themes presented within the design interviews.

Addressing Limitations

Mitigating Self-Report Data

The validity of self-report data has been questioned for decades. This section identifies difficulties with self-report data, the importance of self-report data, and how my research mitigated issues related to students reporting their own disability through the use of self-identification of disability. Self-reported data bring many advantages when utilized within a research design, such as gaining insight into participants' perspectives and being cost effective. However, there are disadvantages to using self-reported data, too, which this section outlines.

Stigmatized Information

The validity of self-reported data about stigmatizing information such as illicit activity, disability status, gender identification, and others has long been debated. Questions that are more sensitive, embarrassing, and self-incriminating are more likely to be biased within self-reported data (Harrison, 1995). However, my data will not be eliciting self-incriminating data but only the sensitive data of self-identified disability status. Despite disability status being a stigmatized quality, demographic information, including disability status, has been proven with relative certainty to remain as accurate as other self-reported, non-illicit information (Chan, 2009). By using the social model of disability and questions that value the input of disabled individuals within both the survey and the follow up interviews, I believe I raised participants' comfort levels in disclosing their disability status. Despite trying to mitigate this limitation, there is no simple way to accurately gather stigmatized information, such as disability status, without trying to change the culture that stigmatizes the information.

Bias: Lack of Objectivity

All reported data has some innate level of bias; however, with self-report data, the bias in the data changes and remains unknown with each individual (Harrison, 1997; Chan, 2009). Socially undesirable behaviors, highly sensitive information, a high propensity to give socially desirable answers, and a high situational pressure to give socially desirable answers are four of the most common reasons that participants will bias or feel the need to bias their answers (Donaldson & Grant-Vallone, 2002). Beyond the internal aspects that can lead participants into biasing their responses are the environmental and external aspects that can lead participants to bias their responses. These external aspects include: the true state of affairs, sensitivity to what is being asked, dispositional characteristics of the participant, and situational characteristics.

The majority of factors reported as influential for self-report bias relate to social perceptions and pressures to give an "acceptable" response as dictated by societal norms. However, the added difficulty with the bias of self-reported data is that the perceptions of societal norms held by the participants is typically unknown to the researchers, and these perceptions can change from participant to participant.

Importance of Self Report Data

Despite the debates surrounding the validity of aspects of self-report data, there are still benefits in receiving and analyzing self-reported data. First, it allows the belief and substantiation of disabled perceptions and voices (Ashby, 2011). Within the disabled community, there is a growing want to have their voices and needs heard by society, designers, engineers, and researchers. By utilizing self-report data, this need is partially fulfilled, and an underrepresented and underheard disabled voice is utilized. Additionally, utilizing self-report data within user interface design and research allows for the perceptions, experiences, limitations, and difficulties of disabled participants to be heard (Albert & Tullis 2013). Finally, self-reported data are important to help deconstruct incorrect stereotypes and perceptions pertaining to disabled individuals and disability (Corrigan, 2007).

Self-Reporting Disabilities in My Research

To help mitigate the self-identification of disability within the self-report data in my proposed research, I propose pairing disability self-identification with Likert scale data about perceived limitations, difficulties with user interface, and disability symptoms. Although the students will disclose their identified disability or disabilities, the classification of their symptoms and barriers will help validate the disability to which they identify. Additionally, by identifying non-Canvas limitations and Canvas barriers, individuals who did not identify with a disability or disabilities but have Canvas barriers similar to the Canvas barriers identified by a self-identified disabled person could be identified and, potentially, placed within focus groups with other participants that experience similar Canvas barriers.

Likert scale questions and data are often used within health and user interface research (Albert & Tullis, 2013). An example of typical user interface questions utilizing a Likert scale can be seen in Appendix A. Likert scale data are particularly useful when measuring barriers, ease of use, and limitations of a digital system because of the continuous scale these data present (Ablert, 2013).

Using this type of data to help mitigate disparities with medical diagnoses, user interface, and self-report data is common. The Software Usability Measurement Inventory and the Website Analysis and Management Inventory, both coming out of the Human Factors Research Group in the University College of Cork Ireland, both utilize this tool, and the tool has garnished great success as a valid measurement tool (Albert et al, 2013). These tools are very similar to the Learning Management Usability Assessment tool, however, the Learning Management Usability Assessment tool, one of the surveys that I plan to use, has more alignment with the TAM and allows for a better understanding of the personalized perspective of the participants.

Addressing Limitations of Participatory Design

This section describes how my research design sought to minimize the limitations presented within research for participatory design. The main limitations addressed in this section are: lack of technological knowledge, rigor and predictive power, contradictory preferences, and difficulty articulating preferences (Spinuzzi, 2005; Luck, 2003; Kensing & Blomberg, 1998; Kensing, 1987; Ehn, 1989; Greenbaum & Kyng, 1991; Trigg et al., 1991; Mogensen, 1992, 1994; Blomberg et al., 1996; Grønbæk et al., 1997).

First, design such as scenarios, mock-ups, simulations of the relation between work and technology, future workshops, design games, case-based prototyping, and cooperative prototyping are key to understanding the usability and functionality of a design for particular populations (Kensing, 1987; Ehn, 1989; Greenbaum & Kyng, 1991; Trigg et al., 1991; Mogensen, 1992, 1994; Blomberg et al., 1996; Grønbæk et al., 1997). These tools and techniques avoid the overly abstract representations of traditional design approaches and allow workers and designers to more easily experiment with various design possibilities in cost effective ways (Kensing & Blomberg, 1998). My study incorporated some of these elements into the design interviews.

Second, the results of the participatory design were paired with the survey response data and not presented as a standalone aspect of the research (Schuler & Namioka, 1993). Additionally, open-ended survey items, interview questions, and the drawn designs of the participants were analyzed. By using multiple methods, a triangulation of data results can be achieved to expand validity of the results (Kensing, 1987; Ehn, 1989; Greenbaum & Kyng, 1991; Trigg et al., 1991; Mogensen, 1992, 1994; Blomberg et al., 1996; Grønbæk et al., 1997).

Third, contradictory preferences are innate to studying disabled individuals and humans in general. Contradictory preferences refer to participants wanting or preferring different design elements within a product, particularly when these design elements are unable to occur within the same design. To help counteract this limitation in my proposed research, I allowed participants in their open-ended responses and in interviews to brainstorm their ideas of alleviating the access barrier. This process allowed me to capture the potentially contradictory preferences and ideas across participants

Finally, to address individuals having difficulty articulating their technological preferences, I specifically chose engineering students as my population (Luck, 2003). Although these students may still have difficulties articulating their preferences, they were versed in the engineering design process and should understand basic technology. Thus, my participants had a general baseline of technological information and design that theoretically helped them to better articulate their desires.

Results

Survey

111 individuals responded to the survey, with 80 participants fully answering the Canvas usability section. 68 participants responded to both aspects of the survey in full, which was a 3.4% response rate for all of the First Year Engineering students. Out of these participants, 31 participants identified with at least one disability (see Figure 25), and the demographic breakdown of other variables was as follows: 68% white, 18% Asian, 4% Hispanic, 3% African American; 65% men and 32% women. It should be noted that because of the nature of disabilities, some participants identified with more than one disability, which is common within the disabled community.

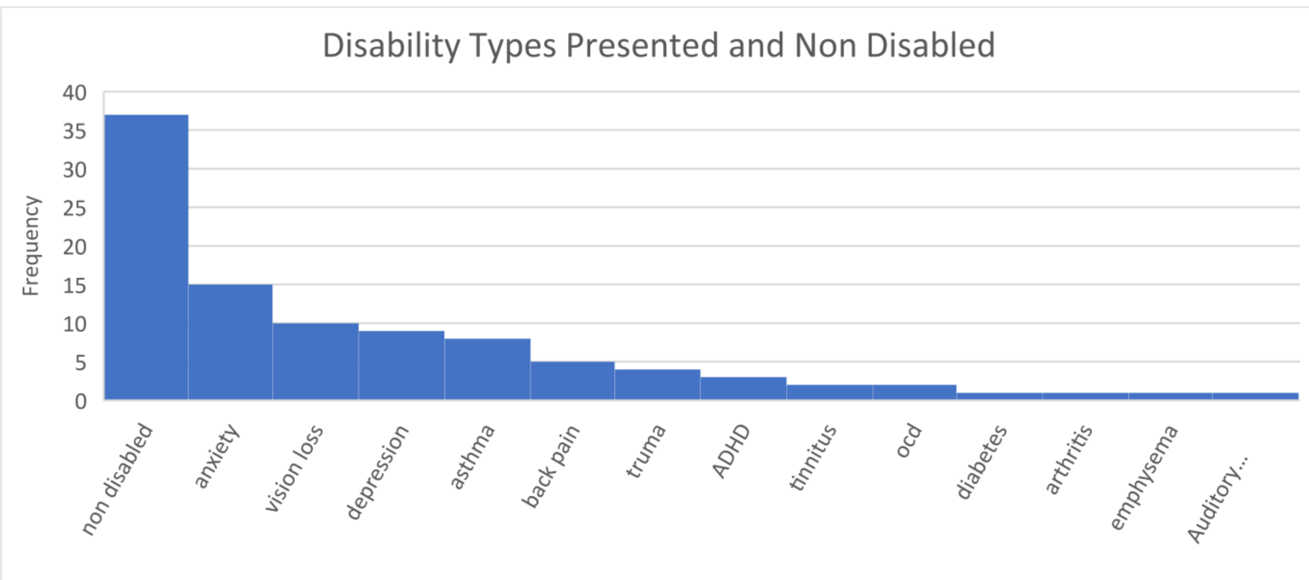


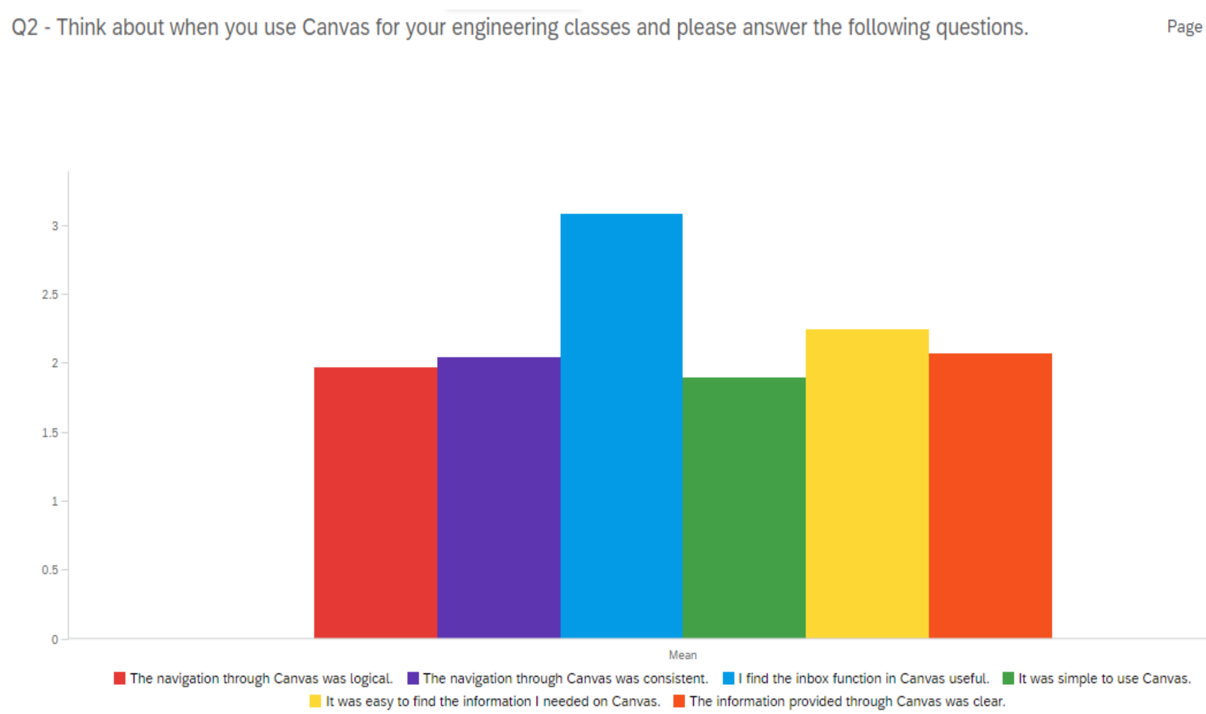
Figure 25: Disability types present as compared to the nondisabled participants

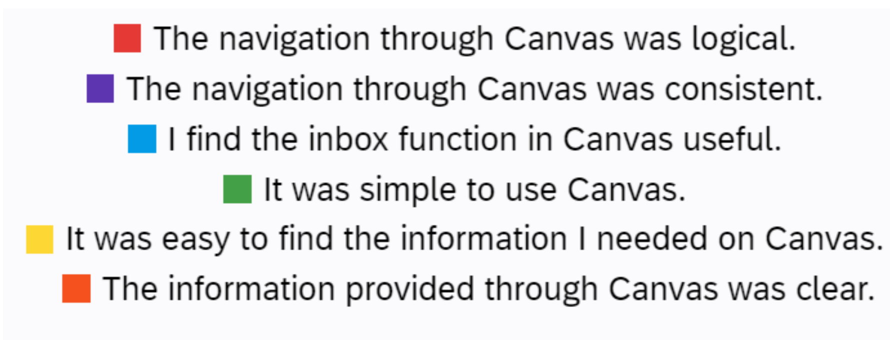
Within this small sample size, the numbers of participants identifying with particular disabilities is also small, and so it would be impossible to draw and statistically significant conclusions from these data. However, an intentional decision was made to avoid combining any specific disabilities into generalized disability groups. This decision was made for a number of reasons. First, numerous studies truncate specific disability groups to increase sample sizes. This truncation allows for tests of statistical significance but ignores important differences that each individual disability encounters. Since grouping disabilities is common, much of the disability literature lacks an understanding of specific disabilities. This creates a gap in knowledge on research on how specific disabilities interact with technology. Second, many of the participants identified with multiple disabilities. Because of this overlap, it is impossible to parse each disability identified to understand which specific disability is affecting the interaction with technology. By aggregating different disabilities together, it is possible that an individual could stretch across multiple categories which would make findings even more challenging to interpret. And third, even within a singular disability, there can be physical and cognitive manifestations, and although there are different methods in grouping disabilities into categories, most of the groups do not take into account the physical and cognitive symptoms that occur together.

Figures 26, 27, 28, and 29 show bar graphs that visualize differences across participants regarding the usability of Canvas. Figure 26 shows averages for all participants, both disabled and non disabled. This figure shows that most of the values are similar, with most responses averaging around a score of 2 out of 5. The statement “I find the inbox function in Canvas useful" scored higher indicating that more participants did not find the inbox function in Canvas useful.

This graph can be compared to Figure 27 for Only Non-Disabled Responses, Figure 28 for Only Disabled Responses, and Figure 29 for averages including only disabled responses broken down by disability. Within Figure 27 for Only Non-Disabled Responses, the average values most of the questions, once again, averaged around 2 out of 5, with the question about the Canvas inbox function being useful remaining elevated. This graph visually looks very similar to the graph shown in Figure 26 of all of the responses.

Figure 28 shows only the responses from disabled participants. In this graph, the scores shown are more varied than the previous two graphs but maintained scores around 1.5-2 for most of the questions and around 3 for the Canvas inbox usefulness statement. Finally, in Figure 29 showing the breakdown of scores for disabled participants broken down by disability, large disparities between disabilities can be seen within every question and statement presented. It should be noted that within the graph showing the averages including only disabled responses broken down by disability, responses that included only one response from a particular disability type were excluded. By comparing these charts, the researcher can see that the responses from specific disabilities change vastly. When all disabilities are combined, much of the nuance from each of the different disabilities is lost.

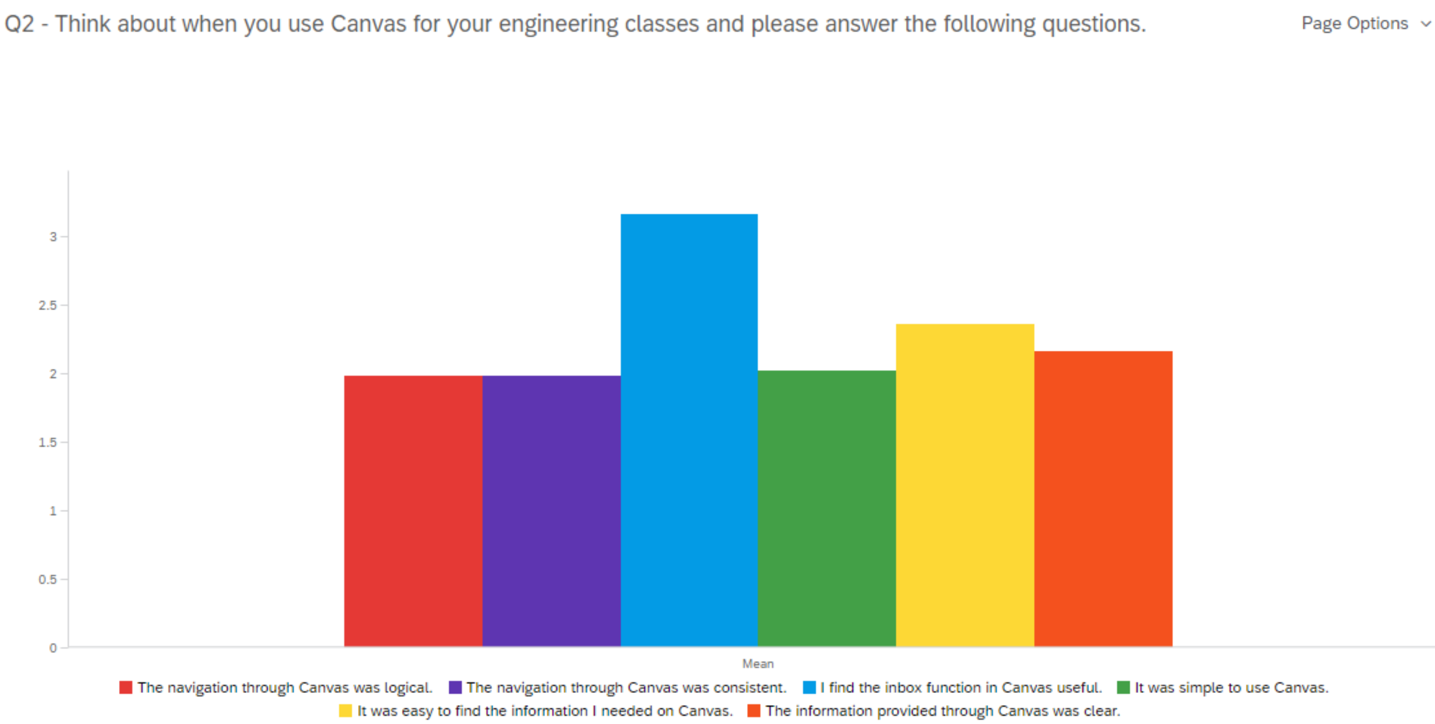


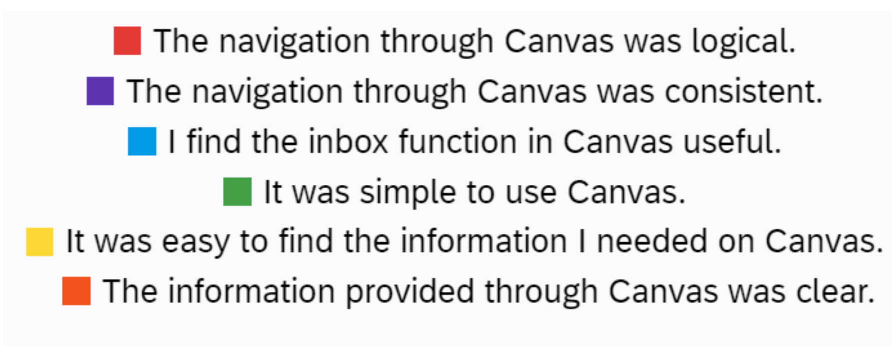


Likert Scale 1-5 with 1 being "Strongly agree" and 5 being "Strongly disagree"

Figure 26: Averages Including Disabled and Non-Disabled Responses.[1]

[1] The x-axis shows the average survey score for six different Canvas usability questions. Each bar represents a different question.

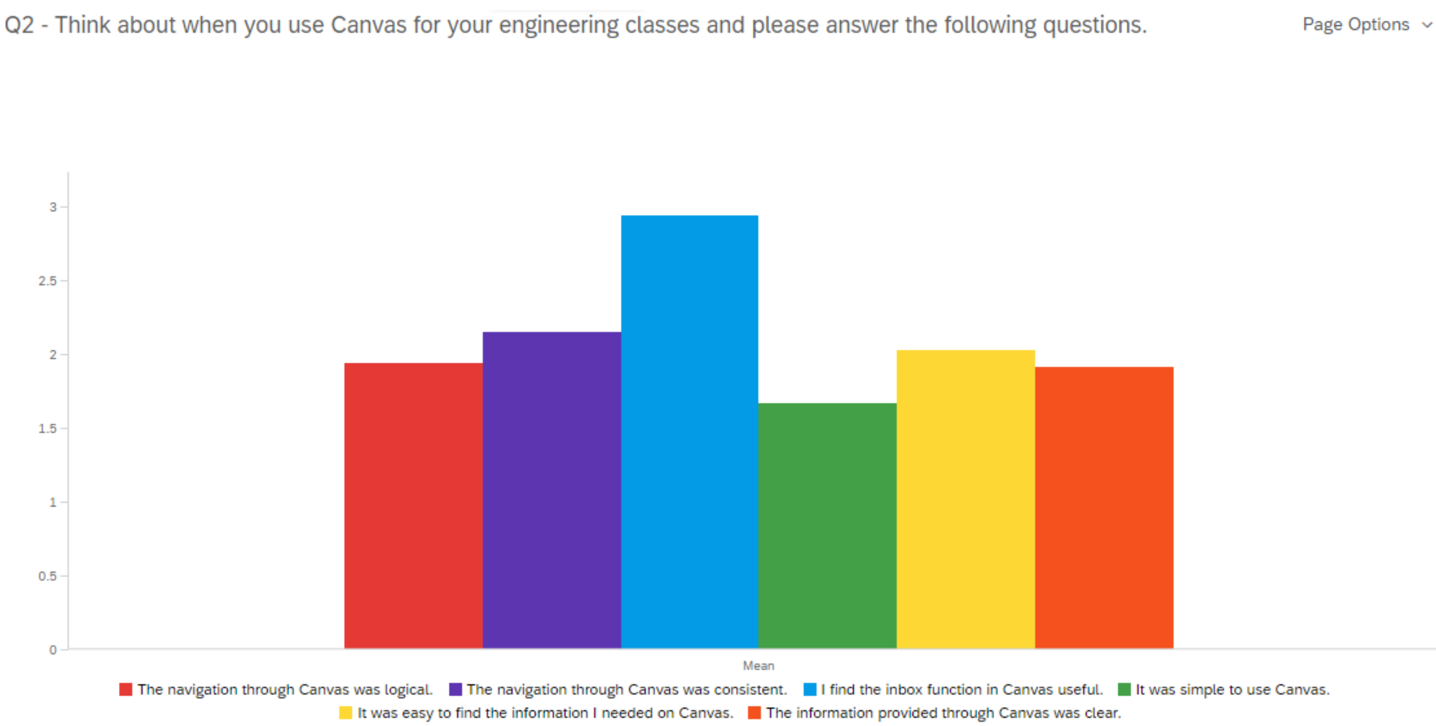


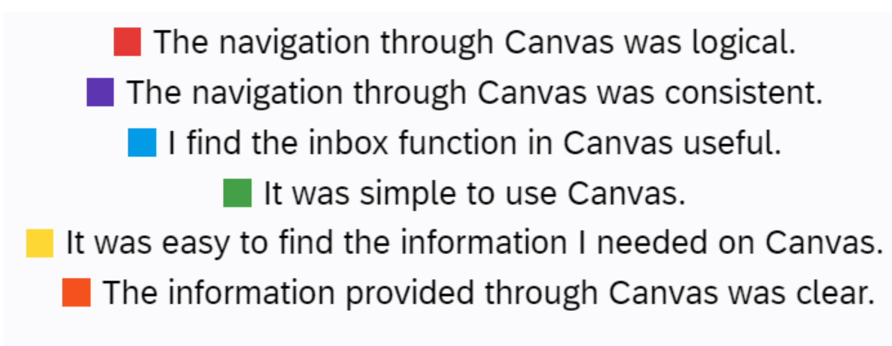


Likert Scale 1-5 with 1 being "Strongly agree" and 5 being "Strongly disagree"

Figure 27: Only Non-Disabled Responses[2]

[2] The x-axis shows the average survey score for six different Canvas usability questions. Each bar represents a different question.

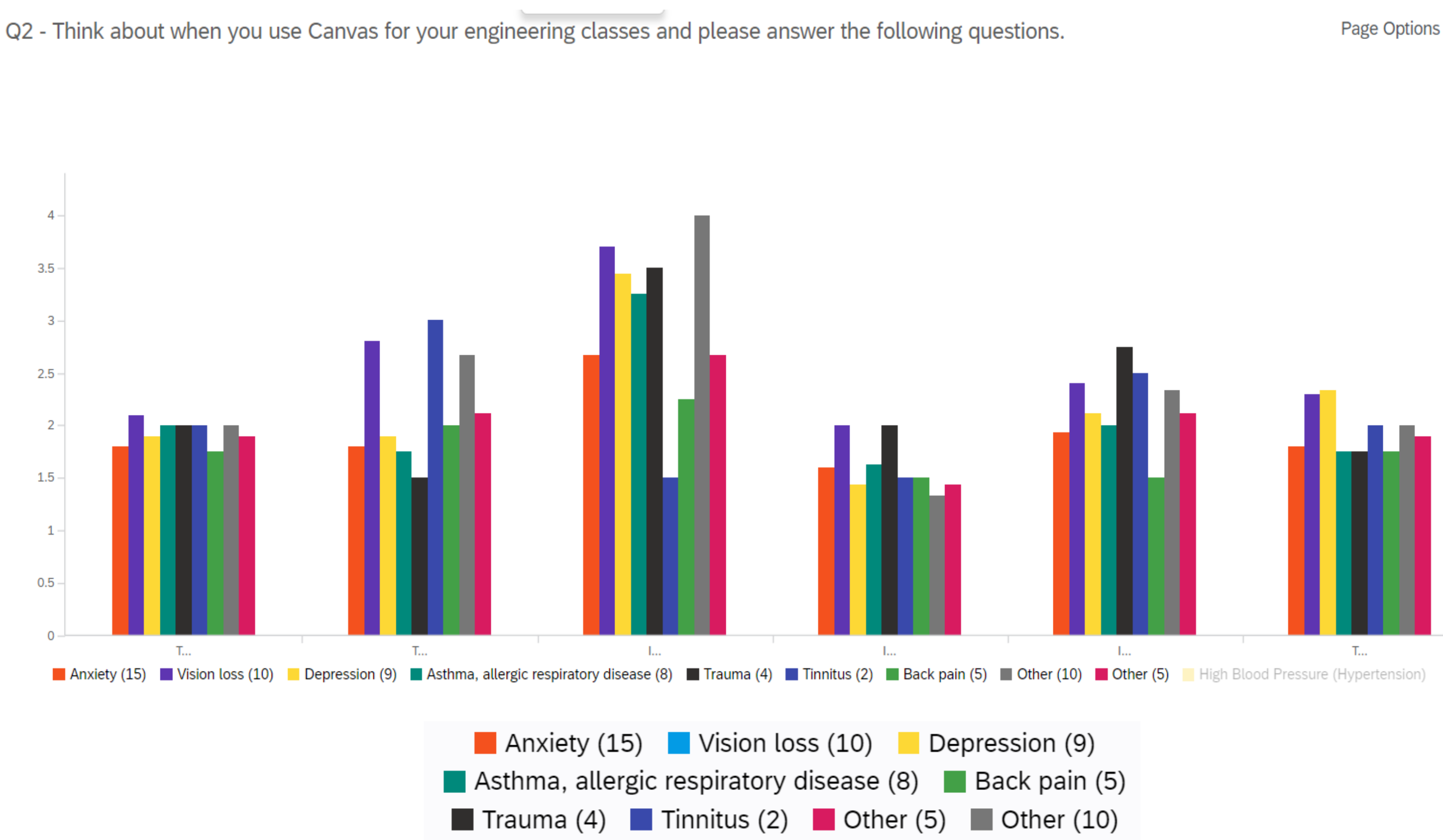




Likert Scale 1-5 with 1 being "Strongly agree" and 5 being "Strongly disagree"

Figure 28: Only Disabled Responses [3]

[3] The x-axis shows the average survey score for six different Canvas usability questions. Each bar represents a different question.



Bar 1: The navigation through Canvas was logical.

Bar 2: The navigation through Canvas was consistent.

Bar 3: I find the inbox function in Canvas useful.

Bar 4: It was simple to use Canvas.

Bar 5: It was easy to find the information I needed on Canvas.

Bar 6: The information provided through Canvas was clear.

Likert Scale 1-5 with 1 being "Strongly agree" and 5 being "Strongly disagree"

Figure 29: averages including only disabled responses broken down by disability for the second block of Canvas usability questions [4], [5]

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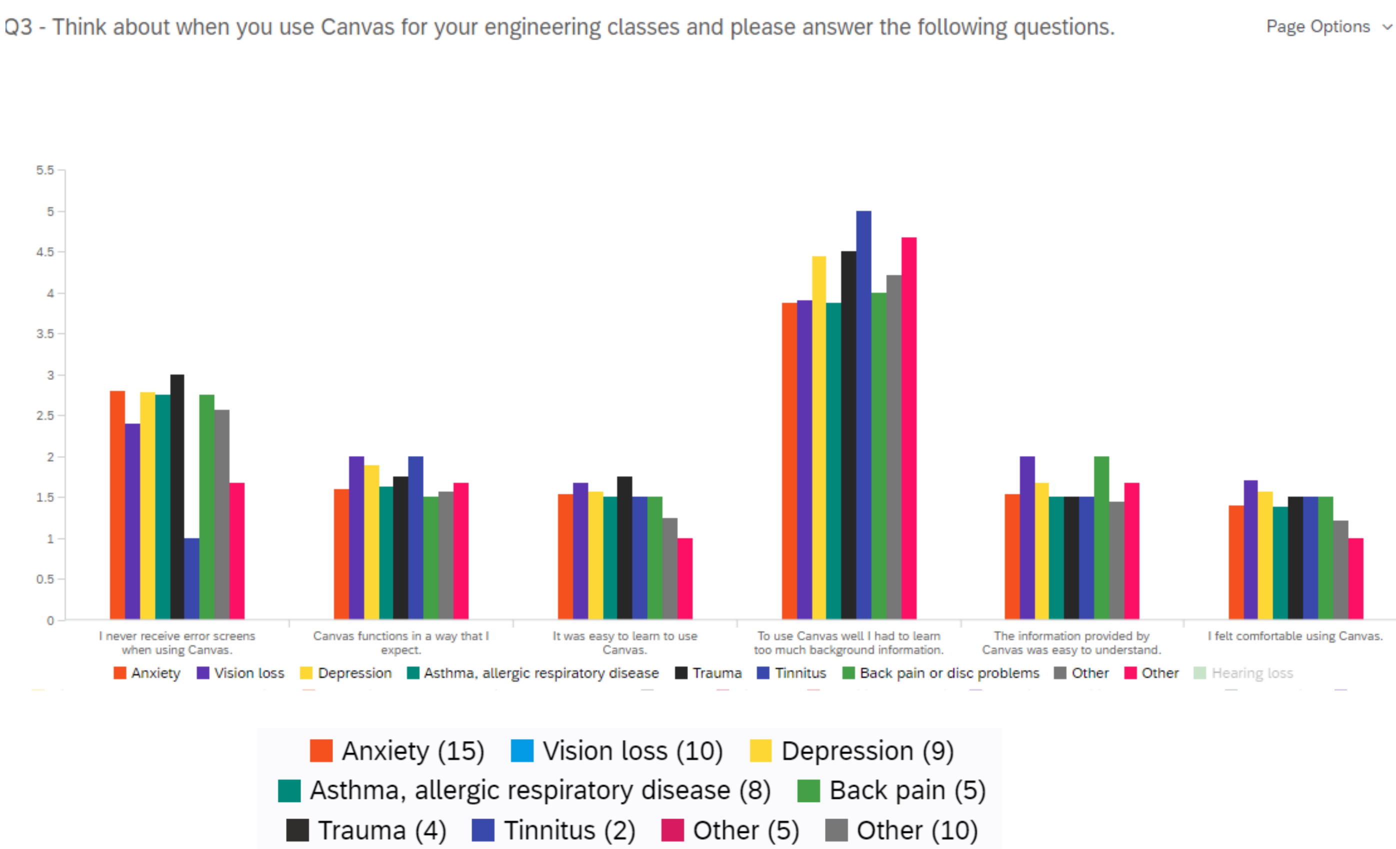
[4] The x-axis shows the average survey score for six different Canvas usability questions divided out by different disabilities. Each group of bars represents a different question.

[5] The "other" categories were two distinct open-ended questions that participants could fill in with different disabilities they identified with. Within these categories were: ADHD, OCD, Auditory Processing Disorder, and additional cognitive and emotional disabilities. Nearly all of the disabilities presented within the other groups were cognitive and emotional disabilities.

Within Figure 29, the disabilities are ordered from least to most common, gauged by number of responses, with the two "other" categories placed at the end. On average, the inbox function and the navigation through Canvas presented disabled participants with the most difficulty.



Likert Scale 1-5 with 1 being "Strongly agree" and 5 being "Strongly disagree"

Figure 30: averages including only disabled responses broken down by disability for the third block of Canvas usability questions[6], [7]

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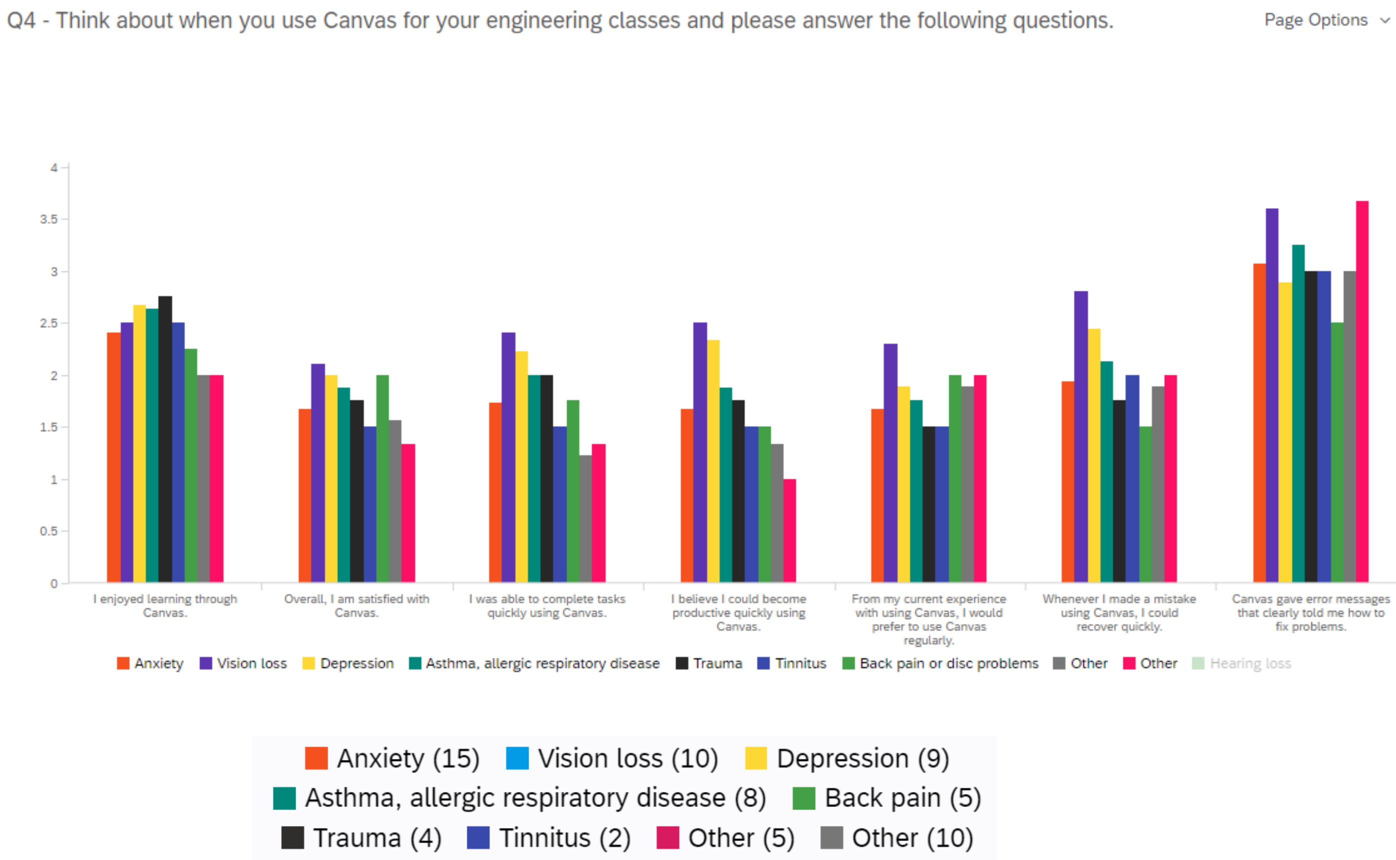
[6] The x-axis shows the average survey score for six different Canvas usability questions divided out by different disabilities. Each group of bars represents a different question.
[7] The "other" categories were two distinct open-ended questions that participants could fill in with different disabilities they identified with. Within these categories were: ADHD, OCD, Auditory Processing Disorder, and additional cognitive and emotional disabilities. Nearly all of the disabilities presented within the other groups were cognitive and emotional disabilities.



Likert Scale 1-5 with 1 being "Strongly agree" and 5 being "Strongly disagree"

Figure 31: averages including only disabled responses broken down by disability for the 4th block of questions [8], [9]

Within Figure 30 there are questions from the survey surround the third block of usability questions. Within this block, none of the disability types said that "to use Canvas well, I had to

[8] The x-axis shows the average survey score for six different Canvas usability questions divided out by different disabilities. Each group of bars represents a different question.

[9] The "other" categories were two distinct open-ended questions that participants could fill in with different disabilities they identified with. Within these categories were: ADHD, OCD, Auditory Processing Disorder, and additional cognitive and emotional disabilities. Nearly all of the disabilities presented within the other groups were cognitive and emotional disabilities.

learn to much background information." However, participants with anxiety, vision loss, and asthma identified less certainty with their response to this item. Within Figure 31 depicting the 4th block of questions asked on the usability survey, students who had vision loss and depression indicated less satisfactory scores about the usability of Canvas. In particular, these students indicated that it was difficult to recover quickly when they made a mistake in Canvas. Additionally, scores for "useful error message" were elevated for the disabled participants, which indicates that those participants thought the error messages given by Canvas did not tell them clearly how to fix the problem to avoid receiving the error message. Interestingly, students who indicated they had anxiety, vision loss, asthma, and other (ADHD, OCD, Audio Processing Disorder) had even higher elevated scores with this difficulty, whereas individuals with back pain indicated less difficulty with this Canvas barrier. Many of the individuals who identified high difficulties with error messages had cognitive disabilities. Also, within Figure 31 of the 4th block of questions, participants with both vision loss and depression had higher scores on the item relating to believing that they could become productive quickly using Canvas. This result indicated that they believe that they are *less likely* to be productive quickly using Canvas. It is interesting that participants with the cognitive disability of depression believed that were not quickly able to become productive when utilizing Canvas. Through these results, there seems to be some differences between typical disability groupings, such as physical and cognitive disabilities, but not all of the difference fell within these typical groupings. The quantitative results that were presented point to differences in perceived usability of Canvas, especially for depressed students and students with anxiety. While some of the different disabilities grouped within traditional disability groupings as to how respondents answered the Canvas usability questions, this was not always the case, and it was found that numerous participants with vision loss had similar answers to the students with depression. Answers from participants with depression and anxiety did not tend to correlate.

Themes from the Open-Ended Survey Items and Interviews

The open-ended items on the survey included the following prompts:

- Please write any additional comments you have about the usability of Canvas here.
- Please write any additional comments you have about having a disability or physical or mental differences on campus here.

Responses to the survey's open-ended items were summarized within six different themes: Inconsistency within a course website, Accuracy of grades, Inconsistency between instructors/instructors, Navigation/complexity, Assurance file is submitted correctly/Timers/accuracy, and Limited customizability by courses. Interviews echoed the same themes, but an additional theme emerged: Distinguishing courses. Generally, for all of the qualitative data, the themes and quotes pointed to four main barriers within Canvas: accuracy, instructor differences, navigation, and customizability. Accuracy is a theme that includes the accuracy of grades and the assurance that a file is submitted. Instructor differences includes the differences between different instructors/course and the inconsistencies within a single Canvas course website. Navigation and customizability are separate themes that include no additional themes within them. These themes and the quotes that they consist of will be explained within the following sections and tables.

Table 26 shows the quotes given by participants presented within the open-ended question in the survey. Table 27 shows the quotes given by participants within the in-depth design interviews. The quotes are broken down by actionable theme categories that are consistent between the surveys and the design interviews. These themes and quotes helped to shape the recommendations presented later within Chapter 5 of this dissertation, and the following subsections describe each theme in greater detail.

Table 26: Themes and quotes from the open-ended survey questions

Themes	Quotes
Inconsistency within a course website	"Page for my engineering class was organized very poorly by my professor." "Too much variation between class pages" "The way our canvas site was laid out was odd."
Accuracy of grades	"The calculated grades that are given as almost always incorrect"
Inconsistency between instructors/instructors	"Appreciate when the teachers use all of its capabilities because it makes it easier as a student." "Some instructors do not use it well enough for students to be satisfied with it" "Very low and not intuitive at all" "Canvas is fine. Instructors are the main point of failure with the system." "Consistency between classes is Canvas's primary issue." "Many professors don't know how to use canvas well."
Navigation/ complexity	"Canvas functions in a weirdly infuriating gray area for me. Navigating everything is just shy of instantaneous, but this delay often causes me to click something I didn't mean to. This is frustrating because of the lack of back button functionality in canvas, which actually caused me to have to restart my respondus lockdown browser in a recent physics test. The combination of canvas being just slow enough to not be considered instantaneous

	and the lack of back button functionality makes canvas fine to use on any normal day, but can be frustrating when pushing deadlines or trying to navigate between assignments quickly." "Occasionally, messages get lost within canvas just because how much information is presented. That being said, I do like that everything is in the same place, but things do get lost. I wish there could be a reminder system in it." "Information, at least for my ENGE 1216 section, is spread across far too many pages, files, and resources tabs. Finding a document could mean scanning several areas instead of one." "Very low and not intuitive at all" "Complex tasks are a bit harder to understand"
Assurance file is submitted correctly	"We're all just guessing when the quizzes & tests are scheduled for." "Canvas once told me that an assignment was submitted, but it never was" "Additionally, there is no way to cross of assignments manually"
Limited customizability by courses	"I would like more customization overall, and some of the features don't seem useful." "It's fine. Just not good. Would like instant emails when my instructor send[s] a message through canvas, some of these things are last minute and time sensitive." "There is no way to alter user entered events on the calendar or mark them as done"

Table 27: Themes and quotes from the design interviews

Interviews

Themes	Quotes
Inconsistency within a course website	"So you had the, like the syllabus option, you had files, you had quizzes, modules, and on top of that you had the page half page. Right. So to me it was like, I would have thought, like when I was first trying to set this all up to me, the pages would be things like the quizzes, the modules, stuff like that. Not, you know, like I would, I would make those the pages. And so then the page, I got really confused with the pages"
Accuracy of grades	"One thing that admittedly like it is true that sometimes like it doesn't calculate your grades properly, but one thing that would be kind of nice is, um, I know like I've mentioned already this once, I have an Excel spreadsheet like to calculate grades and stuff problem Hypatia right. And, but one aspect of it is you can also, um, check and see with your grades as they are now, what score you'd have to get on the exam, the final exam based on its percentage to get like whatever letter grade in the class, like the lowest score to get each letter grade. Perfect. Yeah. And that'd be a nice thing to be able to like to hit a button or whatever and see that."
Inconsistency between instructors	"Categories like a new grade, um, an announcement, a new assignment. Like, I mean that would just be really helpful to have it per class. Cause I know I have it set to where I get them for new assignments. But in a class like physics where you have iClickers, there are times when I just get like 10, 15 emails from canvas in a row for that one class. That's not great. Right. Because then I think, Oh no, I've missed a bunch of emails that are important. And then I go in and it's just like, it's just canvas."

Navigation	"One thing I know is like in my two 1216 course is so usually there's like a sidebar for files, right? But in this class, which definitely took me asking another classmate to figure out was you have to go into pages to find any information you want. Interesting. Um, instead of just like clicking files and there's everything in like neat little folders." "Keeping those two sidebars straight, I struggled with a lot as well cause it was like I just would click on the mold far this left most thing and then it'd be like, where did I go? Like it changed. So having the two, the two menus right next to each other in the same direction really messed with me." "Part of it I think for me too was there were so many ways to do things, which I understand the flexibility's kind of nice, but at the same time, if somebody would like when I was first training on it and somebody's telling me to get to this thing, this one way, if I didn't do that every time I would get totally lost and I couldn't figure out what to do to get back to where I was or get like" "Mostly the, uh, consistency between, um, courses and a navigation was definitely, noted as something that was difficult, uh, throughout the course."
Assurance file is submitted correctly/ Timers	"Um, and then there's of course the submission button. Whereas, um, sometimes if you're looking at it and you click an assignment and sometimes you like it, I don't even realize I'm not clicking on it through the assignment page and it's just gives you like this box. That's where any comments would appear if like you had turned it in in a teacher and your teacher put comments or you went to put your own comment. Um, and it doesn't like give you any of that information or allow you to like go to it through the new, like go to the new, um, assignment, uh, or open in a new tab. I mean, so that's sometimes it's like, wait, what? And then I have to backtrack, go all the way back and um, and go do it again."

	"I'm just like, Ugh. No, I have to figure out how to turn it in. And what if I don't figure it out? It's done. And I don't know if you're out before the deadline and then the system's gonna shut off. And there's also, as I'm thinking about that too, there's also all that anxiety around to me, unnecessary anxiety around turning in assignments. Like I'm much more anxious about turning in an assignment on canvas than I am if I have to email it to somebody because that way I know if I submitted it at 1201 they're still going to be like, Oh fine. But as a student in canvas, I never knew if it was like, what if they don't IX, you know, what if they have it set to where they don't accept the assignment after this time or you know, and, and it was just always this worry about what were the technicalities of, you know, are you technicalities in terms of, you know, obtaining and submitting, you know, what if it wasn't in the right file format and all this stuff."
Limited customizability by courses	"It's also sometimes hard cause I had one like online class where it's basically like three announcements every week. Oh wow. And those were kind of a lot. Um, so that was like at the same time then it became like, is this even important enough to read cause."
Distinguishing courses	"I know I have a class that's in my, like current enrollment sidebar from last semester. Not very helpful. It's chemistry. I'm not in chemistry anymore."

Accuracy

Many participants pointed to the accuracy of grades and accuracy of assignment submission as being problematic issues; these ideas were not captured within the quantitative responses of the survey. This section will encompass themes "Accuracy of grades" and "Assurance file is submitted correctly." This finding is particularly alarming because of the vast effect that inaccurate grades and unsubmitted assignments can have on students within a course. If students do not have a reliable manner to ensure that assignments are submitted correctly, or if that manner is confusing and has a high cognitive load, students, especially disabled students, will struggle to guarantee that their assignment is submitted correctly. This situation is further complicated when instructors intentionally limit the file type allowed within the submission of assignment. Unclear file expectations and lack of accessibility in the programs and software needed to create those file types affects uncertainty and anxiety when attempting to complete and submit assignments. This challenge particularly affects individuals with anxiety disorders based on the participants who identified with anxiety who surfaced these concerns.

Within the interviews and the responses to the survey's open-ended items, multiple individuals noted the lack of accuracy in the grades presented within Canvas, such as this quote found within Table 26: "The calculated grades that are given as almost always incorrect" and "there's of course the submission button. Whereas, um, sometimes if you're looking at it and you click an assignment and sometimes you like it, I don't even realize I'm not clicking on it through the assignment page and it's just gives you like this box.". Typically, instructors and faculty members have to set up the way that grades are calculated within Canvas if there are special allowances and sections of the grades can be weighted or modified in some manner, such as lowest quiz score dropped or last homework is extra credit. However, instructors have to readily understand the intricacies within Canvas when setting up their course website. Additionally, if an instructor does not set up their course website properly with grades, the way Canvas computes the grades may be vastly different than the way Canvas automatically calculates the grades for the students. Such inaccuracy of grade calculations within Canvas presents unique difficulties to students who depend only on Canvas to provide them with accurate grades within their courses, which can be especially problematic for disabled students. Calculating grades independently along with knowing and understanding that the grades in Canvas may be incorrect puts an extra cognitive load on all students and may overburden disabled students who may already have a higher cognitive load.

Instructor Differences

A general theme expressed throughout the entirety of the study was a difficulty with differences between courses, especially with how different instructors and faculty members set up their courses and have different expectations of the use of Canvas and course websites. This section encompasses the themes "Inconsistency within a course website" and "Inconsistency between instructors/instructors." Although Chapter 4 of this dissertation showed that individual instructor differences have a small relationship with traditional accessibility difficulties, the results also showed significant differences between the *type* of page instructors used with respect to accessibility issues. A generalized use of Canvas and the expectations for the usage of course websites from instructors and faculty would bring clarity to many of the instructor differences. When looking at the direct quotes from Table 26, a particularly interesting quote from a participate was "Canvas is fine. Instructors are the main point of failure with the system." This seems to point at the manner in which instructors utilize Canvas is problematic. Perhaps there is a need for consistent training for instructors and Canvas content managers to ensure that each instructor understands the capabilities and functionalities of Canvas and utilizes them in consistent manners.

Navigation

Navigation and general usability of Canvas were general themes that were present within all data streams of this study: the quantitative survey, the qualitative responses, and the interviews. Although the quantitative and qualitative responses in the survey and the interviews seem to have noted increased difficulties for participants with anxiety, depression, low vision, and low fine motor skills difficulties, difficulties with navigation throughout Canvas seemed to be expressed as a general concern for the entire population sampled. Navigation is difficult to program in a "usable" manner because "usable" can mean numerous things for different people, even people within the same demographic group. One notable quote that can be seen within Table 27: "Canvas functions in a weirdly infuriating gray area for me. Navigating everything is just shy of instantaneous, but this delay often causes me to click something [I] didn't mean to. This is frustrating because of the lack of back button functionality in canvas, which actually caused me to have to restart my response." This quote, perhaps, shows how small navigation items within Canvas can have a large impact within courses. The following quote may show how the innate instructor of Canvas as combined with specific instructor use can provide navigation difficulties for students: "Information, at least for my ENGE 1216 section, is spread across far too many pages, files, and resources tabs. Finding a document could mean scanning several areas instead of one." Linking the navigation idea to the prior theme, having consistency between instructors, courses, and departments could enhance students' understanding and familiarity with navigating different aspects of the Canvas infrastructure.

Customizability

Because of the nature of disabilities being unique to individuals and expressing themselves in different ways, many of the qualitative responses from disabled individuals expressed a strong desire for making Canvas, and course websites in general, more individualized and customizable. This these seems to be embodied within this quote from one of the participants: “I would like more customization overall, and some of the features don't seem useful.” Previous research with instructors and faculty show their resistance to allow their students the ability to change the designed layout and usability of the course website they provided. Customizability could be helpful for students, especially disabled students, because it would allow students to make their digital environment adaptable to their specific access needs and preferences. Since disabilities have different access needs and even conflicting access needs, allowing students to customize their digital education layout will allow students to have the most accessible environment without interfering with other students’ digital learning environments whether the students are disabled or nondisabled.

Discussion

When combining the quantitative and qualitative data from the survey and design interviews, I can relate these results back to the three research questions presented for this research study. Research questions 1 (differences between disabled versus nondisabled participants) and 2 (differences among participants with different disabilities) were mainly addressed by exploring the quantitative data from the survey. Overall, most of the difficulties presented by non-disabled participants were also highlighted by disabled participants; however, the disabled participants had stronger responses (i.e., identified usage challenged) to each of the items relative to their nondisabled participants. This can be seen within the “I find the inbox function in Canvas useful.” While, on average, the nondisabled people answered that they did not find the inbox function useful. When the data were broken out into specific disabilities, it could be seen that numerous disabilities, such as depression, anxiety, OCD, ADHD, and vision loss, scored markedly higher on this same usability prompt.

Drilling further into particular disabilities, there were differences in responses between disabilities; importantly, not all of the differences fell within the typical disability categories of “cognitive,” “behavioral,” “emotional,” and “physical.” This finding speaks to the importance of looking at different disabilities separately, and when they are aggregated into larger categories, important nuances can be lost. The most common usability difficulties that students encountered within their digitally mediated courses related to error messages, inconsistencies between instructors and web pages, and inaccuracy of grades.

Research question 3 sought to understand the different design elements raised by disabled participants. This research question was answered by analyzing responses to the open-ended survey items as well as in the design interviews with disabled participants. The themes of these responses are seen in Table 26 and Table 27. These themes were: inconsistency within a course website, accuracy of grades, inconsistency between instructors, navigation, assurance file is submitted correctly/ timers, limited customizability by courses, and distinguishing courses. Within the design interviews, participants brought up the idea of simplifying navigation, establishing templates for instructors to maintain consistency both within a course and between courses, the ability to accurately display grades, customization of courses from an individual user perspective, and being able to minimize timers within timed tests/quizzes.

A generalized use of Canvas and the expectations for the usage of course websites from instructors and faculty would bring clarity to many of the instructor differences. However, I realize that creating generalized guidelines and trainings for instructors and faculty members creates additional difficulties, such as violations of instructor autonomy and course freedom. Despite the difficulties, my findings support the notion that generalized usability suggestions, at a minimum, and optional training on courses around best practices should help to lessen the cognitive burden on students who must utilize multiple course websites and disabled students, in particular, who have a higher cognitive load as a baseline. These generalized best practice standards should include grade guidelines, assignment guidelines, and file guidelines.

Additionally, creating custom elements for a course website provides additional accessibility concerns, as such elements could increase cognitive load for some of the disabled users. Developers must ensure that all configurations of the course website are accessibility compliant and should keep up to date with all of the customizability aspects of the basic course website shell. Furthermore, I recognize that it is difficult to ensure all customizability options are accounted for within accessibility checks, which can be difficult with changing technology and changing student populations. To account for this, allowing students to have the ability to toggle on and off Canvas options within particular individual courses is ideal. This customizability will allow students the ability to adjust Canvas so that it can best meet their accessibility needs.

Chapter 6

Discussion and Conclusion

This chapter discusses the combined results across the studies presented in Chapters 3, 4, and 5 and how these results integrate and inform each other. Additionally, this chapter speaks to the implications of this research and how the results can help affect the work of programmers and digital designers. Finally, this chapter culminates with a list of recommendations for programmers and designers when creating an inclusive place for cognitively disabled people, especially engineering students within higher education.

Discussion

Chapter 3

An overarching question that encapsulates the research and results presented within Chapter 3 is: "What are the perceptions and climate for disabled people within engineering based on academic engineering literature as well as literature published within the American Society of Engineering Education (ASEE)?" Through the systematic exploration of literature in Chapter 3, I found that people within academic engineering literature are still using words toward which the disability community have expressed discomfort and aversion. This finding suggests that individuals publishing within general engineering academic literature do not cross references with current literature on disability or commiserate with disabled individuals as to the proper way to talk about disability and in ways disabled people feel most comfortable in expression their disabled identity. This finding is consistent with the literature that pushes for participatory design within engineering and engineering design projects (Cochran et. al, 2008).

In contrast to the general engineering academic literature, the literature housed by ASEE tended to view disabled people as active participants within their research, whereas general engineering academic literature tended to view disabled people as an abstract population in which their study sought to “fix” their researcher-perceived problem or difficulty. These distinctions further demonstrate different perceptions toward the disabled population between the general engineering academic community and the ASEE community. Including disabled people as active participants within research allows disabled perspectives to be heard and shows that researchers value that opinion within their research. This literature review helps to expand the knowledge of the perception of disability and disabled inclusion within the engineering fields and the education of students as engineers.

Finally, the low presence of emotional disabilities and cognitive disabilities within general engineering academic literature and the low presence of emotional disabilities within the ASEE literature show the lack of literature on cognitive disabilities and emotional disabilities. Since it is reported that most disabilities are either emotional or cognitive (Collins et. al 2005), this finding leaves much of the disabled population out of academic literature within the engineering context.

Chapter 4

A general overarching question that encompasses the specific research questions and results presented within Chapter 4 is: “How accessible are Canvas course websites, and what drives the inaccessibility of the course websites?” Through the quantitative exploration of Canvas course websites used within engineering and engineering-related first and second year courses in Chapter 4, I conducted observational experiments and showed that numerous accessibility errors, according to the WCAG 2.0, appear on each page of the course websites.

Some of these errors are not able to be fixed by the instructors of the course or the individuals who handled the content of the course and were embedded within an inaccessible website design and template created for the university by Canvas and university affiliated website designers. Through the examination of the course websites, I found that the type of page on the course website drove errors of the accessibility of the course website page more so than individual instructors or course ID.

This exploration of the course websites showed the inaccessibility of these websites and how they can exclude disabled engineering students from getting the information they need and, potentially, making it challenging for such students to complete quizzes or assignments. The pages that tested with the most errors included the syllabus pages, file pages, and assignments pages. This result could be concerning for disabled engineering students who need access to their course websites for information and to complete assignments. This inequity of access within course websites for disabled students could lead to inequities in accessing educational information and course assignments, which in turn could possibly lead to lower course grades.

The most common accessibility errors found within the engineering and engineering related Canvas course websites pertained to the way information is presented on a webpage and images without alt text attached to them. Understanding the types of errors that are most common can help accessibility trainers target their training to make the largest impact possible.

Chapter 5

The overall framing question that can embody the research presented within Chapter 5 is: "How would disabled and nondisabled engineering students redesign their Canvas course websites based on the unique difficulties they have had with Canvas?" Through the exploration of survey data and design interviews, the results within Chapter 5 identified six main design themes: insistency within a course website, accuracy of grades, inconsistency between instructors/instructors, navigation/complexity, assurance file is submitted correctly/ timers/accuracy, and limited customizability by courses. An important connection between the results of Chapter 4 and Chapter 5 is that the difficulties disabled and even nondisabled students had with Canvas would not entirely be solved by addressing the accessibility errors found within Chapter 4. This finding is emphasized further when it is realized that many of the accessibility difficulties presented within Chapter 5 were presented by engineering students who identify with depression and anxiety. New studies say that the largest "type" of disability present are cognitive and emotional disabilities. From the findings within Chapter 4 and Chapter 5, it can be surmised that students with cognitive and emotional disabilities, particularly depression and anxiety, are not having their accessibility needs met with the current standards of the WCAG 2.0 that is connected to the ADA—and as I showed in Chapter 3, those are the very students who seem to be left out of the disability literature (Spingola, 2016). Since this group of disabled students is the largest and has been growing over the past decade, it is vital more research is done on the needs of cognitively and emotionally disabled students.

Combined

Chapter 3 of this dissertation, the TAM model, and participatory design all point to the importance of getting the perspective and input of disabled people in the design of accessible products. The combined results of Chapters 3, 4, and 5 emphasize the necessity to not only have disabled people involved in the development of products for disabled people, but that it is necessary to have a wide variety of different disabilities included within the design and redesign of accessible products. The voices of disabled people are crucial when designing inclusive platforms and products. The reduction of cognitive load for disabled people is important to keep in mind when designing accessible technology. Numerous "accessible" products or accessibility features on products are complicated, and it is critical to consider when designing products that disabled people have to remember more elements than their non-disabled peers. This is especially problematic when the disabled person is cognitively disabled and, perhaps, may not have the capacity to successfully engage in products that require a high cognitive load.

Additionally, it is important to realize that accessibility guidelines do not encompass the access needs of disabled people across the range of disabilities, as was seen when looking at the results of both Chapter 4 and Chapter 5. When creating new technology, even if it is not "accessible" technology targeted to disabled individuals, it is necessary to have active participation from numerous disabled people with different disabilities. This disabled voice will help ensure the accessibility of products, even if engineers utilized accessible design standards or other accessibility standards, such as the WCAG 2.0, to create a product. Although research can aid our understanding of disability and how disabled people interact with technology, it is important to accept that our knowledge of disability and disabled people grows and changes along with the growth and morphing of the technological landscape. This information can help add to different design standards and help educate individuals with power who interact with and make decisions that impact disabled people within their professional and personal lives. It is important to ensure that our accessible design standards and accessibility standards are treated as living documents that will constantly be enhanced and improved to better aid disabled people and create a more inclusive environment.

Recommendations

An important goal of this research was to end with a tangible deliverable that can be utilized to help provide a more inclusive digital environment for engineering students.

Throughout the studies present within Chapters 3, 4, and 5, the results and the discussions show that there is a gap in the current accepted standards for digital (website) accessibility. While many curators and developers of website content and structure still struggle to understand, comply, and surpass the WCAG 2.0 guidelines, it is paramount to understand that these guidelines still leave gaps in digital accessibility, especially for cognitively disabled individuals. Furthermore, much of the WCAG 2.0 only is applicable for individuals with only physical disabilities. When cognitive and emotional disabilities are addressed within these standards, it is minimal, generalized, and targeted for more "extreme" cases. Moreover, while there is minimal information put out by the International Association of Accessibility Professionals (IAAP) and the World Wide Web Consortium (W3C) on cognitive disabilities and how to build website accessibility around cognitive disabilities, this information is dated, with citations over 30 years old, and does not suitably consider the ever-changing digital landscape. Additionally, that information does not take into account digital education and cognitively and emotionally disabled individuals within the digital higher education space. As I showed in Chapter 3, the academic literature lacks a focus on certain kinds of disabilities within engineering majors, in particular for cognitive and emotional disabilities. Given this lack of information on the needs of cognitively disabled engineering students, the evident stigma against disability within engineering, and the need presented by cognitively disabled students for a more accessible and usable digital interface for their course websites, this section identifies recommendations for developers, designers, and instructors. Table 28 shows a summary of the recommendations and the chapter where the results helped to inform the recommendation.

Table 28: Recommendations and the corresponding results that helped to inform them

Recommendation	**Informing results**
Easily hideable countdown timers for timed assignments and graded exams/quizzes	Chapter 5
Simplistic and intuitive navigation	Chapter 4, Chapter 5
Consistency within a single course website	Chapter 5
Consistency between course websites	Chapter 5
Flexibility in submission type and time	Chapter 5
Accurate and simplistic grade totals	Chapter 5
Granular customization for notifications per course	Chapter 5

Table 29 shows details as to the individual recommendations and how they could apply to three main groups: the developer, the designer, and the instructor/content manager. Each one of the recommendations included within this table are explained in detail within the following sections.

Table 29 further details the recommendations and how the different populations of developer, designer, and instructor or content manager can implement these recommendations.

Table 29: Detailed information on the application of the recommendations on developers, designers, and instructors or content managers.

Recommendation	**Developer**	**Designer**	**Instructor/Content Manager**
Easily hideable countdown timers for timed assignments and graded exams/quizzes	Allow for minimizing or closing the countdown timer. Make those options easy to find and intuitive.	Make the countdown time visually nonintrusive	Create nontimed digital assignments, exams, and quizzes
Simplistic and intuitive navigation	Only allow populated pages show in the navigation. Require content managers to organize the files on their course website. Eliminate nested navigation. Ensure proper tab-order	Make nested navigation visually different than the parent navigation.	Only use navigation items that are actually utilized within your course.
Consistency within a single course website	Eliminate or put warning messages for implementing duplicate ways of accessing content.	Design only one place to put like content. Create a guiding style guide for instructors or content managers.	Be intentional where information is posted. Always put similar content in the same places.
Consistency between course websites	Eliminate or put warning messages for implementing duplicate ways of accessing content.	Design only one place to put like content. Create a guiding style guide	Create guidelines with colleagues and build course websites together to understand the

		for instructors or content managers.	differences between courses and try to eliminate differences presented within different course websites.
Flexibility in submission type and time	Don't allow for submission file type restrictions or place a warning message when they are used including accessibility concerns. Automatically provide flex time for submissions submitted late and flag them as late.		Be flexible in the files allowed for each submission. Allow for late submissions within reason.
Accurate and simplistic grade totals	Provide a clickthrough survey to understand the instructor's grading scheme and apply those settings to the specific course websites for the instructor. Make this survey mandatory.	Streamline and provide explanations for the grading scheme that the instructor has chosen for the students on the student view of the "grades" tab.	Ensure grades are properly and accurately set up within the course website before the course start date. If your grading changes throughout the semester, ensure you update your grading scheme in your course website.
Granular customization for	Allow for the granular customization per course		Talk with other instructors or content managers to

notifications per course	website that is provided for the general Canvas site.		streamline the way you communication with your students

Easily hideable countdown timers for timed assignments and graded exams/quizzes

Within the study presented in Chapter 5, the interviews revealed strong distaste and difficulty with having a countdown timer on timed exams and quizzes. The students who stated these difficulties identify with having anxiety. Watching the time count down was stressful and distracting. In some cases, the participants would obsess over the time counting down as opposed to the task at hand. Allowing students to minimize, hide, or even close the timer may provide students with a less stressful testing environment.

Simplistic and intuitive navigation

Difficulties with navigation were present within the results presented within both Chapter 4 and 5. Within these results, the quantitative analysis in Chapter 4 showed website violation in the organization of information and the navigation of the course websites, and the qualitative survey response and interviews in Chapter 5 showed the need for a more simplistic navigation that is more intuitive. When developing navigation for course websites, it is important to ensure that only the information that is useful and pertinent for the course is presented within the navigation and that there is a concise and intuitive way to access all of the information for the course.

Consistency within a single course website

The qualitative responses within the survey presented within Chapter 5 revealed course information being presented in many different places within a single course. This scenario presented confusion and anxiety among the students taking the courses. The participants noted how difficult it was to find information and how easy it was to miss important information within the Canvas infrastructure. It is recommended that developers limit the options for content managers and that content managers are intentional and consistent when placing course content on their course websites.

Consistency between course websites

Both the qualitative survey responses and the interviews presented in Chapter 5 indicate frustration and difficulty students have when trying to navigate between course websites. Each faculty member and instructor customize their course website and, in turn, places information and content in different places within their course websites. This discrepancy presents confusion and anxiety with the students. It is recommended that faculty members, instructors, and staff within each department or college try to streamline what the course websites look like and how content will be presented by forming a content guide that outlines where assignments, quizzes, exams, announcements, grades, feedback, files, and additional content should be organized. It is recognized that this approach limits the individual instructors' and faculty members' autonomy and teaching freedom to a limited extent, but it would provide a more consistent and reliable course experience for engineering students. Additionally, students being able to rely on content being in similar places lessens the cognitive load of the students who have multiple different courses that they are taking at the same time each semester. Having this consistency will allow students to only have to remember one layout for the course websites.

Flexibility in submission type and time

Within the interview results presented within Chapter 5, participants expressed anxiety when submitting assignments and work to instructors and faculty members. Much of this anxiety was because of strict submission cut off times and uncertainty in the proper file type to submit. Different platforms have varying levels of accessibility, and particular platforms must be used to create particular file types. This creates external difficulties with accessibility within the different software platforms that can partially be mitigated by instructors and faculty members allowing for the acceptance of different file types.

Accurate and simplistic grade totals

Participants within Chapter 5 noted that many of the grades within the "grades" tab in Canvas were not accurate. Students should be able to receive accurate and simplistic grade totals. Within Canvas there are numerous options with grades. Instructors and faculty members should receive training on how to properly set up the grades within the course. Additionally, grades could be simplified by allowing for department level standards on how grades are produced. This suggestion may receive push back from the instructors and faculty members, but it would eliminate the inaccuracy and confusion when it comes to grades produced within the course and course websites, which potentially seems to have more negative effects on students with disabilities than their peers.

Granular customization for notifications per course

Allowing students to customize notifications per course will allow students to ensure they are not overwhelmed with a multitude of different notifications for courses that have many automatic notifications sent to the students' email. Additionally, this customization will ensure that students are informed of pertinent information and announcements without getting informed about every element of every course they are taking. This shift allows for a lower cognitive load for the students. This recommendation is based on the results of the interviews presented in Chapter 5.

Final Conclusions

There is still much left to research about disabled engineering students and how they interact with digitally mediated education, especially for cognitive and emotional disabilities. However, my dissertation provides a foundation for future research. Within this foundation, I found that specific disability types were commonly excluded from academic literature. This exclusion has potentially led to those perspectives and accessibility needs not being present within the current and commonly used design standards and accessibility standards and recommendations. The inclusion of the disabled perception should not just use the most "convenient" disabilities to find, but rather a diverse group of disabled individuals that includes the perspectives of numerous disabilities. My dissertation lays out an argument for—and presents evidence around—the need to take a participatory design approach when developing digitally mediated course materials that values the perceptions and ideas of disabled engineering students.

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Appendix A:

Edited survey

Understanding barriers for usability in LMS

Start of Block: Default Question Block

Q22 Purpose: Members of the Department of Engineering Education at Virginia Tech are conducting research under the supervision of Liz Spingola and Dr. David Knight. You are invited to participate. The purpose of the study is to examine and understand students' perspectives and ideas on ways to alleviate digital barriers and hard-to-navigate aspects within Canvas. We will use this information to help inform improvements around the accessibility of Canvas and other learning management systems. Additionally, this information will be used in Liz Spingola's dissertation.

Your participation in this survey is completely voluntary. You may withdraw from this study at any time without penalty. The survey should take about 10 minutes to complete.

Benefits and Risks: Your participation may benefit you and other Virginia Tech students by helping to improve digital education. No risk greater than those experienced in ordinary conversations are anticipated.

Confidentiality: Anonymous data from this study will be analyzed by Liz Spingola. No individual participant will be identified or linked to the results. Study records may be inspected by IRB administrators. The results of this study may be presented at meetings, conferences, and at a dissertation defense; however, your identity will not be disclosed. All information obtained in this study will be kept strictly confidential. All materials will be stored in a secure location within a password protected laptop with only the main researcher having access to the identifiable information.

Consent: By proceeding with this survey, you are indicating that you fully understand the above information and agree to participate in this survey

Q16 What is your age?

- under 18 (1)
- 18 (2)
- 19 (3)
- 20 (4)
- 21 (5)
- 22 (6)
- other (7) ____

Skip To: End of Survey If What is your age? = under 18

Q1 Think about when you use Canvas for your engineering classes and please answer the following questions.

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
I liked using the Canvas interface. (1)	o	o	o	o	o
The organization of information on Canvas was clear. (2)	o	o	o	o	o
The Canvas interface was pleasant to use. (3)	o	o	o	o	o
Canvas has all the functions and capabilities that I expect it to have. (4)	o	o	o	o	o
Canvas has all the functions and capabilities that I want it to have. (5)	o	o	o	o	o
The information in the Canvas help window helped me answer my questions. (6)	o	o	o	o	o

Q2 Think about when you use Canvas for your engineering classes and please answer the following questions.

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The navigation through Canvas was logical. (1)	○	○	○	○	○
The navigation through Canvas was consistent. (2)	○	○	○	○	○
I find the inbox function in Canvas useful. (3)	○	○	○	○	○
It was simple to use Canvas. (4)	○	○	○	○	○
It was easy to find the information I needed on Canvas. (5)	○	○	○	○	○
The information provided through Canvas was clear. (6)	○	○	○	○	○

Page Break

Q3 Think about when you use Canvas for your engineering classes and please answer the following questions.

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
I never receive error screens when using Canvas. (1)	○	○	○	○	○
Canvas functions in a way that I expect. (2)	○	○	○	○	○
It was easy to learn to use Canvas. (3)	○	○	○	○	○
To use Canvas well I had to learn too much background information. (4)	○	○	○	○	○
The information provided by Canvas was easy to understand. (5)	○	○	○	○	○
I felt comfortable using Canvas. (6)	○	○	○	○	○

Q4 Think about when you use Canvas for your engineering classes and please answer the following questions.

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
I enjoyed learning through Canvas. (1)	○	○	○	○	○
Overall, I am satisfied with Canvas. (2)	○	○	○	○	○
I was able to complete tasks quickly using Canvas. (3)	○	○	○	○	○
I believe I could become productive quickly using Canvas. (4)	○	○	○	○	○
From my current experience with using Canvas, I would prefer to use Canvas regularly. (6)	○	○	○	○	○
Whenever I made a mistake using Canvas, I could recover quickly. (7)	○	○	○	○	○
Canvas gave error messages that clearly told me how to fix problems. (8)	○	○	○	○	○

Q18 Please write any additional comments you have about the usability of Canvas here.

____

Q5 Answer the following questions on the scale from extremely easy to extremely hard.	Extremely easy (1)	Somewhat easy (2)	Neither easy nor difficult (3)	Somewhat difficult (4)	Extremely difficult (5)
Places where you socialize and engage in community activities make it easy to engage and socialize. (1)	○	○	○	○	○
Do the shops, banks and post office in your neighborhood make it easy or hard for you to use them? (2)	○	○	○	○	○
Does the transportation you need or want to use make it easy or hard for you to use it? (3)	○	○	○	○	○
Does where you live make it easy or hard for you to live there? (4)	○	○	○	○	○
Should you need help, how easy or hard is it for you to get help from a close family member (including your partner)? (5)	○	○	○	○	○

Should you need help, how easy is it for you to get help from friends and co-workers? (6)	○	○	○	○	○
Should you need help, how easy is it for you to get help from neighbors? (7)	○	○	○	○	○

Q6 Please answer the following four questions on a scale from not at all to a great deal.

	None at all (1)	A little (2)	A moderate amount (3)	A lot (4)	A great deal (5)
Do you make your own choices about your day-to-day life? For example: where to go, what to do, what to eat (1)	○	○	○	○	○
Do you feel that other people respect you? (2)	○	○	○	○	○
Do you feel that others value you as a person and listen to what you have to say? (3)	○	○	○	○	○
How much bodily aches or pain do you have? (4)	○	○	○	○	○

Q7 Please think about the last 30 days, taking both good and bad days into account. For each question, please tell me how much of a problem is it for you on a scale from not challenging at all to extremely challenging.

	Not challenging at all (1)	Slightly challenging (2)	Moderately challenging (3)	Very challenging (4)	Extremely challenging (5)
How much of a problem is walking a mile for you? (1)	○	○	○	○	○
How much of a problem is getting where you want to go for you? (2)	○	○	○	○	○
How much of a problem is getting clean and dressed? (3)	○	○	○	○	○
How much of a problem is looking after your health? (4)	○	○	○	○	○
How much of a problem is eating well? (5)	○	○	○	○	○
How much of a problem is exercising? (6)	○	○	○	○	○
How much of a problem is taking your medicines? (7)	○	○	○	○	○
How much of a problem is feeling tired and not having enough energy? (8)	○	○	○	○	○
How much of a problem is coping with all the things you have to do? (9)	○	○	○	○	○

How much of a problem is remembering to do the important things in your day-to-day life? (10)	○	○	○	○	○
How much of a problem do you have with getting your household tasks done? (11)	○	○	○	○	○
How much of a problem do you have with joining community activities, such as festivities, religious or other activities? (12)	○	○	○	○	○
How much of a problem is using public or private transportation? (13)	○	○	○	○	○
How much of a problem is getting things done as required at work or school? (14)	○	○	○	○	○

Q8 Please answer the following questions on a scale from no difficulty to you cannot do the activity. Please answer these questions WITHOUT taking into account any help.

	No Difficulty (1)	Moderately easy (2)	Neither easy or difficult (3)	Moderately difficult (4)	I can not do this task (5)
How much difficulty do you have seeing things at a distance [without glasses]? (1)	○	○	○	○	○
How much difficulty do you have hearing [without hearing aids]? (2)	○	○	○	○	○
How much difficulty do you have walking or climbing steps? (3)	○	○	○	○	○
How much difficulty do you have remembering or concentrating? (4)	○	○	○	○	○
How much difficulty do you have washing all over or dressing? (5)	○	○	○	○	○
How much difficulty do you have sleeping because of your health? (6)	○	○	○	○	○
How much difficulty do you have doing household tasks because of your health? (7)	○	○	○	○	○

Because of your health, how much difficulty do you have with joining community activities, such as festivities, religious or other activities? (8)	○	○	○	○	○
How much difficulty do you have with feeling sad, low, worried or anxious because of your health? (9)	○	○	○	○	○
Because of your health, how much difficulty do you have getting along with people who are close to you, including your family and friends? (10)	○	○	○	○	○

Q9 Do you currently identify with having any of these diseases or health problems?

- ☐ Trauma (1)
- ☐ Tinnitus (2)
- ☐ Vision loss (3)
- ☐ Hearing loss (4)
- ☐ High Blood Pressure (Hypertension) (5)
- ☐ Heart disease, Coronary Disease, Heart Attack (6)
- ☐ Stroke (7)
- ☐ Diabetes (8)
- ☐ Arthritis or arthrosis (9)
- ☐ Chronic Bronchitis or Emphysema (10)
- ☐ Asthma, allergic respiratory disease (11)
- ☐ Back pain or disc problems (12)
- ☐ Depression (13)
- ☐ Anxiety (14)
- ☐ Amputation (15)
- ☐ Other (16) ____

- [ ] Other (17) ____

- [ ] other (18) ____

Q19 Please write any additional comments you have about having a disability or physical or mental differences on campus here.

____

Q14 What do you identify as your gender?

- [ ] Male (1)
- [ ] Female (2)
- [ ] Trans (3)
- [ ] Non-binary (5)
- [ ] Genderqueer or gender nonconforming (6)
- [ ] Other (4) ____

Q15 What is your race?

- ▢ White (1)
- ▢ African American or Black (2)
- ▢ American Indian or Alaska Native (3)
- ▢ Asian American or Asian (4)
- ▢ Native Hawaiian or Pacific Islander (5)
- ▢ Hispanic or Latinx (7)
- ▢ Middle Eastern (8)
- ▢ Multiracial (9)
- ▢ Other (6)

Q20 If you would be interested in participating in a follow up focus group with pizza provided where you brainstorm technology designs, please write your email address below.

____

End of Block: Default Question Block

Appendix B:

Design Interview Guide

Introduction of the study:

Hello and thank you for agreeing to participate in this study. Please help yourself to something to eat and drinks while I review what this study is about before you have a chance to sign the consent form. Please let me know if any of you have any questions at any point.

This study looks to retrieve and understand students' perspectives and ideas on ways to alleviate digital barriers and hard to navigate aspects within Canvas. In a few minutes you will receive a particular barrier that was identified as problematic. You, along with your peers in your group, will work together to brainstorm and design a solution to help alleviate this barrier. I will ask you to write down and draw your ideas as you work through brainstorming and designing. At any time during the secession you will have the opportunity to leave and withdraw consent. Please take the time to read and sign the consent form now. Let me know if you have any questions about the study or the consent form.

Guiding Questions:

1. What makes this particular aspect difficult?

a. How so?

2. What makes other aspects of Canvas easier to navigate?

3. How does your design differ from your peers?

a. Why did you choose to design it in this manner?

4. Could you tell me a bit more about why you decided to go in this direction?

5. Have you personally experienced this difficulty on Canvas?

Tips

1. Encourage participants to write down their ideas
2. Encourage participants to draw their ideas.
3. Encourage participants to work together but allow them to separately write down and draw different individual ideas.

Appendix C:

Consent Form

Consent Form: Design Interviews

Purpose:

Members of the Department of Engineering Education Department at Virginia Tech are conducting research under the supervision of Liz Spingola and Dr. David Knight. You are invited to participate. The purpose of the study is to examine and understand students' perspectives and ideas on ways to alleviate digital barriers and hard to navigate aspects within Canvas. We will use this information to help improve the accessibility of Canvas and other learning management systems. Additionally, this information will be used in Liz Spingola's dissertation.

Procedures:

If you participate in this study, you will be in a group of approximately 8 – 10 students. There will be a facilitator who will ask questions and facilitate the discussion, along with taking notes to write down the ideas expressed within the group. If you volunteer to participate in this focus group, you will be asked some questions relating to your experience with Canvas. Additionally, you be asked to engage in discussion and brainstorm your ideas using drawings. The focus group session will help us better understand the changes in computer science design standards that are necessary to improve accessibility of websites.

Your participation is completely voluntary. You may withdraw from this study at any time without penalty.

Benefits and Risks:

Your participation may benefit you and other Virginia Tech students by helping to improve digital education. No risk greater than those experienced in ordinary conversations are anticipated. However, if something during the group causes discomfort, you will have received a list of campus resources where you can seek counseling and support.

Everyone will be asked to respect the privacy of the other group members. All participants will be asked not to disclose anything said within the context of the discussion, but it is important to understand that other people in the group with you may not keep all information private and confidential.

Confidentiality:

Anonymous data from this study will be analyzed by Liz Spingola. No individual participant will be identified or linked to the results. Study records, including this consent from signed by you, may be inspected by the administrators. The results of this study may be presented at meetings, conferences, and at dissertation defense; however, your identity will not be disclosed. All information obtained in this study will be kept strictly confidential. All materials will be stored in a secure location within a password protected laptop with only the main researcher having access to the identifiable information.

Consent:

By signing this consent form, you are indicating that you fully understand the above information and agree to participate in this focus group.

Participant's signature: ____

Printed name: ____

Date: ____

If you have any questions or concerns about this study, please contact Liz Spingola at lizsping@vt.edu or David Knight at dbknight@vt.edu or (540) 231-2563. If you feel you have not be treated according to the descriptions in this form, or your rights as a participant have been violated during the course of this project, you may contact the Virginia Tech Institutional Review Board at irb@vt.edu or (540) 231-3732.

Appendix D:

Handout from Accessibility Workshop

Digital Accessibility and 1215

Elements in the WCAG

non-text content	**contrast**
focus order	**link purpose**
labels or instructions	**error identification**
parsing	**name, role, value**
info and Relationships	**timing adjustable**
use of color	**section headings**
images of text	**on input**

- reviewed 11 instructors (25 sections)
- from a total of: 30 instructors (75 sections)

Criteria that were especially problematic (and tips to easily correct)

- Links
  - Write descriptive text surrounding the link
  - Do not embed the link within a sentence
    - I.e. " Click here to learn more"
- Images
  - Captions
  - Descriptive alt text
    - Alt text described what students are supposed to understand from each image
- Relationships
  - Making clear, consistent, and logical headings
  - Format so that the pages and the information in the pages follow the same formatting
- Contrast
  - Use online contrast tools to ensure that the colors you are using do not too closely match
  - Print the page out in black and white. If it is hard to determine the differences between colors, change your contrast to be more drastic.

- Consider students who may be colorblind: change a “red vs. green” graph to a dashed-red vs. solid-green.

Appendix E:

Website Module for Accessibility Given in Workshop

Adding Web pages to your course LMS? A guide for accessibility

Most institutions frame course web sites around a Learning management System (LMS) such as Blackboard or Canvas. The LMS gives consistent structure and automated features to each course; these typically include an ability to post weekly / daily / modular information pages with links, homework assignments, automated gradebooks, and teaming tools. These systems allow faculty to build course websites with minimal knowledge of Web development.

Building course sites with an appreciation for accessibility requirements requires that faculty pay attention to those requirements as course content is added to the LMS. Course websites should conform to guidelines defined in the latest version of the Web Content Accessibility Guidelines (WCAG).

Fortunately, conforming to the guidelines is fairly straightforward and the Internet has multiple easy-to-follow guides for faculty at any level. Once faculty intentionally consider the guidelines, they seem to be quite straightforward. Unfortunately, many of the LMS frameworks themselves do not conform to the WCAG, so achieving 100% compliance is difficult.

> Please let your trainer know how helpful this is. I'll make changes to the way I enter URLs immediately, I need to consult the guide to figure out what I need to do to my PDFs.
>
> - Faculty email after a short training session

Planning

Institutions or departments should intentionally plan to educate faculty and others associated with online content with the WCAG guidelines prior to the expected timeline for content development. A departmental strategy / policy adopted with a training plan is an excellent route to ensure success. For institutions or departments with adequate resources, a champion may be identified: this could be someone most familiar with accessibility in design or in web development. Campus-wide or college resources may be available as well: Centers for Teaching are often a good source of assistance and training.

Policies

The level of departmental / institutional policies certainly varies among institutions, so a one-size-fits-all policy would be problematic. However, intentionally incorporating design-for-accessibility into the expectations for those who develop and post online content is a key to ensuring success, whether this be at a policy level or an expressed expectation. Faculty have been generally receptive to incorporating accessibility into their sites as long as adequate training and resources have been made available.

Training

Regular accessibility training is necessary to ensure that web pages and LMS remain accessible.

A successful plan could involve training at the start of the academic year; this training could include an 'expert' in accessible web design. Look beyond the obvious for such an expert: while some departments may have a web developer, accessibility expert, or access to a training program, an expert may be an individual faculty member who has intentionally incorporated these ideas into their course over a period of time.

For best success, these trainings should be integrated within any semester meetings and/or training for engineering teaching faculty. This reinforces the institutional commitment towards being both accessible and inclusive. Regular integrated trainings allow for up to date information to be dispersed to the faculty and staff within the changing world of accessibility and technology. Additionally, by integrating accessibility into regular and typical opportunities provided by the institution and department, disability and accessibility become less obscure and intimidating to tackle. Including a discussion item in regular meetings brings the issue into the forefront and should boost compliance.

Resources for Easy Accessibility

While accessibility, especially digital accessibility, may seem a daunting task for a novice, there are numerous resources available that will enable you to thorough understand the digital accessibility landscape and empower you to incorporate accessibility practices within your digital engineering classroom.

History:

These links can give more background information and help answer the question "why":

- **A Brief Timeline of Accessibility Law in the U.S.**
  A link to the history of accessibility within the United States and how it impacts education: https://cielo24.com/2017/03/a-brief-history-of-accessibility-law-us/
- **About the ADA Standards**
  A link to a document explaining the Americans with Disabilities Act:

https://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-ada-standards

- **WCAG Overview**
  Brief information on WCAG 2.0, 2.1 and tips for incorporating into course web spaces: https://www.w3.org/WAI/standards-guidelines/wcag/

Guides:

- **A Beginner's Guide to Accessibility**
  A link to a guideline about the Web Content Accessibility Guidelines that are the main international digital accessibility guidelines and are referred to in the Americans with Disabilities Act: https://www.deque.com/accessibility-beginners-guide/
- **WCAG 2.**1 at a glance
  How to meet WCAG 2 (quick reference): https://www.w3.org/WAI/standards-guidelines/wcag/

Tools:

- A link to a great digital contrast tool: https://webaim.org/resources/contrastchecker/
- A link to tips for captioning videos: https://www.washington.edu/accessibility/videos/free-captioning/
- A link to tips for making engineering labs accessible: https://www.washington.edu/doit/checklist-making-engineering-labs-accessible-students-disabilities
- A link from UDO-IT and the University of Washington that talks about the program AccessComputing and accessible programing languages for disabled individuals to easily use. https://quorumlanguage.com/
- A link to a web developer's guide to creating accessible spaces: https://www.w3.org/WAI/ER/WD-AERT/ED-AERT

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Appendix F:

ADA Digital Toolkit by Minnesota Used Within the Workshop

MSCOD

Minnesota State Council on Disability

Your Policy, Training and Technical Resource

ADA Digital Toolkit

A Guide to Digital Accessibility

June 2017

Contents

What is in this Toolkit?

This ADA Digital Toolkit is designed to help users understand the importance and impact of digital accessibility and its relation to the Americans with Disabilities Act (ADA). While there are currently *no technical requirements regarding digital accessibility within the ADA*, the exponential growth of the Internet and information technologies into all areas of our lives over the last 27 years makes this a vital area of interest for those concerned with equal access for all. The sections in this Toolkit are intended to provide you with information, tools, and resources you need to make your websites, documents, and others electronic information accessible to people with disabilities.

Part 1: What is Digital Accessibility?

This section provides an overview of digital accessibility and the principles that underlie it.

Part 2: Barriers to Digital Access

This section covers common barriers people with disabilities face when attempting to access electronic information.

Part 3: Digital Accessibility and the ADA

This section reviews how digital accessibility is currently considered under the Americans with Disability Act and what you can do to prepare for proposed new regulations.

Part 4: Digital Accessibility Guidelines

This section provides an overview of the Web Content Accessibility Guidelines (WCAG) 2.0, the internationally-recognized standard for digital accessibility.

Part 5: Getting Started with Digital Accessibility

This section provides some tips and best practices to help you get started with digital accessibility

Part 6: Digital Access Quick Check

This section offers five basic checks you can do to quickly learn something about the accessibility of your web content.

Part 7: Developing an Accessibility Plan

This section provides an overview of a plan your organization can put in place to incorporate accessibility into your existing workflows--and to maintain it moving forward.

Part 8: Digital Accessibility Resources

This section provides additional information and resources for digital accessibility.

What is Digital Accessibility?

In practical terms, digital accessibility is making your content work with the technologies people use, whether that is a mobile phone or a dedicated assistive device such as a screen reader.

Just as including access ramps and curb cuts in the built environment can remove barriers to access, incorporating accessibility features, such as alternative text and keyboard control, can improve the digital “environment”. While there are a number of techniques you can use to achieve this barrier removal, there are four general principles to keep in mind: perceivable, operable, understandable, and robust.

Perceivable

Can users perceive your information? For many people, vision is the primary mode of perception and this explains why so much effort is placed on the visual presentation. However, this does not account for other means of perception: namely, hearing and tactile feedback. Content should be developed with these perceptions in mind. More importantly, content needs to be easily changeable among these three modes--visual, auditory, and tactile--to meet the needs of individual users.

Operable

Can users interact with your information? Traditionally, users have interacted with electronic information using a mouse and keyboard. However, limiting access to these interactions does not account for people who cannot use such devices--or cannot use them in traditional ways--and rely on assistive technology. Nor does it account for the different interactions used with mobile devices. However they choose to access your information, people should be able to use it.

Understandable

Can users understand your information? As the content creator, your information makes sense to you. But would it make sense to someone who has never encountered it before? Is it written in clear and precise language? If people are asked to interact with it, are instructions provided and potential errors anticipated and easily corrected? Does it take into account people who have difficulty comprehending, remembering, or focusing?

Robust

Does the presentation of your content actually work as you intend it to, on any device a user chooses to use? Will it continue to work for the foreseeable future?

Barriers to Digital Access

The four accessibility principles—**perceivable**, **operable**, **understandable**, and **robust**—address potential barriers people with disabilities might face when accessing your information. These barriers can be grouped under five broad categories of disability: auditory, cognitive and neurological, physical, speech, and visual.

Note: Each disability category includes different types and levels of severity. There can also be many areas of overlap.

Auditory Disabilities

Auditory disabilities include various levels of hearing impairment from the moderate (hard of hearing) to the severe (deafness). It also includes people who are both deaf and blind.

Barriers to access

For people with these disabilities, information cannot be accessed if it relies on sound. Examples include:

- Audio content that doesn't provide captions or transcripts
- Media players that do not allow for captions, or players that do not allow for volume controls
- Any interaction that requires someone to speak

Removing those barriers

To make content accessible to people with auditory disabilities, you need to:

- Provide alternatives to audio content in the form of captions or transcripts, depending on the type of media
- Give the user the ability to control any audio they encounter, including the ability to stop, pause, or adjust the volume

Note: Those who are deaf or hard of hearing may use sign language as their first language; therefore, they might have more difficulty understanding written English. As an aid anyone who might have difficulty comprehending, your writing should be concise, straightforward, and easy to understand.

Cognitive and Neurological Disabilities

In addition to affecting mobility and language, cognitive and neurological disabilities can affect how people understand and process information. Examples of this include:

- Attention Deficit Hyperactivity Disorder
- Developmental disabilities that affect intelligence and ability to understand complex concepts
- Learning disabilities, such as dyslexia

- Memory impairments
- Mental health disorders that may affect the ability to remember to and focus
- Seizure disorders

Barriers to access

For people with these disabilities, a barrier to access is anything that causes confusion, distraction, or otherwise makes your content difficult to understand. Examples include:

- Complex navigation and page layouts
- Long passages of text without images, graphs, or other illustrations to reinforce context
- Moving, blinking, or flickering content that cannot be paused or turned off
- Background audio that cannot be turned off
- Visual page designs that cannot be adapted using custom style sheets

Removing those barriers

To make content accessible to people with cognitive and neurological disabilities, you need to present information in a clear, concise, and consistent way while minimizing possible distractions.

- Write in a way that is concise, straightforward, and easy to understand--including graphs and illustrations where beneficial.
- Structure your content so that people can orient themselves to the page and get an overview of it before moving to any one part
- Label links, page controls, and forms consistently so that the function is always apparent
- Provide different ways to navigate your site, such as a search box or site map
- Provide the option to turn off or hide blinking, flashing, or otherwise distracting content

Physical Disabilities

Physical disabilities can affect mobility, strength and endurance, and fine motor control. Examples of such disabilities include:

- Amputation or limb deformity
- Arthritis
- Reduced ability to control hand movements
- Repetitive stress injury
- Tremors and spasms
- Various forms of paralysis

Barriers to access

For people with these disabilities, a barrier to access is anything that fails to consider the difficulty users may have inputting information or otherwise interacting with your content, including:

- Parts of the page that cannot be accessed using only the keyboard

- Insufficient time limits for completing tasks, such as filling out forms
- Lack of location cues to tell people where they are on the page
- Links and other controls that are too close together or have small click targets

Removing those barriers

To make content accessible to people with physical disabilities, you need to:

- Ability to access all elements of a page using only the keyboard
- Extended (ideally no) time limits for interacting with page
- Large clickable areas
- Error identification and suggestions when filling out forms
- Visual focus indicator on all elements that receive keyboard focus
- Ability to skip over repeated items, such as navigation menus
- Design that minimizes the number of clicks needed to get to information

Speech Disabilities

Speech disabilities are those which lead to speech that is difficult to understand. Examples include:

- Issues with fluency
- Stuttering
- Muteness

Barriers to access

For people with these disabilities, a barrier to access is any interaction that requires the use of speech, including the use phone numbers as the only point of contact with your organization.

Removing those barriers

To make content accessible to people with speech disabilities, you need to:

- Provide text-based alternatives to voice interactions
- Provide keyboard commands as an alternative to voice-operated applications
- Provide email or chat options in addition to phone number as point of contact

Visual Disabilities

Visual disabilities include various levels of vision impairment from the moderate (low vision) to the severe (blindness). It also includes people who are both deaf and blind and those who live with various forms of color blindness.

Barriers to access

For people with these disabilities, a barrier to access is anything that relies on a visual component to convey information. Examples include:

- Images, controls, and other structural elements that do not have text alternatives
- Text, images, and page layouts that cannot be resized, or that lose information when resized
- Missing visual and non-visual orientation cues, page structure, and other navigational aids
- Video content that does not have text or audio alternatives, such as an audio-description track
- Inconsistent, unpredictable, and overly complex navigation mechanisms and page functions
- Text and with insufficient contrast between foreground and background color combinations
- Websites that do not support use of custom color combinations

Removing those barriers

To make content accessible to people with visual disabilities, you need to:

- Allow for the presentation of your content to be independent of its structure, i.e. content needs to be able to be presented in ways that best fit the user.
- Create headings, lists, and links that maintain their original meaning if their presentation changes, such as being taken out of context
- Provide text alternatives for all non-text content, such as images, controls, and form fields
- Allow text to be magnified without becoming cut off or obscured
- Ensure that any information that is relayed through color is also relayed through text
- Provide full keyboard access for those not able to see a pointer

Reference

Diversity of Web Users - How People with Disabilities Use the Web | Web Accessibility Initiative (WAI) | W3C (https://www.gw3.org/WAI/intro/people-use-web/diversity) DRAFT.

Digital Accessibility and the ADA

People interested in the enforcement of digital accessibility usually ask: "How do I make my [website or electronic document] ADA compliant?" "ADA" being short for the Americans with Disabilities Act.

The short answer is: you can't.

A Right to Digital Access?

The Americans with Disabilities Act is intended to "provide a clear and comprehensive national mandate for the elimination of discrimination against individuals with disabilities."[10]

To enforce this mandate there are broad anti-discrimination requirements that prohibit discrimination requirements in employment, state and local government, places of public accommodation, and telecommunications. There are **not, however, any such requirements for websites and other forms of electronic information**. When the Americans with Disabilities Act was signed into law in 1990, the Internet as we know it did not exist.

As information technology has advanced over the last 27 years, it has found its way into all areas of life, and as such is increasingly regarded as an avenue for other rights:

- the right to health care information
- the right to financial information
- the right to work
- the right to transportation
- the right to learn
- the right to vote
- the right to entertainment[11]

The timeliness, convenience, privacy, and flexibility of electronic information all reinforce the idea that there are few meaningful alternatives to such access. Failure to provide accessible digital content is increasingly seen as discrimination.[12]

The Web as a Place of Public Accommodation?

Title III of the Americans with Disabilities Act states:

> *No individual shall be discriminated against on the basis of disability in the full and equal enjoyment of the goods, services, facilities, privileges, advantages, or accommodations of any place of public accommodation by any person who owns, leases (or leases to), or operates a place of public accommodation.*[13]

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[10] Americans with Disabilities Act of 1990,AS AMENDED with ADA Amendments Act of 2008 (https://www.ada.gov/pubs/adastatute08.htm)
[11] 2016 Legal Update on Digital Accessibility Cases (http://www.3playmedia.com/resources/webinars/legal-update-09-29-2016/)
[12] An Architect of the ADA on its Application to Modern Technology (http://www.3playmedia.com/resources/webinars/architect-of-ada-10-20-2016/)
[13] Nondiscrimination on the Basis of Disability in Public Accommodations and Commercial Facilities (https://www.ada.gov/regs2010/titleIII_2010/titleIII_2010_regulations.htm)

For businesses in particular, the question of digital accessibility under the ADA hinges on one question: are electronic communications, and specifically websites, considered places of public accommodation?

A public accommodation is a business open to the public that falls under one of 12 categories listed in the ADA (https://www.ada.gov/regs2010/titleIII_2010/titleIII_2010_regulations.htm#a104), including restaurants, movie theaters, schools, recreation facilities, and doctor's offices.[14]

Historically, public accommodations have been thought of solely as physical structures. However, as far back as 1996, the Department of Justice considered public accommodations to extend to the Internet as well. In a letter to Sen. Tom Harkin, Assistant Attorney General Deval Patrick issued the follow guidance regarding electronic communications:

> *Covered entities under the ADA are required to provide effective communication, regardless of whether they generally communicate through print media, audio media, or computerized media such as the Internet. Covered entities that use the Internet for communications regarding their programs, goods, or services must be prepared to offer those communications through accessible means as well.*[15]

Although Patrick's letter makes reference to "places of public accommodation", it does not discuss whether or not a website is a place of accommodation. Among the many discrimination lawsuits (http://karlgroves.github.io/a11y-lawsuits/lawsuits.html) filed overly purportedly inaccessible websites, there has yet to be consensus on the issue. However, two lawsuits point to the changing application of the law.

Websites Connected to Physical Stores

In 2006, the National Federation of the Blind filed a lawsuit against the Target Corporation arguing that Target's website contained accessibility issues that prevented people with disabilities from fully accessing the site's goods and services. Target argued that Title III of the ADA did not apply to its website because it was not a physical accommodation. The court disagreed, denying the motion to dismiss the complaint, stating that Title III applies to "services of a place of public accommodation, not services in a place of public accommodation. To limit the ADA to discrimination in the provision of services occurring on the premises of a public accommodation would contradict the plain language of the statute."[16]

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[14] Public Accommodations and Commercial Facilities (Title III) (https://www.ada.gov/ada_title_III.htm)

[15] Patrick, Deval L. (1996, September 9). Accessibility of "web pages" on the Internet to people with visual disabilities [Letter]. https://www.justice.gov/crt/foia/file/666366/download

[16] National Federation of the Blind v. Target Corp., 452 F. Supp. 2d 946 - Dist. Court, ND California 2006 - Google Scholar (https://scholar.google.com/scholar_case?case=18339911093524957140&hl=en&as_sdt=400006&as_vis=1)

The decision strengthens the idea that websites that serve as a "nexus" to a physical store are likely to fall under the ADA: Target's website, the court found, "is heavily integrated with the brick-and-mortar stores and operates in many ways as a gateway to the stores."[17] Therefore, the inaccessible website impeded access to goods and services offered in the store.

In the resulting settlement, Target agreed to modify its website to ensure "that blind guests using screen reader software may acquire the same information and engage in the same transactions as are available to sighted guests."[18]

Website-only businesses

Beyond websites that serve as a nexus to physical stores, website-only businesses have been found to fall under Title III of the ADA. In 2012, the National Association of the Deaf filed a lawsuit against Netflix asserting that their streaming videos violated the ADA because they lacked closed captions. For its part, Netflix argued that the website was not a place of public accommodation.[19]

The Department of Justice disagreed.

Filing a statement of interest in the case, the DOJ stated outright: "Netflix is subject to [T]itle III of the ADA, even if it has no physical structure." The DOJ, it continued, "has long interpreted [T]itle III to apply to web services, and [our] ongoing regulatory developments concerning the accessibility of web content and services support that Netflix is a public accommodation subject to [T]itle III of the ADA" because it brings its service into people's homes. [20]

Part of the Department of Justice's ongoing regulatory history was an amicus brief filed in *Hooks v. OKBridge*. In 2000, an individual sued the website OKBridge for not allowing him to participate in an online bridge tournament because of a bipolar disorder. In contrast to the previously discussed cases, this was not a matter of technical barriers to access but a question of attitude toward people with disabilities: according to the suit, this individual was denied access to the website when it was discovered he had bipolar disorder. The court found that as a "private club" the defendant was exempt from the ADA and that lacking a physical space, it would not be considered a physical space anyway.[21]

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[17] *Ibid.*

[18] National Federation of the Blind v. Target Corp. Settlement Agreement (PDF) (http://dralegal.org/index.php?get_file=2012/09/settlementagreement_2.pdf)

[19] National Association of the Deaf v. Netflix (PDF) (http://digitalcommons.law.scu.edu/cgi/viewcontent.cgi?article=1092&context=historical)

[20] National Association of the Deaf v. Netflix - Statement of Interest of the United States of America in Opposition to Defendant's Motion for Judgement on the Pleadings (PDF) (https://www.ada.gov/briefs/netflix_SOI.pdf)

[21] Enforcing the ADA: A Status Report from the Department of Justice (https://www.ada.gov/aprsep00.htm#anchor507185)

On appeal, the Department of Justice had the opportunity to weigh in. First, as a business with "18,000 fee-paying members in over 90 countries" OKBridge did not qualify as a private club.[22] Second, limiting the ADA to the site of a physical structure was an "arbitrary and irrational limitation on coverage that conflicts with the clear and important purposes of the Act." The DOJ went on to say that the examples of public accommodations listed in Title III are not exhaustive and that the definition of public accommodation is "plainly broad enough to encompass establishments that provide services in their clients' homes, over the telephone, or through the internet."[23]

An Unclear Path: Enforcing Digital Accessibility Under the ADA

It would be nice if all businesses covered by its provisions agreed with the Department of Justice's interpretation for "[T]itle III to apply to web services." Unfortunately, that is not the case, and the DOJ's "ongoing regulatory developments concerning the accessibility of web content" may, in fact be holding it back.

In March of 2017, a discrimination lawsuit against Domino's Pizza was dismissed on the grounds that having an inaccessible website. Three arguments were made for the case's dismissal. First, websites are not currently covered under by Title III of the ADA. Second, until the ADA contains regulations regarding website accessibility, other modes of access--such as a 24-hour toll-free phone number--are acceptable. Third, holding Domino's accountable for an inaccessible website would violate due process because the Department of Justice has not issued any regulations regarding website accessibility.[24]

Despite its stance that digital accessibility is covered under Title III of the ADA, the Department of Justice has been slow to develop enforceable regulations to that effect.

In September 2010, the DOJ announced in an Advanced Notice of Proposed Rulemaking (ANPRM) (PDF) (http://www.ada.gov/anprm2010/factsht_web_anrpm_2010.pdf) that it would issue regulations for web accessibility under Title III of the ADA. The ANPRM acknowledge the growing role of the Internet in everyday life since the Americans with Disabilities Act was signed in 1990 and repeated the stance that the Department of Justice considers web accessibility for public accommodations to fall under Title III. It also acknowledged that a lack of clear guidance at the federal level had allowed courts to take differing opinions on the applicability of web accessibility, resulting in the absence of consistent enforcement.[25]

A request for guidance from the Department of Justice in the development of regulations seemed like a major step forward for digital accessibility--until it was allowed to languish for

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22 *Ibid*.

23 CRT | Department of Justice (https://www.justice.gov/crt/table-contents)

24 Court Dismisses Website Accessibility Case as Violating Due Process, Since DOJ Still Has Not Issued Regulations (http://www.lexology.com/library/detail.aspx?g=525bdba9-e049-4987-ba59-53e13200b105)

25 Advanced Notice of Proposed Rulemaking (ANPRM) (PDF) (http://www.ada.gov/anprm2010/factsht_web_anrpm_2010.pdf)

nearly six years. Proposed dates for the issuance of final regulations came and went, and court rulings still left the matter unresolved.

In April 2016, the DOJ did act--but not in a way observers had hoped. Instead of issuing regulations, they issued a Supplemental ANPRM (SANPRM) (PDF) (https://www.gpo.gov/fdsys/pkg/FR-2016-05-09/pdf/2016-10464.pdf) requesting further input on the scope, measurement, and possible exemptions for compliance. While these are important issues to consider, it was easy to ask: Why hadn't these things been in the original ANPRM? Why hadn't they been addressed in the ensuing five to six years?

It seemed like the Department of Justice was simply dragging its feet.

The Takeaway

While there is little indication that the DOJ will issue regulations for digital accessibility under Title III of the ADA in the near future, there are two things to take away from this process:

1. The U.S. Department of Justice does believe the digital accessibility of public accommodations is covered under Title III of the Americans with Disabilities Act.
2. Federal regulations regarding digital accessibility, when they are issued, will in all likelihood make the Web Content Accessibility Guidelines (WCAG) 2.0 (https://www.w3.org/TR/WCAG20/) Level AA the measure of compliance.[26]

Reference

The guiding reference for this section was the webinar Websites and the ADA: Accessibility in the Digital Age (https://www.accessibilityonline.org/ada-legal/archives/10351).

Digital Accessibility Guidelines

The four accessibility principles outlined in the section "What is Digital Accessibility?" are part of accessibility guidelines developed by the World Wide Web Consortium (W3C) (https://www.w3.org/), an organization that makes standards for the Internet. These guidelines, the Web Content Accessibility Guidelines (WCAG) 2.0 (https://www.w3.org/TR/WCAG20/), have been recognized and adopted by businesses, organizations, and governments around the world.

WCAG 2.0 Overview

As noted, the Web Content Accessibility Guidelines (WCAG) 2.0 are based on four principles, each of which can be divided in guidance for increasing accessibility:

[26] Supplemental ANPRM (SANPRM) (PDF) (https://www.gpo.gov/fdsys/pkg/FR-2016-05-09/pdf/2016-10464.pdf)

Perceivable

- Provide text alternatives for non-text content.
- Provide captions and other alternatives for multimedia.
- Create content that can be presented in different ways, including by assistive technologies, without losing meaning.
- Make it easier for users to see and hear content.

Operable

- Make all functionality available from a keyboard.
- Give users enough time to read and use content.
- Do not use content that causes seizures.
- Help users navigate and find content.

Understandable

- Make text readable and understandable.
- Make content appear and operate in predictable ways.
- Help users avoid and correct mistakes.

Robust

- Maximize compatibility with current and future user tools.

Meeting WCAG 2.0

WCAG 2.0 is comprised of testable success criteria that need to be met for content to be considered accessible. The point of each success criterion is a particular outcome for end users, not necessarily the use of specific techniques for implementing accessibility (although suggested techniques are provided in an accompanying document [https://www.w3.org/TR/WCAG-TECHS/]).

As you will notice, each criterion is assigned a Level A, Level AA, and Level AAA.

- **Level A** - Meeting this level would provide the minimum level of accessibility.
- **Level AA** - Meeting this level would address the most common and impactful barriers to access.
- **Level AAA** - This is the highest level of accessibility and is considered going "above and beyond" expectations. Fully meeting Level AAA can be complex and is often beyond the resources of most organizations.

The requirement adopted by most organizations and standards (including the Section 508 Refresh) is compliance with WCAG 2.0 Level AA. Beyond that, it is recommended that Level AAA success criteria are incorporated where feasible. The levels of compliance build upon each other: to meet Level AA, content must meet the success criteria under Level A **and** those under Level AA.

Success Criteria

Note: The following is only an interpretation of the WCAG 2.0 guidelines. For complete information, including exceptions, refer to the [official specification](http://www.w3.org/TR/WCAG20/) (http://www.w3.org/TR/WCAG20/).

1.1.1 Non-text Content - Level A

All non-text content that is presented to the user (e.g., images, graphs, and charts) has a text alternative that can serve as its replacement.

1.2.1 Audio-only and Video-only (Prerecorded) - Level A

- **Prerecorded Audio-only:** A descriptive transcript is provided for any audio-only content (such as a podcast).
- **Prerecorded Video-only:** Either a descriptive transcript **or** audio description is provided for any video-only content.

1.2.2 Captions (Prerecorded) - Level A

Captions are provided for all prerecorded audio in a video that contains both audio and visual content.

1.2.3 Audio Description or Media Alternative - Level A

A descriptive transcript **or** audio description of prerecorded video content is provided for a video that contains both audio and visual content.

Note: A transcript is needed to meet Level A; audio description is needed to meet Level AA, *unless* all of the information in the video track is already provided in the audio track.

1.2.4 Captions (Live) - Level AA

Captions are provided for all live audio content in a video that contains both audio and visual content.

1.2.5 Audio Description (Prerecorded) - Level AA

Audio description is provided for all prerecorded video elements in a video that contains both audio and visual content.

1.3.1 Info and Relationships - Level A

Information, structure, and relationships conveyed through presentation (i.e., visual/auditory cues) can be programmatically determined (e.g., through semantic markup, form labels, or table markup) or are available in text (as alternatives).

1.3.2 Meaningful Sequence - Level A

If the meaning of content is affected by the order in which it is read, the correct order can be recognized and displayed by various technologies, including browsers and assistive devices.

1.3.3 Sensory Characteristics - Level A

Instructions for understanding and using content do not rely solely on sensory characteristics such as shape, size, visual location, orientation, or sound.

1.4.1 Use of Color - Level A

Color is not used as the only visual means of conveying information.

1.4.2 Audio Control - Level A [Non-Interference]

If any audio on a Web page plays automatically for more than 3 seconds, the user is able to pause, stop, or adjust the volume of the audio.

Note: This criterion is labeled as Non-Interference. That is, an issue that will interfere with someone's ability to use the entire page, regardless of how other accessible technologies are implemented.

1.4.3 Contrast (Minimum) - Level AA

The visual presentation of text and images of text has a contrast ratio of at least 4.5:1 (3:1 for large text).

1.4.4 Resize text - Level AA

Text can be resized up to 200% and all content remains readable and functional.

1.4.5 Images of Text - Level AA

Wherever possible, actual text is used and not images of text.

2.1.1 Keyboard - Level A

All functionality of the content can be accessed using only a keyboard (or its equivalent).

2.1.2 No Keyboard Trap - Level A [Non-Interference]

Keyboard focus does not become stuck on any of the elements that can receive focus, requiring a mouse click or other pointer method to become unstuck.

Note: This criterion is labeled as Non-Interference. That is, an issue that will interfere with someone's ability to use the entire page, regardless of how other accessible technologies are implemented.

2.2.1 Timing Adjustable - Level A

Avoid having a time limit for interacting with content, unless such a limit is necessary.

2.2.2 Pause, Stop, Hide - Level A [Non-Interference]

For any moving, blinking or scrolling content, the user can pause, stop, or hide it unless the movement, blinking, or scrolling is essential to an activity. For any auto-updating content, the user can pause, stop, or hide it or to control the frequency of the update unless it is essential to an activity.

Note: This criterion is labeled as Non-Interference. That is, an issue that will interfere with someone's ability to use the entire page, regardless of how other accessible technologies are implemented.

2.3.1 Three Flashes or Below Threshold - Level A [Non-Interference]

Content does not contain anything that flashes more than three times in any one second period. Also, the flash only occurs on a small portion of the screen and does not involve too much of certain colors.

Note: This criterion is labeled as Non-Interference. That is, an issue that will interfere with someone's ability to use the entire page, regardless of how other accessible technologies are implemented.

2.4.1 Bypass Blocks - Level A

A mechanism (such as skip links, landmarks, or headings) is available to bypass blocks of content that are repeated on multiple Web pages.

2.4.2 Page Titled – Level A

Web pages have titles that describe their topic or purpose.

2.4.3 Focus Order - Level A

Elements that can receive focus do so in a logical order.

2.4.4 Link Purpose (In Context) - Level A

The purpose of each link can be determined from the link text alone **or from the link text and the link's context**. Examples of acceptable link context include within the same sentence, paragraph, list item, or table.

2.4.5 Multiple Ways - Level AA

Within a website there is more than one way to locate a particular page. Example ways to locate a page include:

- a list of related pages
- a table of contents
- a site map
- a site search
- a list of all available web pages
- links to all pages from the home page

2.4.6 Heading and Labels - Level AA

Headings and labels (text used to identify particular components in content, such as a form field) describe their topic or purpose.

2.4.7 Focus Visible - Level AA

For any elements that receive keyboard focus, the focus indicator is visible.

3.1.1 Language of Page - Level A

The default language of each page can be recognized and displayed by various technologies, including browsers and assistive devices.

3.1.2 Language of Parts - Level AA

The language of each passage or phrase in content that is different from the default can be recognized and displayed by various technologies, including browsers and assistive devices.

3.2.1 On Focus - Level A

When any component receives focus, it does not automatically initiate a change of context. Examples include:

- forms submitted automatically when the last field is exited
- new windows launched when a menu item receives focus
- focus is automatically changed from one component to another when the first receives focus

3.2.2 On Input - Level A

Changing the setting of any user interface component does not automatically cause a change of context unless the user has been advised of the behavior before using the component. For example, selecting an item from a drop down menu doesn't automatically cause a change; the user must click a Submit button first.

3.2.3 Consistent Navigation - Level AA

Navigational mechanisms that appear on multiple pages of a website occur in the same relative order, unless a change is initiated by the user.

3.2.4 Consistent Identification - Level AA

Components that have the same functionality within a website are identified consistently. For example:

- the same icons refer to the same functions
- references to other pages are consistent
- an icon and its adjacent text link go to same destination

3.3.1 Error Identification - Level A

If an input error is automatically detected, the error is identified and described to the user in text.

3.3.2 Labels or Instructions - Level A

Labels or instructions are provided when content requires user input.

3.3.3 Error Suggestion - Level AA

If an input error is automatically detected and suggestions to correct it are known, then the suggestions are provided to the user.

3.3.4 Error Prevention (Legal, Financial, Data) - Level AA

For webpages that cause legal commitments or financial transactions for the user to occur, that modify or delete user-controllable data in data storage systems, or that submit user test responses, at least one of the following is true:

1. Submissions are reversible.
2. Data entered by the user is checked for input errors, and the user is provided an opportunity to correct them.
3. A mechanism is available for reviewing, confirming, and correcting information before finalizing the submission.

4.1.1 Parsing - Level A

The website is coded properly, using current specifications.

4.1.2 Name, Role, Value - Level A

For all user interface components:

- name and role can be recognized and displayed by various technologies
- states, properties, and values that can be set by the user can be set by various technologies
- notification of changes to these items are available to user agents (including browsers and assistive devices)

Note: This success criterion is primarily for developers who create their own user interface components. Standard HTML controls already meet this success criterion when used correctly.

Section 508

The other major digital accessibility standard in the United States is Section 508 of the Rehabilitation Act of 1973 (https://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-section-508-standards). Section 508 requires that information and technology developed, procured, maintained, or used by federal agencies be accessible to people with disabilities. Businesses that contract with the federal government may also be subject to Section 508.

Section 508 does have standards for web accessibility; however, the Section 508 Refresh (https://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-ict-refresh) of January 2017 largely incorporates WCAG 2.0 into those standards. (Section 508 contains other provisions covering hardware and communication systems, but the provisions for electronic content--including documents and websites--reference to WCAG 2.0.)

References

How to Meet WCAG 2.0 (https://www.w3.org/WAI/WCAG20/quickref/). Copyright © 2016 W3C ® (MIT, ERCIM, Keio, Beihang)

WCAG 2.0 at a Glance | Web Accessibility Initiative (WAI) | W3C (https://www.w3.org/WAI/WCAG20/glance/). Copyright © 2016 W3C® (MIT, ERCIM, Keio, Beihang).

Getting Started with Digital Accessibility

Attempting to address all of the issues covered in the section “Digital Accessibility Guidelines” might seem like an overwhelming challenge. However, it need not be. Here are some tips and best practices to help you get started with digital accessibility.

HTML

Here are six things you can do to begin making your web content accessible

Add alternative text to every meaningful image

Add alternative text (or "alt text") to your images adds text content that can be read be screen readers and other assistive technologies. Alt text should be concise and descriptive. A good question to ask is: if I could not use this image, what text would I replace it with?

For more information, refer to WebAIM's article on alternative text (http://webaim.org/techniques/alttext/).

Structure your content with headings

Headings divide your content into manageable, well-organized sections. Visually, headings allow users to scan your content for important information and to see how pieces of that information relate to each other. Headings also allow assistive technology users to quickly navigate your information.

For more information on the use of headings, refer to WebAIM's article on semantic structure (http://webaim.org/techniques/semanticstructure/).

Add navigation landmarks to your page

Like headings, navigation landmarks (or ARIA landmarks) allow users to quickly navigate by taking them directly to a portion of your site. For example, the "navigation" landmark would take users to your navigation menu, the one for "search" would take them to your site search box, and the one for "main" would take them to the main content of the page.

Unlike headings, landmarks are typically hidden and only available to assistive technologies.

For more information on the use of navigational landmarks, refer to this article: ARIA landmarks (https://accessibility.oit.ncsu.edu/it-accessibility-at-nc-state/developers/accessibility-handbook/aria-landmarks/).

Use a custom focus indicator

Visual users should be able to see where they are on your web page as each element receives keyboard focus. The visual focus indicator varies by browser, but the default is typically a dotted outline that can be difficult to see. Use a custom focus indicator that is easier to see and that will be consistent across browsers.

For more information, refer to Deque's article on useful and usable focus indicators (https://www.deque.com/blog/give-site-focus-tips-designing-usable-focus-indicators/).

Make sure your content can be accessed using the keyboard

It can be argued that keyboard access forms the basis of web accessibility. Keyboard access not only benefits people who cannot operate a traditional pointer device, but it also forms the underlying interactions for most assistive technologies. Ensure that all links, form fields and buttons, and other interactive elements can be reached and operated using the keyboard alone.

For more information, refer to WebAIM's article on keyboard accessibility (http://webaim.org/techniques/keyboard/).

Use descriptive links

Links function like road signs in your content, telling people where to go, or where you would like them to go. Link text should describe for users where they are being taken to or the function that will be performed when clicked. "Click here" is not a descriptive link; it does not provide the user with any meaningful information.

For more information, refer to WebAIM's article on links and hypertext (http://webaim.org/techniques/hypertext/).

Microsoft Word

Follow these best practices to help ensure your documents are accessible. For more information, visit mn.gov/mint/accessibility.

Use document styles

Use paragraph and heading styles to structure the document.

Add alternative text to images and objects

This includes pictures, clip art, charts, shapes, SmartArt graphics, and embedded objects. Use clear, concise terms in your description. For example, "Person in wheelchair on ramp may suffice rather than "Smiling woman in wheelchair posing on ramp."

Use short titles in headings

Keep headings short (fewer than 20 words or one line long). This makes it easy for readers to quickly navigate your document.

Name your hyperlinks appropriately

Your link should contain meaningful text that reflects the link destination or subject, rather than simply saying "click here."

Use simple table structure

Avoid using nested tables, merged or split cells, or blank cells for formatting.

Set column header rows in tables

Clear column headings provide context and assist with navigating the table. Bookmarks are also a useful tool.

Avoid using repeated blank characters

Extra spaces, tabs, and empty paragraphs can cause people using screen readers to repeatedly hear the word "blank." Instead, use styles with formatting and indenting to create white space.

Avoid using floating objects

Place objects in line with text for easy navigation.

Avoid watermarks

Watermarks and other background images may be hidden or confusing to people with vision or cognitive disabilities. Instead of using a watermark to identify a document as a "draft" or "confidential," include the text in the document title or heading.

Fill in document properties

In advanced document properties, enter title, subject, and author.

Use the Accessibility Checker

This built-in tool will tell you about some possible accessibility issues in your document and give suggestions on how to correct them. Note that the Accessibility Checker will not find every possible accessibility issue; it is only a place to start.

Social Media

Follow these best practices to help ensure your social media content is as accessible as it can be. For more information, visit mn.gov/mint/accessibility.

Profile Tips

Don't use text in banner art images

Outside of your name, or that of your organization, assistive technologies do not recognize text in your banner photo. Only use text in text fields.

Use high resolution images

Images should be easy to see no matter how big they are viewed.

Use text colors that can be easily seen

When possible, choose good contrast between text and background. Validate your colors with contrast checkers such as WebAIM's contrast checker (http://webaim.org/resources/contrastchecker/).

Point of contact

List a point of contact on your profile to address questions.

Posting Tips

Add alternative text to images

When this is not possible, describe the image in clear, concise terms as part of the post. This includes pictures, clip art, tables, and charts.

Place hyperlinks toward the end of the post

Let people read your message before providing the link. Consider adding [PIC], [VIDEO], [AUDIO], or [PDF] before hyperlinks to help the reader know where they are going.

Put extra hashtags after hyperlinks

Hashtags can be complicated for those using assistive technology. One or two is OK in the main body; otherwise, post them at the end.

Use CamelCase for hashtags

Capitalizing the first letter in each word helps people decipher the hashtag.

Multimedia needs to be seen and heard

Any video you create or link to needs to have captioning. Podcasts must have transcripts. When writing a script, describe key visuals.

Use plain language

Clear content will engage more readers. Avoid acronyms.

Email

Follow these best practices to help ensure your emails are accessible. For more information on email accessibility, visit mn.gov/mnit/accessibility. Note that although these tips were written with Outlook in mind, the principles apply to other email clients, as well.

Use HTML format when possible

Avoid using Rich Text Format (RTF) as it may not be compatible with other email programs.

Fonts and font size are important

Choose san serif fonts of at least 12-point size for greater readability. Calibri, Arial, Helvetica, Tahoma, or Verdana are good font options.

Add alternative text to images and objects

All graphics (photos, images, charts, screen shots) require alternative text or captions. Use clear, concise terms in your descriptions.

Adding attachments

When attaching documents or other files to emails, ensure those documents are accessible. Consider using descriptive file names so users know what they are opening.

Use styles

If your email client supports it in HTML, when writing longer emails, use built-in formatting styles such as lists and headings.

Name your hyperlinks appropriately

Use meaningful text for hyperlinks. It is acceptable to display just the URL for your email address in your signature. Links should go to accessible content: linked websites and PDFs should be accessible and linked videos should have captions.

Avoid using repeated blank characters

Extra spaces, tabs, and empty paragraphs can cause people using screen readers to repeatedly hear the word "blank." Instead, use styles with formatting and indenting to create white space.

Check your color contrast

Backgrounds for emails should be white. Custom backgrounds can cause security issues and load slower on mobile devices. They also may prevent people from being able to read an image's alternative text if they do not accept the automatic downloading of images (e.g., mobile). Font styles also need good contrast.

Use plain language

Put key information up front. Use bulleted lists to segment supporting points. Write using active voice: the subject of the sentence performs the action.

Make your signature accessible

Do not use tables to format signatures. Contact information should be in real text, not a graphic. If a logo is included, ensure it has alternative text.

Digital Access Quick Check

Here are five checks you can do to quickly learn something about the accessibility of your web content. These checks *are not* meant to be part of a comprehensive testing process; rather, they may clue you in to potential barriers to access.

1. Do audio files, such as podcast episodes, come with transcripts?
2. Do videos have the option to enable captions? Do those captions reflect the content of what is spoken? (YouTube's auto-generated captions, for example, frequently contain transcription errors.)
3. If you increase the browser zoom to 200%, is all content still readable and functional?
4. Can you move through the interactive elements (links, form fields, on-page controls) on the page using the TAB key? Some form fields, such as radio buttons, require additional commands, but can you tab to each group of buttons?
5. As you are tabbing through page elements, is there a visual focus indicator that shows you where you are?

Developing an Accessibility Plan

The accessible best practices given in the section "Getting Started with Digital Accessibility" is good place to start, but if you want to make digital accessibility a part of your organization's culture, you should develop an accessibility plan. Not only will it aid you in incorporating accessibility into existing policies and procedures, but having an accessibility plan to point to could help you avoid discrimination lawsuits.

As part of an accessibility plan, your organization should:

Address all areas of your digital platform

Usable and functional web content is an important part of digital accessibility, but it is not the only part. Ensure your plan covers mobile sites and applications, electronic documents, emails, and social media presence.

Use WCAG 2.0 AA as your accessibility standard

The Web Content Accessibility Guidelines (WCAG) 2.0, have been recognized and adopted by businesses, organizations, and governments around the world. They are also the guidelines most often referenced in discrimination settlements.

Appoint an accessibility coordinator

Find someone within your organization to lead your accessibility efforts. This person should have knowledge of digital accessibility, or is willing to learn, and should continually advocate for accessibility at all levels of your organization.

Hire an independent consultant, if needed

If you don't have the expertise for determining your current levels of accessibility, find someone who does. They will be able to identify issues and help you develop a plan and approach for fixing them.

Training all staff in the creation of accessible content

Everyone who creates digital content in your organization should have a basic understanding of accessibility principles and how to implement them as best practices. Creating content free of major accessibility errors should be as common as creating content with no spelling errors.

Add accessibility to performance evaluations

Consider accessibility as just another part of your content creation processes. Don't think of it as a collection of features to be added when content is finished. Regularly reviewing accessibility efforts will make it a part of your organizational culture.

Adopt an accessibility policy

Develop an official written policy that outlines your organization's commitment to digital accessibility as well as how you plan to maintain and improve such accessibility.

Post an accessibility statement on your website

Your accessibility statement should convey your organization's commitment to delivering content in an accessible manner. It should (1) reference the accessibility standard you are working towards achieving, (2) provide information users might need to successfully access your content, and (3) provide a point of contact for accessibility concerns.

Test your content for accessibility

Regularly test your content for accessibility, and review the accessibility of new content before it is released to the public. Proper accessibility testing should rely heavily on manual review. Automated testing can give you a high-level view of issues, but it typically only finds between 25 and 40% of all accessibility issues.

Reference

Accessibility plan components taken from: March 2017 Digital Accessibility Legal Update - Law Office of Lainey Feingold

Digital Accessibility Resources

Here you will find additional information and resources for digital accessibility.

What is Digital Accessibility?

Introduction to Web Accessibility - WebAIM

An introduction to digital accessibility that provides a brief overview of how people with disabilities interact with the Web, what you need to consider before implementing accessibility in your organization, and the basic principles of accessible design.

Getting Started with Web Accessibility - W3C-WAI

Provides an introduction to the concept of digital accessibility, explores how it affects people with disabilities, and offers some basic considerations for making your website more accessible.

Considering the User Perspective - WebAIM

A summary of the barriers people with disabilities often face when they encounter common design issues. The Electronic Curb Cut (Video) - MNDHS Video produced by the Minnesota Department of Human Services highlighting how digital accessibility can benefit everyone, not just people with disabilities. Audio described version

Digital Accessibility and the Law

Federal Regulations

ADA.gov - Accessible Technology Index

The Americans with Disabilities Act (ADA) broadly protects the rights of individuals with disabilities in employment, access to State and local government services, places of public accommodation, transportation, and other important areas of American life. The Department of Justice's regulation and enforcement efforts have repeatedly emphasized that websites and other forms of electronic communication are covered under the ADA.

Section 508 - US Access Board

In 1998, Congress amended the Rehabilitation Act of 1973 to require Federal agencies to make their electronic and information technology (EIT) accessible to people with disabilities. Inaccessible technology interferes with an ability to obtain and use information quickly and easily. Section 508 was enacted to eliminate barriers in information technology, open new opportunities for people with disabilities and encourage development of technologies that will help achieve these goals.

Section508.gov

This site provides information and links to guidance, resources, tools and blog articles focusing on helping the government implement the requirements of Section 508. Using this web site, federal employees and the public can access resources for understanding and implementing the requirements of Section 508 as they apply to the development, procurement, maintenance, or use of Information and Communication Technology (ICT) products and services.

Section 504, Rehabilitation Act of 1973

Section 504 of the Rehabilitation Act of 1973 prohibits discrimination against qualified individuals with disabilities. Upon request, federal agencies are required to provide reasonable accommodations--including accessible information and communication--to people with disabilities to ensure equal access to their programs and activities.

Minnesota State Regulations

Minnesota Statute 16E.03, Subd. 9: State Information and Communications Systems

Effective July 1, 2009 or when standards become effective (which turned out to be September 1, 2010), the statute requires all state agencies to adhere to standards for accessibility developed by the State Chief Information Officer. Those standards were to incorporate both Section 508 of the Rehabilitation Act and Web Content Accessibility Guidelines (WCAG) 2.0 or to have an exception to the requirements granted by the State CIO. Refer to State of Minnesota Accessibility Standard.

Minnesota Statute 363A.42: Public Records; Accessibility

Under the Minnesota Human Rights Act:

> *Upon request by an individual, records must be made available within a reasonable time period to persons with disabilities in a manner consistent with state and federal laws prohibiting discrimination against persons with disabilities.*

Minnesota Statute 363A.43: Continuing Education; Accessibility

Under the Minnesota Human Rights Act:

> *Upon request by an individual, any continuing education or professional development course, offering, material or activity approved or administered by the state, political subdivisions of the state, the University of Minnesota or the Minnesota State Colleges and Universities, must be made available within a reasonable time period to persons with disabilities in a manner consistent with state and federal laws prohibiting discrimination against persons with disabilities....Violation of this section is subject to a penalty of $500 per violation, plus reasonable attorney fees, costs and disbursements.*

Executive Order 14-14, Providing for Increased State Employment for Individuals with Disabilities

Governor Dayton signed Executive Order 14-14, Providing for Increased State Employment for Individuals with Disabilities on August 4, 2014 tasking Minnesota Management and Budget (MMB) with developing best practices for the recruitment and retention for individuals with disabilities, The strategies developed are to ensure that state employment of individuals with disabilities reaches its goal of 7% in the next four years.

Guidelines and Standards

WCAG 2.0 Overview - W3C-WAI

The Web Content Accessibility Guidelines (WCAG) are developed through the W3C process in cooperation with individuals and organizations around the world, with a goal of proving a single shared standard for web content accessibility that meets the needs of individuals, organizations, and governments internationally.

Web Content Accessibility Guidelines (WCAG) 2.0

Web Content Accessibility Guidelines (WCAG) 2.0 covers a wide range of recommendations for making Web content more accessible. Following these guidelines will make content accessible to a wider range of people with disabilities, including blindness and low vision, deafness and hearing loss, learning disabilities, cognitive limitations, limited movement, speech disabilities, photosensitivity and combinations of these.

Guide to the Section 508 Standards - US Access Board

The purpose of this technical assistance document is to ensure successful implementation of section 508 of the Rehabilitation Act of 1973, as amended.

Section 508 Checklist - WebAIM

WebAIM's unofficial checklist of portions of the Section 508 standards.

State of Minnesota Accessibility Standard (PDF)

The goal of the Accessibility Standard is to improve the accessibility and usability of information technology products and services for all government end-users in the State of Minnesota. The standard incorporates the Web Content Accessibility Guidelines 2.0 and Section 508 of the Rehabilitation Act of 1973.

Document Accessibility

Minnesota State Accessible Document Reference Guide: Office 2013 (PDF)

The Office of Accessibility offers a reference guide for the creation of accessible Word, PowerPoint, and Excel documents. A reference guide for Office 2010 documents (PDF) is also available.

Microsoft Word Accessibility Quick Card (PDF)

A checklist of best practices to help ensure your Word documents are accessible. Use in conjunction with the Minnesota State Accessible Document Reference Guide.

Microsoft PowerPoint Accessibility Quick Card (PDF)

A checklist of best practices to help ensure your PowerPoint documents are accessible. Use in conjunction with the Minnesota State Accessible Document Reference Guide.

Microsoft Excel Accessibility Quick Card (PDF)

A checklist of best practices to help ensure your Excel documents are accessible. Use in conjunction with the Minnesota State Accessible Document Reference Guide.

PDF Accessibility Overview - Adobe

This guide details what is meant by accessibility in the PDF file format. It distinguishes between the accessibility features of the file format, of Adobe Acrobat DC and of the Adobe Acrobat Reader application, and how the features of the software and the file format interact to achieve accessibility for people with disabilities.

Acrobat Pro DC PDF Accessibility Repair Workflow

This guide provides a step-by-step method for analyzing existing PDF files and making them accessible based upon that analysis. This workflow coincides with the workflow provided in the Make Accessible Action wizard and potential issues tested for in the Accessibility Checker tool.

Acrobat Pro DC Accessible Forms and Interactive Documents

This guide describes how to use the forms tools within Adobe Acrobat Pro DC to add descriptions to form fields, tag untagged forms, set the tab order, manipulate tags and perform other PDF accessibility tasks.

Using the Accessibility Checker in Acrobat Pro DC

This guide describes the PDF accessibility checkers that are included in Adobe Acrobat Pro DC. Even if you generate an accessible PDF file from an authoring application such a word processor or desktop publishing program, you should then follow the steps in this guide in order to identify any items that may have been missed in the initial conversion, or to add PDF accessibility features that were not provided by the authoring tool.

PDF Accessibility Quick Card (PDF)

A checklist of best practices to help ensure your PDF documents created with Adobe Acrobat Pro are accessible.

Email - Office of Accessibility

Tips for creating accessible email.

Outlook 2013 & 2016: Creating Accessible Emails (PDF)

Email is an important communication tool for most of us. One of the unknown factors about email is that we never know who the final recipients of our messages may be. Therefore, we want to be sure that our emails can be read by anyone, including people with disabilities.

Website Accessibility

Tips on Designing for Web Accessibility

This page introduces some basic considerations to help you get started making your user interface design and visual design more accessible to people with disabilities. These tips are good practice to help you meet Web Content Accessibility Guidelines (WCAG) requirements.

Tips on Writing for Web Accessibility

This page introduces some basic considerations to help you get started writing web content that is more accessible to people with disabilities. These tips are good practice to help you meet Web Content Accessibility Guidelines (WCAG) requirements.

Tips on Developing for Web Accessibility

This page introduces some basic considerations to help you get started developing web content that is more accessible to people with disabilities. These tips are good practice to help you meet Web Content Accessibility Guidelines (WCAG) requirements.

HTML Accessibility - WebAIM

A collection of articles covering various elements of accessible HTML, including:

- Semantic Structure
- Links & Hypertext
- "Skip Navigation" Links
- Alternative Text
- Keyboard Accessibility
- Web Accessibility Tutorials - W3C-WAI

This collection of tutorials shows you how to develop web content that is accessible to people with disabilities, and that provides a better user experience for everyone.

How to Meet WCAG 2.0

A customizable quick reference to Web Content Accessibility Guidelines (WCAG) 2.0 requirements (success criteria) and techniques.

Techniques for WCAG 2.0

A collection of techniques--and failures--for meeting the Web Content Accessibility Guidelines 2.0. The techniques listed are only informative; they are not required to meet WCAG 2.0. For important information about techniques, refer to Understanding Techniques for WCAG Success Criteria.

Great Lakes Accessible Information Technology Initiative

The Great Lakes Accessible Information Technology (AIT) Initiative, within the Great Lakes Center, provides individuals and organizations with information and resources on Information Technology (IT) and its ease of use to the widest range of end users. They provide technical assistance, education, training, referrals, and materials to individuals and entities that seek information related to information technology accessibility.

Social Media Accessibility

Social Media - Office of Accessibility

The Office of Accessibility offers tips for effective, accessible social media use and outreach--including a social media accessibility checklist (PDF).

Federal Social Media Accessibility Toolkit Hackpad

This Toolkit is your guide to improving the accessibility of social media for public service. Created with the input of social media leaders and users across government and the private sector, this living document contains helpful tips, real-life examples and best practices to ensure that your social media content is usable and accessible to all citizens, including those with disabilities.

Multimedia Accessibility

Captions, Transcripts, and Audio Descriptions - WebAIM

An overview of the use of captions, transcripts, and audio descriptions in accessible multimedia.

Testing for Accessibility

The 6 Simplest Web Accessibility Tests Anyone Can Do A list of six accessibility checks you can perform on a webpage--without needing to know accessibility guidelines or development practices.

Easy Checks: A First Review of Web Accessibility - WAI-W3C

This page helps you start to assess the accessibility of a web page. With these simple steps, you can get an idea whether or not accessibility is addressed in even the most basic way.