Choice and Participation of Career by STEM Professionals with Sensory and Orthopedic Disabilities and the Roles of Assistive Technologies

by

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ABSTRACT

This is a qualitative study about sources of self-efficacy and roles of assistive technologies (AT) associated with the science, technology, engineering and mathematics (STEM) choice and participation of STEM professionals and graduate students with sensory and orthopedic disabilities. People with disabilities are underrepresented in STEM, which can be traced back along the STEM pipeline to early undergraduate participation in STEM. Little research exists, however, about pathways and factors associated with successful STEM participation for people with disabilities at any point along their trajectories. Eighteen STEM professionals and graduate students with sensory and orthopedic disabilities were interviewed for this study. Sources of self-efficacy were sought from interview transcripts, as were emergent themes associated with the types, uses and roles of AT. Findings suggest that people with sensory and orthopedic disabilities weigh sources of self-efficacy differently from white males without disabilities in STEM and more like other underrepresented minorities in STEM. Social persuasions were most frequently reported and in far more detail than other sources, suggesting that this source may be most impactful in the development of self-efficacy beliefs for this group. Additionally, findings indicate that AT is critical to the successful participation of people with sensory and orthopedic disabilities in STEM at all points along their STEM pathways. Barriers center around issues of access to full engagement in mainstream STEM classrooms and out of school opportunities as well as the impact of ill-informed perceptions about the capabilities of people with disabilities held by parents, teachers and college faculty who can act as gatekeepers along STEM pathways. Gaps in disability specialists' knowledge about STEM-specific assistive technologies, especially at the college level, are also problematic. The prevalence of mainstream public school attendance reported by participants indicates that classroom teachers and disability-related educators have important roles in providing access to STEM mastery experiences as well as providing positive support and high expectations for students with disabilities. STEM and disability-based networks served to provide participants with role models, out of school STEM learning experiences and important long-term social connections in STEM communities.

DEDICATION

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Woohooo!!! We did it!

And now, the greatest adventure is what lies ahead….

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INTRODUCTION

Background of the Study

According to the National Science Board (2012), STEM degrees prepare people for a wide range of career opportunities and people in STEM careers experience less unemployment than those in non-STEM careers. Today, baby boomers are retiring and vacating important positions in STEM fields. In addition, the STEM workforce in the U.S. has grown continuously over the last 50 years. It is currently growing globally and in order to compete in this global market, our nation must continue to increase its production of STEM professionals (NSB, 2012). All of these factors are important because they mean that there are opportunities for people in this country to make major positive changes in their socioeconomic status and stability within one generation. This kind of change has the potential to positively impact not only individuals, but also communities. The very people for whom I see this as an ideal opportunity are those who are underrepresented in STEM fields: women, ethnic minorities, people from low socioeconomic status and people with disabilities. The National Science Foundation's (NSF) report *Women, Minorities and Persons with Disabilities in Science and Engineering* (2013) identified individuals with disabilities as underrepresented minorities in science, technology, engineering and mathematics (STEM) education and employment. NSF has been reporting this for years, and the NSF is not alone in this recognition (Burgstahler, 1994; George & Neal, 2006; Seymour & Hunter, 1998). This dissertation research was initiated in response to the identification of this underrepresentation of people with disabilities in STEM alongside the recognition of the benefits STEM careers can have for Americans. The fundamental goal of this research is to increase our understanding of why this disparity exists and where and how it begins in order to inform targeted strategies to broaden and increase participation in STEM.

The trend of underrepresentation, over the past four decades, of people with disabilities in STEM persists even with the multitude of policies aimed to support them. The advent of the Civil Rights movement and the expansion of disabilities studies initiated a slow shift away from the deficit-oriented medical model of disabilities toward the person-centered, contextually and culturally relevant model of disabilities. While policies associated with access and opportunities for individuals with disabilities did exist before the Civil Rights movement, they slowly increased in number in the 1970s. Examples include the Rehabilitation Act (1973) and Education for All Handicapped Children Act (EHA) (1975). These Acts led to pioneering policies designed to establish equality and access to resources for people with disabilities. This marked the start of legislation prohibiting discrimination against people with disabilities who apply for federal jobs, federal contractor jobs, federal programs and programs receiving federal financial aid. Critical mandates for education included Free Appropriate Public Education (FAPE), Individualized Education Plans (IEPs) and education provided in the Least Restrictive Environment (LRE). While important, these were still early steps and their implementation proved challenging. In the 1980s, the trend continued with the Voting Accessibility for Elderly and Handicapped Act (1984), the Fair Housing Amendments Act (1988) and the Technology Related Assistance for Individuals with Disabilities Act (1988, Tech Act), among others. These Acts worked toward increasing the visibility and presence of people with disabilities in communities and were designed to support increased participation and access to resources by people with disabilities. It was not until the 1990s that the Americans with Disabilities Act (ADA) (1990) and Individuals with Disabilities Education Act (IDEA) (1990), formerly EHA, came into play, addressing major issues of rights and access to opportunities for individuals with disabilities. The shift in language in the policy names is reflective of the shift in perceptions about people with disabilities, formerly referred to as "the handicapped." The focus was oriented toward the individual person and their needs throughout their lives. In the education policy, the focus was directed away from handicapped children as a group and toward individual students with disabilities and their contexts, needs and goals. The 2000s have seen expansion and refinement of major steps taken in the 1990s with the 2008 ADA amendment and the 2004 reauthorization of IDEA and alignment with the Elementary and Secondary Education Act (ESEA) (2001), also known as No Child Left Behind (NCLB). The ADA legislation clarified and expanded the definition of disabilities and decreased barriers to declaring disabilities. Among other changes, the education reauthorization redefined Free Appropriate Public Education (FAPE) with high expectations for students with disabilities and the mandate that FAPE must prepare students for lives that include more education, jobs and independent living. Over the latter half of the 20th century and the start of the 21st century, American disability legislation has evolved from early notions of inclusion, equity and access to modern legislation designed to support people with disabilities in the pursuit of their life choices and goals including meaningful educational experiences and engagement in productive careers.

Little data or consensus exists about constraints and affordances associated with successful choice, participation and persistence. Instead, there appear to be two parallel conversations. One conversation, rooted in large-scale federally gathered quantitative data, begins and ends by identifying the participation of people with disabilities in STEM as an issue of underrepresentation. This conversation has been spurred on directly by evolving legislation and indirectly by evolving philosophies about disabilities. The other conversation has an emphasis on classroom-based innovations, accommodations, and modifications and reflects little attention to research design or data gathering. The result is a body of literature that lacks cohesion and a clear message. In addition, little data or consensus exists about constraints and affordances associated with successful choice, participation, and persistence of people with disabilities in STEM. In short, the need for a study that brings together the two parallel conversations in the literature and adds the voice of actual people with disabilities in STEM fields is well justified.

Statement of the Problem

People with disabilities comprise approximately 12% of the American population of people living outside of institutions. Their representation in undergraduate education is close to that of their national representation (NSF, 2013). In STEM careers and education, however, people with disabilities are underrepresented. Fewer than 3% of undergraduate STEM majors report having one or more disabilities, and the percentage drops even lower in STEM graduate education. In the workforce, people with disabilities holding STEM bachelors, masters and doctoral degrees comprise less than 7% of the STEM workforce (NSF, 2013). The National Academies explained that we "must invest in research, encourage innovation and grow a strong and talented science and technology workforce," in order to preserve and cultivate our leading role in the competitive global community of science and technology (NAS, 2011, p.18). People with disabilities are underrepresented in STEM and are therefore an underutilized segment of the American population. They too should be encouraged, fostered, and involved in the process of striving to meet our nation's goals for not only broadening but also increasing participation of Americans in the STEM workforce.

Purpose of the Study

The current study was intended to establish an understanding of the factors that people with disabilities in STEM fields identified were critical to their successful choice and participation in STEM. Identifying and understanding these factors will enable us to articulate the key components critical to the participation of people with physical disabilities in STEM. These understandings can then inform programs, projects and systems developed by agents of STEM education to best foster interest, engagement, choice and participation of STEM fields by people with physical disabilities.

Overview of the Study

For the purposes of this study, people with disabilities were identified by their status at the time of the study as having one or more physical disabilities according to the Americans with Disabilities Act (ADA) (1990), 28 Code of Federal Regulations (CFR) pt 3656 (1991) and the ADA Amendments (2008), outlined in Appendix A. These include visual, hearing and orthopedic impairments.

Eighteen professionals with sensory and/or orthopedic disabilities in STEM domains consented to participate in this qualitative study. Sixteen of the participants had visual impairments. Participant eligibility was assessed via a brief online survey and participants were then engaged in phone interviews. The interview protocol included questions from the Zeldin and Pajares (2000) self-efficacy study of women in mathematics-focused careers. These items were used to probe participants' perspectives on the four sources of self-efficacy (mastery experiences, vicarious experiences, social persuasion and affective/physiological) and how they influenced their STEM participation. Questions were also designed specifically for this study. They were used to gather demographic data about participants and their parents and to elicit information about participants' experiences with the assistive technologies they used to support their participation in their STEM pathways. *A priori* and emergent-theme analyses revealed critical factors that were associated with participants' choice and participation in their STEM domains.

Research Questions

Three research questions guided this study of the critical factors and roles of assistive technologies (AT) associated with the successful choice and participation of people with sensory and/or orthopedic disabilities in STEM. They included:

1. What were the characteristics of critical experiences that science, technology, engineering and mathematics (STEM) professionals and graduate students with sensory and physical disabilities identifed as integral to their participation in STEM?

2. What role(s) did these critical experiences play in the development of participants' self-efficacy beliefs about their STEM domain?

3. What was the nature of the role(s) ATs played in the STEM trajectories of these professionals and upper level students?

These questions were aimed to support the development of an understanding of the factors that STEM professionals with physical disabilities perceived were most important for engaging and persisting in their STEM trajectories. They were also intended to shed light on the practical implementation of disability legislation designed to decrease barriers for people with disabilities and support their access to education, career, and opportunities.

CHAPTER 2

LITERATURE REVIEW

Disabilities in American Policy

Defining disability.

Throughout most of the 20th century, American disabilities legislation has been dominated by a singular philosophy called the medicalisation of disabilities. Deficit models of disabilities have three elements (Pfeiffer, 2002) that cover a range of life circumstances: medical model, rehabilitation model related to employment, and special education model. In these models, humans with disabilities are identified by their deficits, establishing what is wrong with the person and how they can be fixed and made normal. Armundson (2000) makes the argument that the idea of biological normality is a biological error based on poorly conceived notion of diversity. "Diversity of function", he explains, "is a fact of biology" (Armundson, 2000, p34). This indicates that disability is merely a natural condition associated with being human and that all humans exist within a continuum of conditions. There is no definitive line separating normal and not normal. Legislation about disabilities is enacted in the form of supports and programs and stems from medical disability definitions. The medical field, a branch of biology, provides deficit-oriented definitions aligning biological form and function.

Armundson (2000) describes Christopher Boorse's Biostatistical Theory (BST) of disease as the most influential account of normality rooted in biology, because it serves as the philosophical foundation for health care ethics writers in this country. Foundational literature about health theory from this influential author (Boorse, 1977) argues that the definition of health is the absence of disease and that health is based on statistical normality of function. Disease is defined in Boorse's (1977) philosophy as the undesirable conditions that are treated by doctors. He attempts to separate generally undesirable conditions based on values (appearance, height) and universal weaknesses such as the need for sleep, food and water from true diseases. Explicit in his definition of disease is the involvement of the medical field. Existing and standard treatments of conditions largely dictate what constitutes disease. However, given the broadness of diseases and the limits of treatments, he applies the broader notion of disease as falling within medical practice (Boorse, 1977).

The process of defining disabilities as diseases, which are defined in turn as the absence of medical health and deviation from normality, creates a line between normal and abnormal characteristics. It takes a functional determinism approach to the concept of disability (Armundson, 2000). It is the culture- and context-free medicalisation of disabilities. And, with the touchstone of normality, it has served as the philosophical underpinnings of our American health care ethics writers (Armundson, 2000). This process of defining disabilities stands in stark contrast to the World Health Organization's (WHO) 2001 International Classification of Functioning, Disability and Health (ICF). In the WHO classification, disability is interpreted as a normal component of the human condition, specifically that it is a universal human experience (WHO, 2001, p.ICF Classification). This international classification is used as a framework for WHO multi-country disabilities studies and environmental factors are integrated to more thoroughly identify contextually created/moderated/removed abling/disabling elements. Rather than looking at the causes of the disabilities, the ICF looks at the consequences and the context of people living with these consequences.

Differences in federal definitions of disabilities.

The National Science Foundation (NSF) (2013) has identified Americans with disabilities as underrepresented minorities in the community of science, technology, engineering and mathematics (STEM) professionals. Federal resources include different details and distinctions in their datasets about people with disabilities. The U.S. Census Bureau (USCB) recognized three domains of disability in their 2010 Household Economic Studies including communicative, mental and physical and disabilities, which were then disaggregated by severity (severe, non-severe, no disability) (Brault, 2010). According to the USCB 2001-2006 American Community Survey (ACS), there are six categories of disabilities including sensory, physical, mental, self-care, go-outside-home, and employment (U.S. Census Bureau (USCB), 2006) and according to the ACS 2006-2010 there are six different classifications of disabilities including hearing difficulty, vision difficulty, cognitive difficulty, ambulatory difficulty, self-care difficulty and independent living difficulty (USCB, 2010). NSF's Division of Science Resource Statistics offers survey participants six options on the Survey of Earned Doctorates if they identify that they have a disability. The options are blind/visually impaired, deaf/hard of hearing, learning disabilities, physical/ orthopedic disability, vocal/speech disability, other/unspecified. American legislation broadly defines disability in three parts: (1) a physical or mental impairment that substantially limits one or more major life activities, (2) a record of such impairment, and (3) being regarded as having such an impairment (ADAA, 2008). Details of the ADA definition (1990, 2008) are provided in Appendix A. Disability, according to the Social Security Administration (SSA) (2012), is defined by one's inability to work. Data about people with disabilities is often aggregated across disabilities, which obscures the details of representation of people with various disabilities in authoritative reports.

Brault addressed the issue of the coexistence of the definitions above and many others not listed, “because of the differences in definitions, an individual may be considered to have a disability under one set of criteria but not by another,” (2010, p.1). These differing definitions lead to differing estimates of the population of people living with disabilities overall and also those living with specific kinds of disabilities. NSF’s assessments about participation in STEM fields are impactful, because their mission is to financially support all fields of fundamental science and engineering (except for medical science) (NSF, 2012). This positions NSF as a stakeholder. NSF’s definition of underrepresented minority is quantitatively derived, reflecting a comparison between of the population of a group of interest (people with disabilities) in a field (STEM) and the group’s population in the country. When representation of a group in a given field is less than their representation in the population in their country, they are considered an underrepresented minority (NSF, 2013). These population estimates are based on definitions of groups, which establish boundaries for inclusion within a given group.

Underrepresentation of people with disabilities in STEM.

According to NSF (2013), the 2010 ACS data indicates that 12% of the non-institutionalized civilian population of the U.S. has at least one of the following disabilities: hearing, vision, cognitive, ambulatory, self-care or independent living difficulty. This is consistent with the 2010 ACS data (USCB, 2010). These disabilities are not mutually exclusive, though data is not provided about the overlap of multiple disabilities. Table 1 provides an overview of disabilities (disaggregated) in our nation according to age and relative prevalence of each ACS disability category. Note that as people age, the occurrence of disabilities increases. This is easily seen in the change in percent of Americans with disabilities living outside of institutions. The group aged <5 years had an incidence of 0.8% with disabilities. The percent of people with disabilities increased to 25.4% in the 65-74 year age bracket.

As detailed in Table 2, nearly 11% of all undergraduates identify that they have one or more disabilities. Recall that approximately 12% of Americans have one or more disabilities,

Table 1
Disabilities in America by age band (USCB (2010)) as presented in NSF (2013))

	<5 – 74 yrs % total (actual)	<5 years old % total (actual)	5-17 years % total (actual)	18-34 years % total (actual)	35-64 years % total (actual)	65-74 years % total (actual)
Total Pop	100% (304,287,836)	100% (20,132,071)	100% (53,885,453)	100% (69,856,706)	100% (121,281,354)	100% (21,614,390)
W/Disab. Aggreg.	11.9% (36,169,875)	0.8% (156,038)	5.2% (2,798,597)	5.4% (3,745,876)	12.6% (15,302,550)	25.4% (5,498,041)
*Hearing difficulty	17.3% (6,298,204)	67% (104,624)	12% (338,527)	15% (551,125)	22% (3,373,235)	35% (1,930,693)
*Vision difficulty	12.6% (4,598,500)	58% (90,580)	14% (399,837)	17% (625,628)	17% (2,583,439)	16% (899,016)
*Cognit. difficulty	30.9% (11,231,896)	No data	76% (2,113,555)	61% (2,275,773)	37% (5,667,229)	21% (1,175,340)
*Ambul. difficulty	37.6% (13,669,070)	No data	12% (347,495)	26% (981,245)	58% (8,875,463)	63% (3,464,867)
*Selfcare difficulty	13.4% (4,871,802)	No data	18% (490,887)	15% (550,713)	19% (2,839,489)	18% (990,713)
*Indepen . Living	23.1% (8,401,218)	No data	No data	36% (1,367,172)	35% (5,280,886)	32% (1,753,160)

*Values reflect percent of people with disabilities compared to overall population of people with disabilities by age bracket

indicating that individuals with disabilities are well represented in undergraduate programs. The relative percentages of all STEM majors compared to all undergraduates and all STEM majors with disabilities compared to all undergraduates with disabilities are similar, 22.8% and 21.7% respectively. This portrayal of this relative data can be misleading, however. It implies that participation of individuals with disabilities in undergraduate STEM is comparable to the overall participation of people in STEM undergraduate programs. This is not the case. A calculation, reflected in the Table 2 column % Total Student Body comprised of students with disabilities, shows the percentage of students with disabilities in various STEM programs compared to the entire undergraduate student body population for the purpose of highlighting the actual state of representation of individuals with disabilities in STEM programs. This calculation reveals that only 2.3% of undergraduates are both in STEM degree programs and have one or more disabilities. This data reflects the disparity of representation of people with disabilities in STEM. While nearly 12% of the population of the nation has disabilities, only 2.3% of people in STEM undergraduate degree programs have disabilities. Data from these authoritative reports provides evidence that people with disabilities are underrepresented in STEM undergraduate education. This subset of STEM specialists with disabilities gets smaller at the graduate school level.

Table 3 includes a third calculated column of data showing the representation of individuals with disabilities in STEM graduate programs compared to all graduate students. Nearly 7.5% of all graduate students have one or more disabilities but only 1.5% of graduate students who have one or more disabilities are in STEM graduate programs. Recall that these data reflect representation of people with disabilities who comprise nearly 12% of our American population. People with disabilities are underrepresented in both overall graduate education as well as STEM graduate education. These data are partially disaggregated by STEM domain in Table 3.

Table 2
Undergraduate students with disabilities (aggregated) compared to total undergraduate student body by field (NPSAS (2008) as reported in NSF (2013))

Undergraduate Program	Total Student Body	Total Students with Disabilities (aggregated)	% Total Student Body with disabilities
All undergraduate	100% (19,667,500)	100% (2,127,700)	10.8% (2,127,700)
All STEM	22.8% (4,484,190)	21.7% (461,711)	2.3% (461,711)
Computer/ Information Science	3.6% (708,030)	3.8% (80,853)	0.41% (80,853)
Engineering	5.3% (1,042,378)	4.9% (104,257)	0.53% (104,257)
Life Sciences	5.7% (1,121,048)	5.4% (114,896)	0.58% (114,896)
Mathematics	0.5% (9834)	0.5% (10,638)	0.05% (10,638)
Physical Sciences	0.9% (17,701)	0.5% (10,638)	0.05% (10,638)
Social / behavioral sciences	6.8% (1,337,390)	6.6% (140,428)	0.71% (140,428)

Table 3
Graduate students with disabilities (aggregated) compared to the total graduate student body (based on NPSAS (2008) as reported in NSF (2013))

Graduate Program	Total Student Body	Total Students with Disabilities (aggregated)	% Total Student Body comprised of students with disabilities
All Graduate Programs	100% (3,250,000)	100% (242,857)	7.47% (242,857)
All Science and Engineering	21.4% (695,500)	20.3% (49,300)	1.5% (49,300)
Computer /Information Science, Engineering & Mathematics	9.0% (292,500)	5.0% (12,143)	.37% (12,143)
Life Sciences & Physical Sciences	5.3% (172,250)	6.4% (15,543)	.47% (15,543)
Social & behavioral sciences	7.1% (230,750)	8.9% (21,614)	0.67% (21,614)

Table 4 shows change over time from the NSF Survey of Earned Doctorates (2001-2010). At the Ph.D. level in STEM, the percent of people with disabilities earning doctorates is reduced to less than 2%, evidencing underrepresentation of people with disabilities earning STEM doctorate degrees.

Table 4
Science and Engineering (S&E) Doctorate Recipients with disabilities for select years (NSF Survey of Earned Doctorates 2001-2010 as reported in NSF, 2013)

Disability Category	S&E Doctorate Recipients 2001 Percent (actual)	S&E Doctorate Recipients 2005 Percent (actual)	S&E Doctorate Recipients 2009 Percent (actual)
All S&E Doctorate Recipients	100% (25,529)	100% (28,026)	100% (33,503)
Aggregated disabilities	1.3% (342)	1.1% (307)	1.6 % (388)
Blind/visually impaired*	11% (39)	8% (25)	5% (21)
Deaf / hard of hearing*	14% (48)	13% (40)	13% (50)
Learning disabilities*	25% (84)	29% (89)	35% (135)
Physical/orthopedic disability*	29% (99)	28% (85)	24% (93)
Vocal/speech disability*	2% (8)	5% (14)	2.6% (10)
Other / unspecified*	19% (64)	18% (54)	20% (79)

Note: The method of data gathering in 2010 differed from the method used in previous years and is therefore not included in this table.
*Values are reported as percent of S&E doctorate recipients with specific disabilities compared to those with aggregated disabilities.

Table 5 provides employment data for all scientists and engineers and those with disabilities, organized by their highest degree attainment. The trend in employment rates for scientists and engineers overall and those with disabilities are parallel. However, again the presentation of the data can be misleading, because the data, disaggregated by disabilities, is based on percentages of employed scientists and engineers with disabilities, not the percentage of total employed scientists and engineers. The top line of the With Disabilities row of data in Table 5 provides the percentage of scientists and engineers employed in this country that has disabilities.

Table 5
Employment of scientists and engineers by highest degree level and disability status: 2008 (NSF Scientists and Engineers Statistical Data System, 2008 as reported in NSF, 2013).

	Totals for STEM degree holders	Undergraduate STEM degree % All degrees (actual)	Masters STEM degree % All degrees (actual)	Doctorate STEM degree % All degrees (actual)
All	100% (4,874,000)	56% (2,720,000)	31.2% (1,519,000)	12.1% (592,000)
With disabilities	6.6% *100%* (318,000)	3.7% *56.9%* (181,000)	1.9% *28.9%* (92,000)	0.8% *12.6%* (40,000)

Note: Values in *italics* reflect the percentage of degrees awarded to individuals with disabilities under column header criteria compared to the all degrees awarded to individuals with disabilities.

These data indicate that underrepresentation of people with disabilities exists at the point when people first identify their commitment to STEM through the declaration of an undergraduate major. Then in graduate school, representation drops further. The status of representation of people with disabilities in the STEM workforce parallels this trend. Regardless of STEM degree held, people with disabilities have nearly half the representation in the STEM workforce than they do in the nation's population.

Self-Efficacy Beliefs

Overview.

Self-efficacy beliefs are those we hold about our capabilities to successfully accomplish tasks (Pajares, 2008). These beliefs are fundamental to our motivation, accomplishments and well-being (Schunk & Zimmerman, 2009). This construct of beliefs is part of the larger social cognitive theory, described by Bandura (1986). He described a system of interactions between people, their behavior and the environment are reciprocal, impacting each other and influencing how people perceive, interpret and make decisions about themselves, others and the world around them. This reciprocal relationship is modeled in Figure 1.

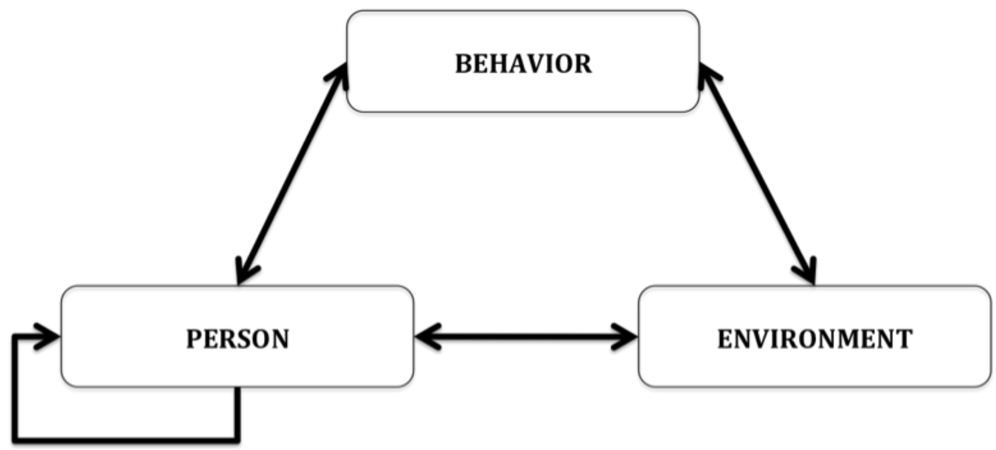

Figure 1. Triadic reciprocality based on Bandura as included in Schunk, Pintrich & Meece (2008, p)

Social cognitive theory ascribes human agency to people's behaviors and responses to the environment. This contrasted starkly with theories of human behavior common by the mid 20th century (Schunk, Pintrich & Meece, 2008). Behavioral theories explained people's motivated behaviors as responses to environmental stimuli. Social cognitive theory proposed a feedback loop between a person, their behavior and the environment in which all three elements have an ongoing and dynamic influence on the others (Schunk et al. 2008). There are three central tenets of social cognitive theory. These are that (1) interactions among people, behavior and the environment are reciprocal (triadic reciprocality, modeled above), (2) learning occurs both by doing and experiencing (enactive learning) and through observation of live models, symbolic models or print models (vicarious learning) including observation of the consequences of the modeled behaviors, and (3) learning is separate from performance. While motivation is helpful for learning it is not required, motivation is required, however, for a person to engage in performing learned actions/skills (Schunk et al., 2008). Within the greater social cognitive theoretical framework, self-beliefs vary by grain size and application. Self-concept is a broad self-belief involving ideas about self-worth and esteem, how one feels about oneself on a global level, while self-efficacy beliefs are narrow, task-specific beliefs about one's capabilities (Pajares, 2008). Within the theoretical and research literature associated with self-efficacy, there are multiple ways to view the inputs and outputs of self-efficacy. The following sections examine these different factors.

Sources and dimensions of self-efficacy.

Self-efficacy is informed by four distinct sources and it also predicts and mediates other variables. Self-efficacy beliefs are dynamic and are subject to modification as given tasks are attempted, modeled or discussed. "The more dependable the experiential sources, the greater are the changes in perceived self-efficacy" (Bandura, 1977, p 191).

Sources of self-efficacy.

Bandura (1977) identified four sources that inform our self-efficacy beliefs. Mastery experiences are first hand experiences in which a particular task or performance has been successfully completed. Vicarious experiences include observations of others successfully completing particular tasks or performances and experiencing the outcomes of success. Social persuasion is the verbal communications from others about a person's abilities associated with a particular task or performance. Physiological or affective states are emotional responses associated with engagement in particular tasks / performances. These four sources of self-efficacy beliefs are part of a feedback loop in which the beliefs influence an individual's future choices about engaging and persisting in particular tasks / performances, which then, in turn, provide more information for self-efficacy beliefs. Research examining these four sources was conducted quantitatively through surveys and questionnaires followed by path analyses and other statistical methods. Research on sources of self-efficacy was also conducted qualitatively with interviews and case studies. These different approaches yielded similar findings but varied in the nature of these findings. Quantitative studies tend to present categorical findings of sources (i.e. mastery experiences were identified, emotional arousal was not) while qualitative studies elicited participant memories and perceptions to be interpreted (i.e. all the female participants shared that their mothers were very comfortable with mathematics, though not all were in math-related careers). Figure 2 (Bandura, 1977, p.195) presents a model of inputs and outputs associated with the self-efficacy construct and details the modes of induction associated with each source of self-efficacy expectations.

The disaggregation of these induction modes (Figure 2) reveals the origins of performance accomplishments, vicarious experiences, verbal persuasion and emotional arousal. Only performance accomplishments originate within the self. Mastery experiences have been long identified as the most influential source of self- efficacy beliefs across STEM courses and disciplines (Bandura, 1977; Britner, 2008; Britner & Pajares, 2006; Hutchinson, Follman, Sumpter & Bodner, 2006; Hutchinson-Green, Follman & Bodner, 2008; Lent, Lopez & Bieschke, 1991; Lopez, Lent, Brown, 1997; Luzzo, Hasper, Bibby & Martinelli, 1999; Miura, 1987; Zeldin, Britner & Pajares, 2008; Chen & Usher, 2013).

Vicarious experiences and verbal persuasion originate with others, outside of the self, leading Bandura (1977) to argue that vicarious experiences and verbal persuasions are likely less dependable and subsequently weaker sources informing self-efficacy because they come from others rather than from the self. The self-efficacy in STEM

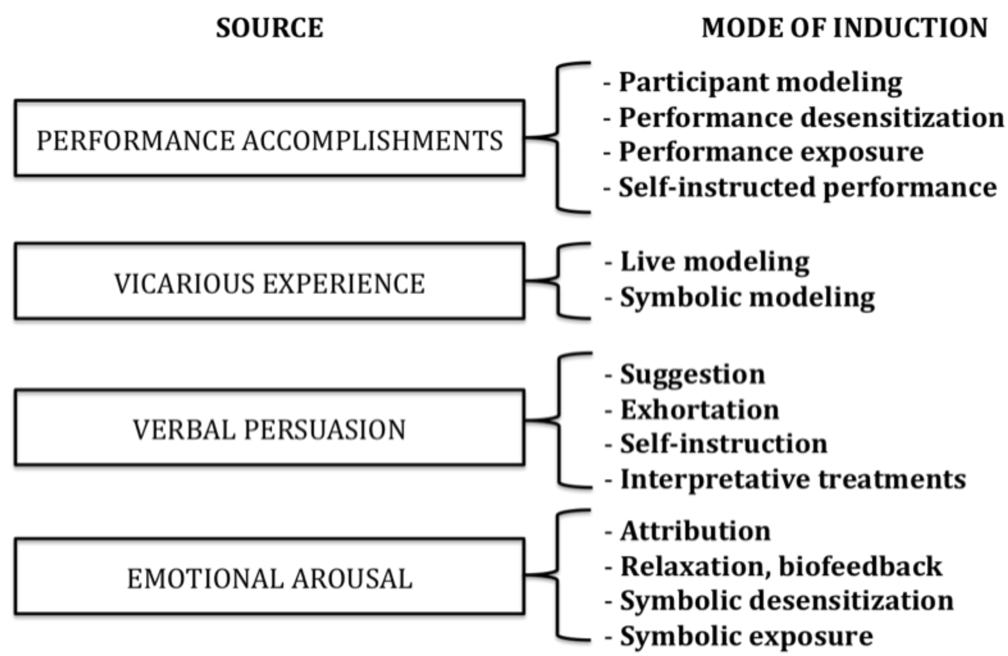

Figure 2. Efficiency expectations (Bandura, 1977, p195)

literature generally supports the dominance of first hand successful mastery experiences, however studies of women across age ranges in traditionally male-dominated STEM fields/classes find that women weigh vicarious experiences, such as role models (Hutchinson et al., 2006; Marra, Rodgery, Shen & Bogue, 2009; Nauta, Epperson & Kahn, 1998) or both vicarious experiences and social persuasions, such as verbal praise, (Lent, Lopez, Brown & Gore, 1996; Zeldin & Pajares, 2000) as the exceptionally influential or primary sources informing their self-efficacy beliefs. A study of female life science majors and female physical science / mathematics / engineering majors found that the relationship between vicarious experiences and self-efficacy beliefs was stronger for the women in traditionally male-dominated fields (Nauta et al., 1998). Social persuasion met or exceeded the importance of mastery experiences in the development of self-efficacy beliefs in math for mixed major African American college students (STEM and non-STEM) (Gainor & Lent, 1998). The same was found for STEM undergraduates with disabilities for their STEM self-efficacy beliefs (Jenson, Day, Truman & Duffy, 2011).

Bandura (1977) explains that emotional / physiological states, identified above as the fourth source of self-efficacy beliefs, result from an individual's appraisal of a situation. His early work with snake-phobias tends to orient emotional arousal associated with fear, however he also acknowledges that appraisals can be energizing and lead to motivated behavior (Bandura, 1977). Regardless of the valence of the emotions, high emotional arousal can be debilitating for performance (Bandura, 1977). Emotional arousal was identified as the strongest predictor for high school girls in a group of physical science courses and was found to contribute negatively to the girls' self-efficacy beliefs in both the physical science and life science classes. The girls in these classes were found to have math anxiety levels higher than their male peers (Britner, 2008). This fourth source of self-efficacy information is the least discussed in the literature about self-efficacy in STEM.

A recent study examined the self-efficacy beliefs of a group of middle and high school students (N=1225) (Chen & Usher, 2013). Chen and Usher (2013) found that students who relied on more than one source of self-efficacy held more positive views of all four sources of self-efficacy. They also found that these students had the greatest amount of mastery experiences, higher achievement than their peers in science and the most self-confidence in their science abilities (Chen & Usher, 2013).

Dimensions of self-efficacy.

According to Bandura (1977), performance is impacted by three dimensions of self-efficacy beliefs: magnitude, generality and strength. Tasks can have a range of difficulty, simple to highly difficult or complex. Consider the task of docking a sailboat and two people who both identify that they feel efficacious about this task. One person is a seasoned sailor and brings the sailboat to the dock under sail. She is able to finesse the craft into its goal position without knocking the boat into the dock. She gracefully steps from the vessel and, dockside, ties the lines at the cleats – success! The second person, new to sailing, pulls the sails down 10 meters from the dock and paddles the craft the remaining distance, causing the boat the smack into the dock – success! Winded but triumphant, she ties the craft off at the cleats. Both people feel efficacious about the task of docking a sailboat but their beliefs about their capabilities fall within different portions of the range of the task difficulty. This variability is referred to as the magnitude of efficacy expectations. Self-efficacy beliefs can be more or less readily generalizable depending on the nature of the task. For example, the principles of sailing can be learned through the use of a small sailing vessel like a sunfish that has only one sail. This task of sailing is relevant, in so much as there are essential skills that are necessary to learn regardless of the size of the vessel. Self-efficacy beliefs about sailing are therefore relatively generalizable. A person who has had many mastery experiences with a small sailing vessel could have efficacious beliefs about his capability for sailing a larger craft. For large vessel captains, the task of successfully navigating in and out of one's home harbor is unlike the task of navigating in and out of other harbors. Knowledge of the tides, currents, bathymetry and anthropogenic subsurface structures are required for this task. Given that the task of successfully navigating home harbors is not generalizable and that experienced captains have low efficacy expectations about navigating new harbors, pilot boats and crews work to serve their own home harbors to help foreign vessels navigate in and out.

The third dimension of efficacy expectations is strength. Efficacy expectations are influenced by four information sources: first hand experiences (mastery experiences), observations of models (vicarious experiences), verbal encouragement or discouragement (social persuasion) and arousal feelings (physiological / affective arousal states). These sources work in concert to create beliefs of one's capabilities regarding particular tasks. Consider, again, the example of sailing. For the self-efficacy dimension of strength we will consider two sailors, one from a sailing family and one from a desert ranching family. The sailor from the sailing family has been sailing since infancy. Both her mother and father sailed and were avid and supportive instructors. They owned a small flotilla of sailboats and permitted the child to sail independently from a young age, encouraging her to progress into larger and more complex crafts as her skills developed. She loved sailing. The sailor from the desert left her ranching family to attend college on the east coast. None of her immediate family had ever been on a boat. The big city left her feeling isolated and she sought out hobbies. With lessons, she eventually found solace in the sailing, which she did alone, along coastal rivers. She loved sailing. The sailors' daughter had years of formative sailing experiences with skill-appropriate vessels, accomplished and successful role models by people who provided praise and encouragement. She had a great deal of very positive experiences to inform her self-efficacy beliefs and consequently, they are likely very strong. A failure for her, such as capsizing a boat in winter waters, is not likely to turn her off of sailing. The desert ranchers' daughter did not learn to sail until her college years, she took lessons with a class but preferred to sail alone. The rancher's daughter had relatively few mastery experiences, due to the short time she had been sailing, and because she tended to sail alone, she was not experiencing as much vicarious learning from role models or encouragement and praise from others as the sailor's daughter. A failure for her, such as capsizing a boat in winter waters, may not turn her off of sailing either. But it will likely have a more powerfully negative impact on her self-efficacy beliefs about sailing than the sailor's daughter's beliefs. The rancher's daughter has relatively little information informing her beliefs, leaving her with relatively weak self-efficacy beliefs compared to the sailors' daughter. Missing information, negative information, poorly timed or frequent failure experiences can all lead to weak self-efficacy beliefs. Experiences associated with any of these information sources that serve to disconfirm weak efficacy beliefs will smother these beliefs. Strong efficacy beliefs, however, are robust to disconfirming experiences (Bandura, 1977).

Modeling self-efficacy.

The dynamic nature of self-efficacy is well illustrated by the role of failure. Failure is not technically a mastery experience or performance accomplishment, but it is still an authentic first-hand experience that will impact an individual's self-efficacy. Therefore it contributes to the feedback loop that will influence future engagement and persistence. The timing, frequency, degree of failures and the strength of efficacy beliefs, referred to as "the total pattern of experiences in which the failures occur" (p. 195), will determine the impact of failure on one's self-efficacy beliefs (Bandura, 1977). Another potential consequence of failure is the discrediting of a persuader if the encouragement raises personal competence expectations without changing conditions to support successful performance. The discrediting of the persuader removes an informant from the individual's self-efficacy information source, which is likely to further decrease self-efficacy (Bandura, 1977). Figures 3 and 4 model the development of high and low self-efficacy for particular tasks, respectively, as described by Bandura (1977). Unlike Figure 1, in which triadic reciprocality is modeled, environment is not explicitly indicated in Figures 3 and 4. Instead the environment is the implicit context of the model. Note also that self-efficacy is task-specific and can be generalized to the level of domain when tasks can be grouped by domain. For example, self-efficacy beliefs about the performance / task of sailing are constructed of self-efficacy beliefs about each task involved in the process of sailing such as tying appropriate knots and raising sails. Figures 3 and 4 models the construction of high and low task-specific self-efficacy beliefs, respectively.

Figure 3 models the relationships and direction of information within the system of self-efficacy. Pink boxes indicate sources of self-efficacy and feed into self-efficacy beliefs through pink arrows. Self-efficacy beliefs influence the person who then acts. The actions of the subject (person) are indicated by orange arrows while actions of others are indicated with green boxes and arrows. Purple arrows show pathways for establishing the information that makes up each of the four sources of self-efficacy beliefs. Purple boxes add relevant detail. Note that outcome is not the same as the triadic reciprocality environment (Figure 1). Environment is the context of the entire model. On the left side of the model in Figure 3, self-efficacy beliefs influence a person who then can choose to initiate a behavior (see the bottom half of the figure). Persistence can lead to either the target outcome, creating a mastery experience and logging emotional / physiological

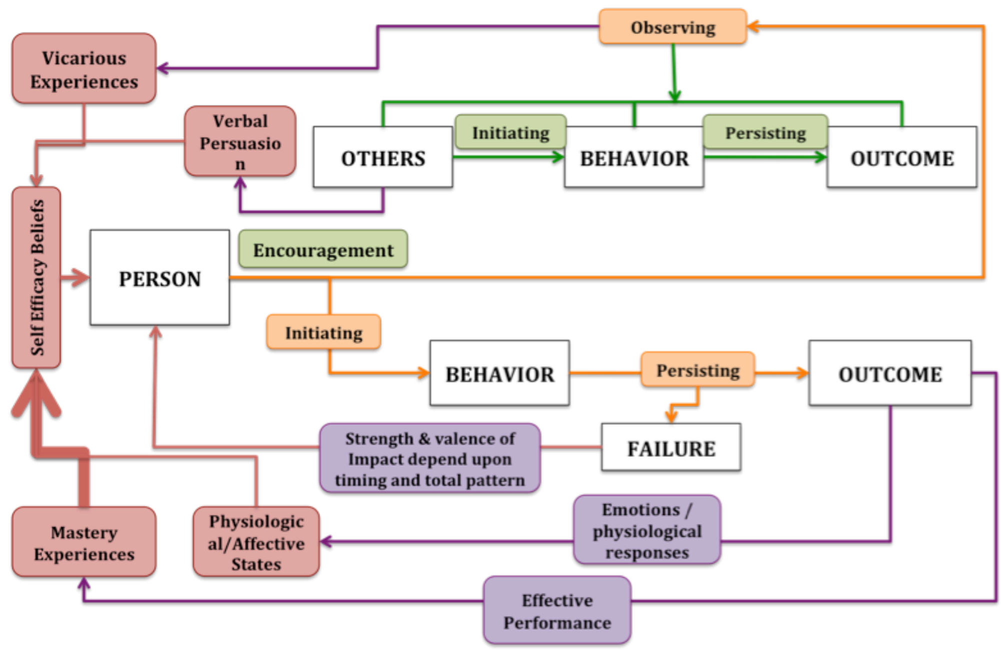

Figure 3. Development of high self-efficacy as described by Bandura (1977)

responses, or to failure. The consequences of this failure are highly dependent upon the unique with pattern of experiences associated each individual and each set of task-specific self-efficacy beliefs. Note that in the model mastery experiences have a relatively thick input arrow into self-efficacy beliefs, representing the community-held conclusion about the relative importance of mastery experiences in the development of self-efficacy beliefs. The top half of the figure models information from others, impacting the individual through vicarious experiences and verbal persuasion. The subject can have the vicarious experience of observing others initiating behavior, persisting and experiencing the outcomes associated with the behavior. The person can also experience verbal persuasion by receiving encouragement / praise from another. These two sources also inform self-efficacy.

There are many ways that this system can be interrupted or impaired. Figure 4 models a scenario in which the subject has no role models and only negative verbal persuasions associated with a given task. The color scheme for Figure 4 is nearly identical to Figure 3. Only fear has been added to the orange arrows, shifting them slightly from their Figure 3 description of subject actions. Coping is persistence (Bandura, 1977) and in this model, the subject does not continue to cope, leading to many experiences that have ended in failure and/or behavior avoidance. Note that mastery experiences, long identified in the literature as the primary source of information for self-efficacy beliefs, is still represented by a relatively thick arrow. But now, modeling the development of low self-efficacy, it is dashed, indicating that mastery experiences can still play a major role in shaping self-efficacy beliefs even when they are limited in number.

Figure 4 models an example of an individual with low self-efficacy and indicates that the subject has had few performance accomplishments to inform self-efficacy beliefs. This model shows how the weight assigned to each information source can change. In this situation, the subject's self-efficacy has been heavily influenced by the lack of vicarious experiences such as role modeling. Consequently, the idealized four sources of self-efficacy are reduced to three sources. In this model, there is only the social persuasion of discouragement, the physiological / affective states of fear and anxiety and few mastery experiences. Together, they shape low self-efficacy for a given task.

Several self-efficacy studies of students in STEM provide examples of situations in which negative or reduced avenues of self-efficacy information are associated with lowered self-efficacy. In Usher's (2009) study of male and female African American and

White middle school students with high and low self-efficacy (N=8, evenly distributed), each of the four students identified as having low mathematics self-efficacy were without

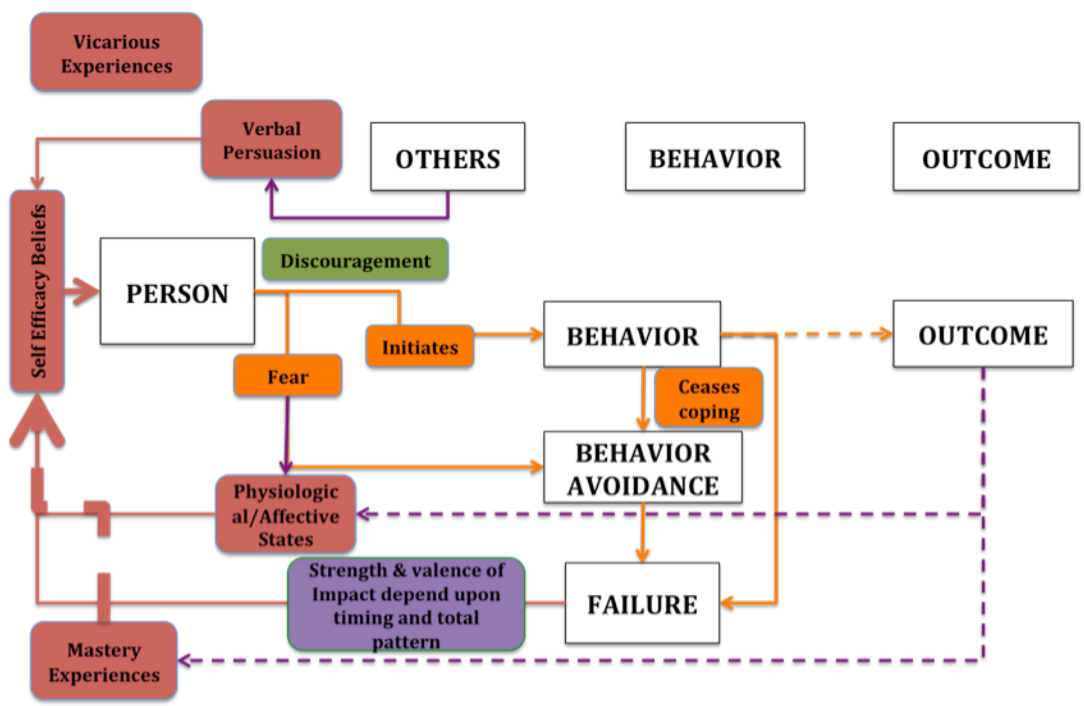

Figure 4. Model of low self-efficacy based on information from Bandura (1977)

people in their homes who could model successful mathematics skills, strategies and applications. Instead, mothers in these homes expressed dislike for mathematics and low math self-efficacy. In addition to the lack of positive role modeling, at least one of these students was told by his mother that she couldn't understand why he would bother studying for the state math exam because he was never going to pass it (Usher, 2009). This was a clear example of negative verbal persuasion. A study of the mathematics self-efficacy beliefs of Hispanic and Caucasian high school students found that Hispanic students were more dependent upon mastery experiences than Caucasians whose beliefs were informed by multiple sources (Stevens, Olivarez Lan & Tallent-Runnels, 2004). This led the authors to speculate that the Hispanic students had fewer role models and

STEM-specific social praise to contribute to their self-efficacy beliefs, leaving only prior math achievement to inform the math self-efficacy beliefs of these Hispanic students (Stevens et al., 2004). Emotional arousal was not addressed in this article. Chen and Usher (2013) classified students in their study as having At Risk profiles of science self-efficacy. This included lower achievement compared to their peers and significantly lower science self-efficacy. Compared to their classmates, Chen and Usher (2013) found that students in the At Risk category had fewer successful experiences in science as well as fewer role models in science. They had higher anxiety and stress related to science in school and they received less positive feedback about their science abilities (Chen & Usher, 2013). Consider each of these studies in the context of the self-efficacy models presented in Figures 3 and 4. The subjects have reduced and/or negative sources informing their self-efficacy beliefs in mathematics. These beliefs were constructed based on the information available to them and will, theoretically, limit the choice, persistence and future achievement of these students in mathematics (Bandura, 1977).

Self-efficacy as predictor, mediator and predicted variable.

Quantitative studies dominate the research on self-efficacy. According to Bandura (1977, 1982), self-efficacy may not only be the major predictor of future performance, but it also appears to be the central mediator of prior experience and performance (Hackett & Betz, 1989). Quantitative studies have found self-efficacy to predict academic achievement across STEM disciplines, sex, ethnicity, age and school year (Andrew, 1998; Britner, 2008; Britner & Pajares, 2001; Britner & Pajares, 2006; Hackett et al., 1992; Jones et al., 2010; Lent et al, 1986; Pajares & Graham, 1999; Stevens et al., 2004; Zusho, Pintrich & Coppola, 2003). Self-efficacy has been shown to predict choice of science/math career interests for high school students (O'Brien et al., 1999), perceived career options in a range of technical / scientific fields for students interested in science and engineering majors (Lent et al., 1986), and choice of math-related college majors for students in introductory-level psychology courses (Betz & Hackett, 1983; Hackett, 1985; Hackett & Betz, 1989). Self-efficacy predicted math-related interest of black college students (Gainor & Lent, 1998), high learning goal orientation of male biology majors (Cavallo et al., 2004) and persistence of college students interested in science and engineering majors (Lent et al., 1986). Lastly, self-efficacy predicted changes in the motivational orientation of middle school students (Stevens, et al., 2004).

Self-efficacy served as a mediator of between interest and prior performance of white college students (Lent et al., 1991) and of interest and effect of ability / achievement for black college students (Gainor & Lent, 1998). Self-efficacy has been shown to mediate the effects of gender and prior experiences on math concepts, perceived usefulness of math and math performance for undergraduates education majors (Pajares & Miller, 1994) and it also mediates performance engagement on prior experience (Ponton et al., 2001Information sources identified by Bandura (1977) (e.g. mastery experience, vicarious experiences, verbal persuasion and physiological / affective states) have been found to predict self-efficacy, as he proposed. Self-efficacy was predicted by mastery experiences for middle school science students (Britner & Pajares, 2001) and white male high school students in life, physical and Earth science classes (Britner, 2008). It was also predicted by specific mastery experiences including level of math achievement for introductory-level undergraduates (Hackett, 1985) and high school math students (O'Brien et al., 1999). In addition, self-efficacy was predicted by the completion of high school computer programming course, college major and past enrollment in computer science classes (Miura, 1987). For white high school females in physical science courses, physiological / affective arousal states predicted self-efficacy (Britner, 2008). Belief in a fixed view of science abilities held by high school and middle school students predicted lower science self-efficacy and less access to science self-efficacy building information (Chen & Usher, 2013). Sociocultural factors also predicted self- efficacy including ethnicity of middle (Hackett et al., 1992) and high school science students (O'Brien et al., 1999) and marital status of engineering students (Santiago & Einarson, 1998). The grouping of self-efficacy as predictor and mediator and the identification of predictors of self-efficacy allow for the assembly of a model of self-efficacy as it is described in the literature. The sections identified in Figure 5 reflect two major foci within the research literature on self-efficacy in STEM. Quantitative research is heavily represented on the right side of this model. There, self-efficacy is investigated as a variable. Most of the research literature on self-efficacy in STEM has focused on the right side of this model. The left side of the model represents sources of self-efficacy. This is measured both quantitatively and qualitatively.

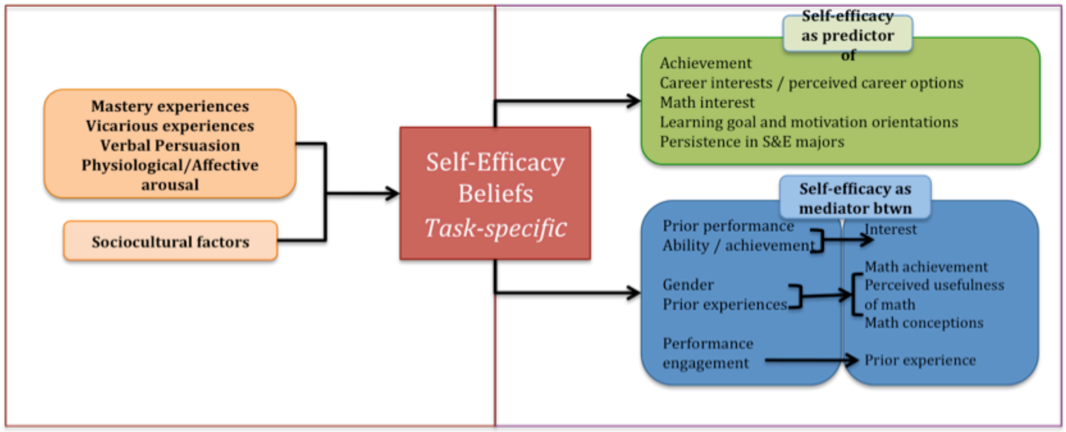

Figure 5: Self-efficacy as it is described in the research literature

Research on self-efficacy sources and STEM.

Self-efficacy beliefs are specific to tasks and can be investigated in terms of groups of tasks that can relate to broader domains such as STEM. Information that comes to people through mastery experiences, social persuasion, vicarious experiences and physiological / affective states act as sources in the development of self-efficacy beliefs. Studies about differences in the development of STEM self-efficacy beliefs for males and females were the first to address issues of underrepresentation of minorities in STEM. Research focused on differences between STEM self-efficacy development for white males and ethnic minorities started more recently and are, therefore, less numerous than studies of sex-based differences in self-efficacy. Most recently, people with disabilities have come under study for investigations about the development of self-efficacy beliefs of underrepresented minorities in STEM.

Mastery experiences.

Bandura (1977) theorized that mastery experiences have the greatest impact on the development of self-efficacy beliefs. Research indicates that this is true but exposure to these impactful experiences can vary. Studies suggest that mastery experiences are particularly impactful for the development of STEM self-efficacy beliefs in males. In a study of high school students in life, physical and Earth sciences, mastery experiences were the only significant predictor of self-efficacy for males across disciplines (Britner, 2008). Sawtelle, Brewe and Kramer (2012) found that success of males in introductory physics courses could be predicted by mastery experiences alone. Zeldin et al. (2008) found that male STEM professionals identified mastery experiences as the most influential information source for their self-efficacy beliefs.

Mastery experiences are theorized to be impactful for all. A study of math-related interest for high school students yielded a path analysis indicating that mastery experiences were the largest path coefficient to self-efficacy for males and females (Lopez et al., 1997). Chen and Usher (2013) found that secondary school students with the greatest amount of science mastery experiences reported the highest science self-efficacy and those with the fewest science mastery experiences reported the lowest self-efficacy. Male and female STEM majors reported mastery experiences as significant contributors to their self-efficacy beliefs (Marra et al., 2009). STEM majors with disabilities reported that the mastery experience of success in their STEM courses contributed to their sense of self-efficacy in college (Jenson et al., 2011). The subjects in the Jenson et al. (2011) study also reported that student support offices, family, friends, classmates, peers and, most importantly, instructors contributed to the success of their mastery experiences.

Access to STEM mastery experiences can vary. Females in college were consistently found to have lower self-efficacy beliefs than males for STEM-related topics. This finding was related to participation in fewer college courses for females (Betz & Hackett, 1983) and greater exposure to mastery experiences in the form of STEM preparation / courses in high school for males (Hackett, 1985; Hackett & Betz, 1989; Lapan et al., 1996; Lent et al., 1991; Muira, 1987). Researchers examined the association of sociocultural factors association with the socialization of men and women and the impact on mastery experiences, concluding that women likely have less access to this critical information for the development of self-efficacy beliefs (Hackett, 1985; Hackett & Betz, 1989; Lent et al., 1991; Miura, 1987). With fewer culturally acceptable opportunities to gain mastery experiences, women had less information and less opportunity to develop robust self-efficacy beliefs, which was related to achievement, anxiety and choice of majors (Lent et al., 1991). The differences in mastery experiences for men and women reflecting different socialization practices aligned with Bandura's (1977) seminal work that identified mastery experiences as the most authentic and influential source of self-efficacy information for people.

Lack of information potentially impacts Hispanic students in STEM as well. A quantitative study of Hispanic and Caucasian high school students revealed a greater influence of mastery experiences on the construction of mathematics self-efficacy beliefs for Hispanic students than for Caucasian students (Stevens et al., 2004). Authors speculated Caucasian students were likely better networked within a community of higher STEM literacy and experience than Hispanic students. The lack of role models and verbal praise in Hispanic students' home communities left them to develop self-efficacy beliefs with much less information Stevens et al., 2004).

Social persuasion.

Studies indicate that social persuasion is crucial in the development of self-efficacy beliefs for women, ethnic minorities and people with disabilities. Social persuasion was identified as a critical source of math self-efficacy beliefs for African American students at the middle school level (Usher, 2009) and for African American non-math majors at the college level (Gainor & Lent). Usher (2009) conducted a qualitative study of African American and Caucasian, male and female middle school students with high and low self-efficacy. Usher (2009) identified a distinct difference in the quality of social persuasion being employed by teachers and parents of African American students than the kinds of social persuasion communicated to non-African American students. Teachers and parents of African American students focused on the importance of the students being more vigilant about effort than everyone around them, working extra hard and needing to prove their worth and right to achieve to the world. "In other words, the positive social persuasions operating at a local level may have served to immunize African American students against some of the negative messages they received from the broader culture." (Usher, 2009, p. 300).

According to Britner (2008), social persuasion was more important than mastery experiences for the development of self-efficacy beliefs for women in college life and physical science courses. In a study of the math self-efficacy of undergraduates considering science and engineering fields, Lent et al. (1996) found that social persuasion was more important to females than to males in the same context. While mastery experiences were identified as major factors in the development of self-efficacy beliefs about STEM classes, women in STEM majors also identified social persuasion as impactful while men in STEM majors did not (Hutchinson-Green et al., 2008). A year-long study of female engineering undergraduates by Marra et al. (2009) measured significant gains in coping self-efficacy and engineering self-efficacy alongside significant declines in feelings of inclusion. These declines were expressed most strongly by African American females and least strongly by Asian American females (Marra et al., 2009). A study comparing first year male and female engineering students in a semester-long engineering seminar suggested that they differed in the sources of information they used to inform their self-efficacy beliefs (Hutchinson-Green et al., 2008). As the semester progressed and students were presented with increasingly novel situations that built less and less on their high school mastery experiences Both males and females reported that their self-efficacy beliefs were based on social comparisons. Hutchinson-Green et al. (2008) found that males expressed that their beliefs were shaped by their desire to outcompete their peers. Women, however, reported lower self-efficacy and beliefs shaped by negatively perceived peer comparisons (Hutchinson-Green et al. 2008). A study by Hackett et al. (1992) indicated that both Mexican and American white male engineering students were more encouraged by program faculty than females. Here, the implication is that social persuasion is important to the STEM self-efficacy beliefs of all people.

STEM majors with disabilities acknowledged family, peers and instructors as sources of social persuasion (Jenson et al., 2011). However, encouragement from instructors was weighted more heavily than that from family or peers because they offered less STEM-specific encouragement and more general support (Jenson et al. (2011). Students also consistently expressed that classroom instructors had the greatest impact on successful experiences in classes. They explained that peers seemed uncomfortable providing feedback, thereby limiting students' self-efficacy building information (Jenson et al., 2011). The Jenson et al. (2011) study found that there was consensus regarding the role of self in social persuasion. The authors identified this concept as novel, but it is similar to the concept mentioned in Bandura's (1977) seminal self-efficacy work described as self-instruction and also in Hutchinson et al. (2006) as drive and motivation. The students with disabilities in the Jenson et al. (2011) study identified themselves as major sources of self-efficacy. They explained that their personal beliefs in themselves were what kept them going on a daily basis. The persistence fostered by the self-beliefs of the Jenson et al. (2011) participants is reminiscent of the immunizing social persuasions provided to African American students by parents and teachers (Usher, 2009; Jenson et al., 2011).

Zeldin and Pajares (2000) found that female STEM professionals identified social persuasion as vital building blocks of their self-efficacy beliefs. Researchers suggested that women in male dominated STEM fields might weight social persuasion more heavily than women in traditionally female-dominated fields (Zeldin & Pajares, 2000).

Vicarious experiences.

Studies of STEM self-efficacy sources indicate that vicarious experiences are of high importance to the development of self-efficacy beliefs for women and possibly for people with disabilities. Many of these studies also indicate that vicarious experiences were not identified as important to males without disabilities. The Britner (2008) study revealed that vicarious learning outweighed mastery experiences in the development of self-efficacy beliefs for females in life and physical science college courses. Sawtelle, Brewe and Kramer (2012) conducted a study that explored the relationship between retention in introductory physics classes and self-efficacy. They found that vicarious learning predicted success in the introductory physics class for females (Sawtelle, Breye & Kramer, 2012). Lent et al. (1996) found that female undergraduates considering science and engineering fields reported that vicarious experiences were important to their mathematics self-efficacy while males did not.

Vicarious experiences such as classroom-based teaming practices were important to first year female engineering students (Hutchinson et al., 2006) and STEM majors with disabilities (Jenson et al., 2011). The sample of students with disabilities from the Jenson et al. (2011) study, however, balanced this appreciation of teaming with apprehension. These STEM majors with disabilities expressed concerns about having their abilities questioned by other students, especially in laboratory settings (Jenson et al., 2011). Participants in the Jenson et al. (2011) study also made a distinction between peers and classmates. Peers included other students in class with disabilities but classmates were other students in class without disabilities (Jenson et al., 2011). This distinction between peers and classmates has implications for understanding subcategories within sources of self-efficacy. Like the role of the self in social persuasion, the distinction between peers and classmates is another glimpse at the nuanced complexities that may exist for subcategories within sources of self-efficacy. The Jenson et al. (2011) sample was divided about the value of having peers with disabilities in classrooms. Some students indicated that seeing peers with disabilities experience success was a powerfully positive motivator. Others explained that they had to stay focused on their own achievement and performance and not allow the struggles or successes of other students to impact them.

Some students also expressed concerns about being lumped together with other students with disabilities and not being seen as individuals (Jenson et al., 2011).

Marra et al. (2009) found that female engineering majors reported that, in addition to mastery experiences, vicarious experiences were important contributors to their self-efficacy beliefs about their STEM classes. Male STEM majors who took part in the same study indicated only mastery experiences were important to their self-efficacy beliefs about their STEM classes (Marra et al., 2009). Marra et al. (2009) also found that vicarious experiences through role modeling impacted female engineering students across ethnicities similarly.

Vicarious experiences may be more impactful for women in fields traditionally dominated by men. Nauta et al. (1998) found that females in science, engineering and math majors ranked role modeling high in their overall career trajectories. This role modeling both reduced role conflict about cultural expectations for motherhood, marriage and career aspirations and also provided positive models of success (Nauta et al., 1998). Influences on self-efficacy beliefs including STEM-abilities and positivity of role model-influences were found to be more significant for women in the physical science, math and engineering majors than for women in life science programs (Nauta et al., 1998). Authors concluded that there are differences in the construction of women's self-efficacy beliefs that are shaped by representation of females in their chosen fields (Nauta et al., 1998). In their study of women in math-related STEM professions, Zeldin and Pajares (2000) had similar findings about females. Women in their study identified vicarious experiences as vital to the development of self-efficacy beliefs related to their math-related careers (Zeldin & Pajares, 2000). Researchers suggested that women in male dominated STEM fields might weight these vicarious experiences (e.g. role modeling) and social persuasion (e.g. verbal feedback) more heavily than women in traditionally female-dominated fields (Zeldin & Pajares, 2000).

Physiological / affective states.

Few studies have examined the role of physiological states in the development of self-efficacy beliefs. A study of science self-efficacy beliefs resulted in findings supporting Bandura's (1977) assertion that physiological states becomes stronger when people have few information sources of self-efficacy to draw from (Chen & Usher, 2013). Findings from the Chen and Usher (2013) study indicated that secondary students with little access to competent role models, little positive feedback about their science performances and few science mastery experiences exhibited anxiety and depressive moods in relation to science. Conversely, they also found that students who attended to multiple sources of self-efficacy and had many science mastery experiences exhibited little negative affective arousal (Chen & Usher, 2013). Physiological states were important self-efficacy sources for females in life and physical sciences courses but not for males (Britner, 2008). Finally, in the Jenson et al. (2011) study, there was inconsistency about the role physiological states played in self-efficacy beliefs. Some people experienced debilitating anxiety while others felt energized and focused (Jenson et al., 2011).

Conclusions about self-efficacy, STEM and underrepresented minorities.

The research on self-efficacy identifies it as a critical factor in the success of people in STEM courses, programs and careers. Specifically, self-efficacy predicts achievement, career interest and persistence in STEM for people across ethnicities, sex and age. The limited literature about individuals with disabilities in STEM indicates that self-efficacy may also predict these same variables.

Findings about sources that inform self-efficacy beliefs for majorities and minorities in STEM have different implications. STEM minorities seem to weigh sources of self-efficacy in ways that are different from people who are not underrepresented in STEM. Additionally, the quality of self-efficacy source information may also differ between majorities and minorities. Data sufficient to make clear distinctions between the sources of self-efficacy beliefs for people in general and people with sensory and orthopedic disabilities does not yet exist. However, the self-efficacy sources research on STEM minorities suggests that further study of individuals with disabilities in STEM has the potential to illuminate unique differences for the underrepresented minority group of people with sensory and orthopedic disabilities.

People with Disabilities in STEM: Barriers and Supports

In the following section, the technical, physical, social and psychological barriers and supports for people with sensory and orthopedic disabilities in STEM fields is reviewed. There were very few studies available to inform this section that met the question criteria of people with sensory and orthopedic disabilities who have been successful in STEM. Much of the research discussed in this section includes data about people with disabilities that is aggregated, meaning that research about people with disabilities in STEM was focused on groups of people with all kinds of disabilities including learning, hearing, vision, mobility, psychological and other disabilities. The aggregated nature of the samples limited the power of researchers to develop robust conclusions about barriers and supports for individuals with sensory and orthopedic disabilities only. Assistive technologies are addressed in this final section of the literature review and are therefore not explored within the discussion of barriers and supports.

Barriers.

Technical barriers.

Technical barriers are, by far the most prohibitive of all the barriers described in this section because they include logistics, curriculum, faculty, funding and resources. Stefanich, Norman & Egelston-Dodd (1996) conducted a study of K-12 secondary science specialists and science educators at the college level. They concluded that students with disabilities (SWD) can expect to be mainstreamed in science where they will have instructors with no training or experience with students with disabilities and who have unsubstantiated concerns about lab safety and lowered expectations for student achievement (Stefanich, Norman & Egelston-Dodd, 1996). Students with disabilities should also expect to have no advocate for discipline-specific accommodations to support their learning. If they are not mainstreamed, their science instruction will be provided by a teacher with little to no scientific training (Stefanich, Norman & Egelston-Dodd, 1996).

There is a consistent message in the literature about the prevalence of insufficient preparation for science teachers to support the learning of students with disabilities (Abner and Lahm, 2002; Alston & Hampton, 2000; Stefanich et al., 1996). Based on self-report, teachers of science and science educators have little to no experience or training in working with SWD and are subsequently not knowledgeable about best practices for accommodations / modifications or adaptations for facilities, equipment and safety (Stefanich et al., 1996). Stefanich et al. (1996) found that educators had outdated and stereotypical beliefs about what SWD can and cannot do in science classes. They were also found to lack knowledge of relationships between physical / health impairments and student learning in science or resources and agencies that can provide information / assistance for meeting the needs of this student population (Stefanich et al., 1996). Futhermore, science educators at the college level believed that science classroom accommodations /modifications were the responsibility of special educators, not classroom science teachers. The Abner and Lahm (2002) study of teachers of blind/low vision (BLV) students revealed that while teachers have access to computers and use them, they lack adequate training in technology education and do not feel competent enough to teach their students about them. Consequently only half of their students were exposed to technology in the classroom. This leads to the significant under preparation of BLV high school graduates in basic technical literacy as defined by the International Society for Technology in Education (ISTE) technology standards (Abner & Lahm, 2002). Alston and Hampton (2000) implemented a study of parent and teacher perspectives about how effectively their schools could prepare students with disabilities for entering careers in science and engineering (S&E). Data was collected by surveys completed by parents and teachers of children with sensory and orthopedic disabilities affiliated with the schools under study. Alston and Hampton (2000) found that parents and teachers agreed that teachers did not possess the skills or knowledge to adequately meet the learning needs or understand the potential of their students in S&E.

Findings associated with college STEM faculty also present technical barriers in STEM education. The Seymour and Hunter (1998) study of STEM majors with disabilities found that some STEM faculty constructed barriers by restricting student access to accommodations through failing to provide assessments to Disability Services for approved alternative testing. STEM faculty members were also reported to have verbally expressed skepticism about the participation of their STEM majors with disabilities and had made attempts to discredit the need for accommodations (Seymour & Hunter, 1998). Seymour and Hunter (1998) also found that there were incidents of STEM faculty reducing credit for work completed under accommodations and outright refusal to uphold accommodations under the justification that they were simply preparing students for life after college.

For STEM majors with disabilities, financial aid, the logistics associated with managing disabilities and time all served as major technical barriers Seymour and Hunter (1998) found that financial aid for college attendance hinges upon carrying a full course load, which can be extremely challenging for SWD. Some students with disabilities have disability-related regimes that limit opportunities to attend classes and can become fatigued through the exertion of attending classes. There are also those who must deal with time restrictions and demands associated with public transportation. These disability-related issues end up dictating course selection, which can interfere with STEM programs of study and lead to dropped, failed and incomplete courses (Seymour & Hunter, 1998). Accommodations and supports provide access for students but they also can serve as major impediments. Assistive technologies require maintenance, batteries need charging (wheel chairs, classroom electronics), new editions of textbooks may not be translated into Braille or into audio form in time for class and interpreters may not be available for spur of the moment meetings with professors (Seymour & Hunter, 1998). Seymour and Hunter (1998) use the expression "time disadvantaged" to describe all SWD in STEM majors. Time issues are affiliated with all aspects of SWD attending college regardless of disability and this sets them apart from STEM majors without disabilities.

Hitchcock and Stahl (2003) described the technical barriers associated with the transition from classroom resources that are paper-based to those that are digital. Resources are becoming increasingly prohibitive for SWD in this transition and third parties must be contracted to make these resources accessible to students with a broad spectrum of abilities. This system of outsourcing accessibility has no financial incentive to change and creates issues of time-delayed resources and cost dilemmas for schools with diverse student needs (Hitchcock & Stahl, 2003). Hitchcock and Stahl (2003) identified that increasing reliance on digital science resources creates obstacles for classroom teachers who must cope with formats and platforms that are not necessarily compatible with students' assistive technologies (AT). There are also other issues associated with the use of AT in schools. These included a lack of funding and layers of bureaucracy associated with AT purchases, insufficient knowledge and subsequently poor AT purchase decisions. Furthermore there is inadequate teacher training to support classroom AT use, a dearth of trained AT specialists to evaluate technologies and match them to domain-specific student needs and lack of continuity between K-12 and college access to technologies (Burgstahler Comden. Lee, Arnold & Brown 2011).

Physical barriers.

Physical barriers confront people with disabilities in STEM fields in many ways. College campuses provide unique challenges to access for students with disabilities. Students with sensory and orthopedic disabilities reported issues of access and excessive time demands associated with inaccessible/ crowded labs and classrooms, dexterity-intensive lab equipment, locked elevators and long distances across campuses between classes (Burgstahler, 2005; Seymour & Hunter, 1998). With increasing dependence on the Internet in STEM education, barriers to accessible education are exacerbated through the heavy reliance on computers. For students with sensory and/or orthopedic disabilities all facets of computers can prove challenging, ranging from the hardware of the keyboard and mouse to the computer's operating system, the web browser and the web-based resources that are being accessed for education (Burgstahler, 2005; Hitchcock & Stahl, 2003).

While not limited to STEM classes, the classroom can create significant obstacles to student learning. Students with sensory / orthopedic disabilities can struggle with sitting for long periods of time and seeing the board clearly (Seymour & Hunter, 1998). For hard of hearing students, the acoustics of the classroom as well as the accent/delivery style of faculty can pose major challenges and for deaf/hard of hearing students who lip read, eye fatigue sets in after long periods in the classroom (Seymour & Hunter, 1998).

Social barriers.

The literature addressing social barriers to success in STEM for people with disabilities is limited to STEM education. Social barriers are described in the literature across academic levels and address many aspects of student academic interactions including friends, other students, faculty and parents. Stefanich et al.'s (1996) study of teachers of science and science educators found that science teachers are not aware of opportunities for students with similar disabilities to network or opportunities for students with disabilities to network with practitioners and professionals in science fields. Alston and Hampton (2000) report that parents and teachers of children with disabilities believed that these students lack exposure to role models of people with disabilities in science and engineering. They felt that the lack of representation of people with disabilities in workplaces and in science and engineering classes is a negative influence (Alston and Hampton 2000). This study also found that parents and teachers agreed that career guidance counselors were counseling students out of STEM pathways (Alston & Hampton, 2000).

College can pose social challenges for many students and even greater challenges for students with disabilities. Burgstahler (2005) identified that bridging efforts to support students as they make the move from high school to college are inadequate. Once there, students with disabilities are not necessarily encouraged in their STEM classes. Seymour and Hunter (1998) found that students with disabilities were encouraged by STEM faculty to drop their STEM classes and change their STEM majors. STEM faculty further constructed social barriers by embarrassing students by publically discussing students' disabilities and their accommodations and insisting on knowing details about students' disabilities (Seymour & Hunter, 1998).

Psychological barriers.

Burgstahler (2005) found that teachers, counselors, social service agents and faculty lacked knowledge about the big picture of STEM education. She found that they communicated low expectations and little encouragement, limiting students' abilities to reach their full potential in difficult STEM fields (Burgstahler, 2005). In the Seymour and Hunter (1998) study of STEM majors with disabilities, they found that students experienced ongoing stress from needing to be pushy with their STEM instructors in order to have accommodations honored. Students felt that some STEM instructors exercised judgment about the genuineness of their disabilities. Instructors expressed skepticism about those they deemed not genuine (Seymour & Hunter, 1998). Students made the distinction between academic rigors and those they felt STEM professors imposed as fitness tests for participation in STEM academics and fields (Seymour & Hunter, 1998).

Supports.

Technical supports.

Technical supports for people with sensory and orthopedic disabilities in STEM come in many forms. These technical supports can be found throughout the education system and can be leveraged to foster change. An AT study of STEM professionals with disabilities provides a clear example of the role parents can play in supporting students with disabilities in STEM fields (Burgstahler et al, 2011). An AT specialist with cerebral palsy who uses a wheelchair for mobility and speech output device for speaking reported that he was in K-12 at a time when inclusion was being implemented and AT were being introduced (Burgstahler et al., 2011). He explained that his parents, teachers and rehabilitation specialists were excited about investigating new technology options and he was provided with an Apple IIe at school. His parents, seeing his success with the computer at school, bought him one for home to use for games and schoolwork. Having the computer in the home increased his parents' involvement, allowed him to excel in using the support and it contributed to his educational progress and hand therapy work (Burgstahler et al., 2011). Educators can be receptive to receiving additional training to better support the learning of their students with disabilities while others can be neutral (Alston & Hampton, 2000); Stefanich et al., 1996). Curriculum and school opportunities for students can open doors and provide students with unique experiences. Jepson (2006) reports on a hands-on science and field experience program piloted with deaf high school students in which geologists came into the classroom and went with students, teachers and interpreters on a geology trip to Utah. Jepson (2006) was measuring self-efficacy associated with science careers and saw gains after this intervention.

Students with disabilities in STEM identified specific services and accommodations that they found to be particularly valuable that were arranged by the Disability Services on campus (Seymour & Hunter, 1998). These included pre-registration and arranging accommodations and services of note-takers, readers and interpreters. Seymour and Hunter (1998) also found that students identified critical services of ensuring that audio versions of textbooks were prepared before classes, assistance in changing inaccessible/remote classrooms, support for trying out ATs, help withdrawing from classes and intervening to help students negotiate with faculty and administration. While none of these services are STEM-specific, they all support students with disabilities in their STEM major endeavors and target specific issues identified in the technical barriers section above.

Izzo and Bauer discussed the Universal Design for Learning (UDL) framework that was defined of the Higher Education Opportunities Act (2008) as a mechanism for increasing support for the spectrum of learners including students with disabilities. UDL guides practices that support flexibility in the presentation of learning resources and methods by which students can demonstrate learned knowledge Izzo & Bauer (2013). It also supports instruction through high achievement expectations for students, appropriate accommodations for students and decreasing obstacles to implementing accessible instruction practices. In the context of STEM learning, the UDL framework enables students with disabilities to access many kinds of computer applications and also engage with course content in multiple ways and settings (Izzo & Bauer, 2013). Izzo and Bauer (2013) suggest that devices developed under the UDL framework can obviate the need for individual accommodations for students with disabilities in STEM. This claim is based on data from research indicating that students with special needs have greater learning accomplishments when they work in UDL online learning contexts than those who work in traditional instruction settings (Izzo & Bauer, 2013).

Physical supports.

The most powerful tools associated with physical supports for people with sensory and orthopedic disabilities are solid and sustained planning, organization and communication between the individual with disabilities and everyone with whom they are working. The literature supporting this is rooted in STEM education. Students who experienced success in STEM programs worked closely and continuously with their college Disability Services, created elaborate systems for transportation and back up plans and communicated clearly and frequently with their instructors about their needs (Seymour & Hunter, 1998). In the prior sections of barriers, teachers and faculty were identified as constructors of barriers, however they also can be tremendous student supporters. Students with disabilities in secondary and college levels identified teachers and faculty as extremely influential in their success in school (Jenson, Petric, Day, Truman & Duffy, 2011; Stevens, Steele, Jutai, Kalnins, Bortolussi & Biggar, 1996).

Social supports.

Social supports serve key roles in fostering choice and participation in STEM fields for underrepresented minorities (Zeldin & Pajares, 2000). Studies identified supportive social interactions between students with disabilities and their professors and peers. Jenson et al. (2011) found that students with disabilities in STEM classes held the social support from their instructors in higher regard than that of their families because it was STEM-relevant. Seymour and Hunter (1998) concluded that students with disabilities who were most successful in their STEM programs were those who clearly identified their needs to their professors. This was only effective when faculty respected and met these needs and sought to meet the requirements of accommodations (Seymour and Hunter, 1998).

Jenson et al. (2011) found that the social classroom practice of student teamwork had a positive impact on the self-efficacy of students with disabilities. Some students also enjoyed the social aspect of having other students with disabilities in their classes (Jenson et al., 2011). Seymour and Hunter (1998) found that a student-run social organization outside of the classroom, the Disabled Students' Cultural Center (DSCC) proved valuable for students with disabilities in STEM because it provided opportunities for connecting with peers, developing friendships and access to academic support and acceptance. The DSCC allowed students with similar disabilities to connect and provided a safe space for students to be relieved of the social stresses associated with faculty and classmates identified in above, allowing them to let down their guard and just be comfortable (Seymour & Hunter, 1998).

Psychological supports.

There is little information about psychological supports for people with disabilities in STEM. Jenson et al. (2011) found that students with disabilities identified themselves as major motivators for persistence in their STEM degree coursework. Their motivation stemmed from their belief in themselves (Jenson et al., 2011).

Assistive Technologies for People with Disabilities in STEM

According to Cook and Polgar (2008) *Assistive Technologies: Principles and Practices* textbook, *assistive technologies* (AT) are a "broad range of devices, services, strategies, and practices that are conceived and applied to ameliorate the problems faced by individuals who have disabilities" (p. 545). The Assistive Technology Act (ATA) of 1998 (amended 2004) identifies two aspects of the definition of AT referred to as devices and services. The ATA defines *assistive technology devices* (ATD) as "Any item, piece of equipment or product system, whether acquired commercially or off the shelf, modified or customized that is used to increase, maintain or improve functional capabilities of individuals with disabilities". The ATA (2004) defines *assistive technology service* (ATS) as "Any service that directly assists an individual with a disability in the selection, acquisition or use of an assistive technology device". The purpose of the ATA (2004) is to provide some financing along with support for improvement of continuous access, provision and training associated with ATS and ATD through grants to States, to meet the needs of individuals with disabilities.

Cook and Polgar (2008) point out that the ATA (2004) definitions of ATS and ATD are important, because functional outcomes are the central metric. There is a task orientation to these definitions in this legislation that de-emphasizes the medical conditions of individuals and the pre-established parameters associated with various disability conditions (i.e. if you have mobility impairments you can / cannot do this or that). This is distinctly different from much of the other disabilities legislation, which uses medical diagnoses to establish disability classifications. Note, however, that the ATA policy is only relevant to people who have made it through the medical diagnosis process and have been federally registered as having disabilities. The person-centered orientation of ATA (2004) is distinct. It represents the modern direction of philosophies about disabilities. The final section of this review focuses on assistive technology (AT). As with other aspects of the choice, participation and persistence in STEM of individuals with disabilities, our understanding of the role of AT in the career trajectories STEM professionals with disabilities is extremely limited due to a lack of research.

People with three kinds of physical disabilities were the focus of the AT literature of interest. They were blind/low vision (B/LV), deaf/hard of hearing (DHH), and mobility impairments. Etiology and details of these disabilities are not described in this literature. Instead, tasks take precedence, specifically the tasks students are expected to perform in classroom settings. Attention to tasks displaces attention to student learning in this literature. There is little research on students' academic performances associated with their successful completion of tasks.

There are two waves of research reflected in the literature about AT in STEM education. The first wave came in the 1970s from science teachers and resource specialists who focused on altering existing curriculum to incorporate AT. The two foci of these papers were: (1) creating modifications to exiting lab and classroom materials and (2) determining whether the students can use the modified resources (Baughman &

Zollman, 1977; Franks, 1970; Franks & Butterfield, 1977; Franks & Murr, 1978; Weems, 1977). The second wave came in the 2000s, primarily from technologists. There were three foci of these papers: (1) determining whether student can use the AT devices, (2) assessing the compatibility of the AT devices with technologies common in daily use, and (3) ascertaining whether the students were enjoying themselves / motivated to learn (Bouk, Flanagan, Joshi, Sheikh & Schleppenback, 2011; Duerstock, 2006; French, McBee, Harmon & Swaboda, 2003; Mansoor, Ahmed, Samarapungavan, Cirillo, Schwarte, Robinson & Duerstock, 2010; Sanchez & Aguagyo, 2008; Sanchez & Elias, 2009; Sanchez & Flores, 2002; Supalo, 2010). While there are exceptions, learning was not generally measured or examined in articles about AT that was designed to support student learning in STEM classrooms. Benefits for learning as a result of using these technologies, however, were regularly suggested.

AT for people with vision impairments in STEM.

AT for B/LV students dominated the AT in STEM literature for people with disabilities. Isaacson, Schleppenback and Lloyd (2010) described the role of AT designed to support B/LV learners in STEM as ways to “increase information accessibility” (p.25). Increasing information accessibility is the dominant goal in the AT literature for B/LV students in STEM. Table 6 provides details of AT studies for B/LV students since 2000. Early low-tech studies emphasized the ease of modifying existing lab equipment and the minimal expenses incurred from buying parts for the modifications. Modern articles on technology have been orientated towards leveraging existing technologies both for cost and the experience and comfort of users with existing technologies. This included technologies common in daily school science use such as

Table 6
Details for Recent AT studies for B/LV students in STEM

Authors	Yr	AT	Findings
Sanchez & Flores	2002	AudioMath: audible interactive virtual environment designed to support math learning by developing short term memory skills	- 10 B/LV students age 8-15 at school for blind - 3 assessments, no indication of content or design 1. immediate audio memory test, pre/post; claim: some gains indicate that short-term memory can be enhanced by AudioMath 2. evaluation of math knowledge test, pre/post; claim: students learning was improved due to AudioMath 3. usability evaluation: students liked it and were "motivated"
Sanchez & Aguayo	2008	AudioGene: role playing video game to teach genetics concepts; audible element for blind, graphic interface designed for LV; addition of force feedback joystick provides tactile feedback to reduce audio pollution for LV	- 5 B/LV and 3 sighted students worked in 2 groups - B/LV students reported that they enjoyed themselves and they felt like they were under the same conditions as sighted peers
Sanchez & Elias	2009	AudioLink: interactive audible virtual environment for B/LV students to learn science	- promoted independence and users could work at their own pace - software was "appealing, challenging and encouraging as a science learning tool"
Isaacson, Schleppenback & Lloyd	2010	MathSpeak: math expressions rendered audible, constructed based on Nemeth Braille for encoding Math to Braille; incorporated into computer module	- tested on non-disabled students - they accurately interpreted math expressions
Supalo	2010	Independ. Lab Access of the Blind (ILAB): audible hard/software; uses JAWS and LoggerPro interface to audibly report data gathered through Vernier Probes; talking balance, audible light sensor, talking scientific stopwatch	- 4 B/LV in mainstream - Chem., AP chem. and AP physics - "seemed" to have some benefit - students reported tools helped them to have more participation and increased enjoyment
Bouk, Flanagan, Joshi, Sheikh &	2011	VISO calculator: computer-based voice input / speech output; VISO enabled font magnification for low vision students	- 3 high school B/LV - timed on their completion of problems - students improved their efficiency with practice - students reported positive perceptions about calculator
Supalo, Wohlers, & Humphrey	2012	Camp Can Do 2009-2010 weeklong chemistry workshops for students with visual impairments implemented by the Independent Laboratory Access for the Blind (ILAB) team	- 14 (2009) and 16 (2010) B/LV high school aged students from Trinidad and Tobago, Jamaica, Barbados and Antigua; Focus on teaching students how to do STEM-related projects independently using accessible equipment, hardware and software; Students reported: able to connect wkshp experiences to real life; understood how their accurate lab work were conducive to their personal independence and their academic success

Microsoft programs, Internet explorer and LoggerPro as well as for AT-specific technologies such as JAWS.

AT for B/LV in STEM classrooms has included both tactile and audible forms. AT were designed to allow B/LV students to make lab measurements and observations first through low-tech solutions. These solutions included educator-made tactile graduation marks on lab materials such as timers, balances and rulers and Brailling lab equipment (Baughman & Zollman, 1977; Franks, 1970; Weems, 1977). Tactile resources were also expanded to include raised line graphing surfaces, embossed images, and 3-dimensional biology models (Franks, 1970; Franks & Murr, 1978; Fraser & Maguvhe, 2008). Later in the high tech wave of 2000s, increasing information access came in the forms of audible software for digitized lab equipment, digital games, and computer-based platforms to support hardware/software interfaces for easy access and magnification of lab and classroom resources (Bouk et al., 2011; Isaccson et al, 2010; Mansoor et al., 2010; Sanchez & Agauyo, 2008; Sanchez & Elias, 2009; Sanchez & Flores, 2002; Supalo, 2010; Supalo, Wohlers & Humphrey, 2012).

Audio-based AT for B/LV students have been used in two ways. One group of researchers used audible resources to provide voice input and output resources for texts, making measurements, and coping with data collection and analysis for science and math calculations (Bouk et all, 2011; Hadary, 1977; Isaacson et al., 2010; Supalo, 2010; Supalo, Wohlers & Humphrey, 2012); Weems, 1977). The other group used audible resources for feedback in gaming environments. In research on educational game design, math and science relevance and content development were unclear. The focus was not on student learning but student motivation for learning (Sanchez & Aguavo, 2008); Sanchez & Elisa, 2007; Sanchez & Flores, 2002).

In addition to research of various AT design, recent studies have addressed specific issues related to B/LV disabilities such as audio pollution, social isolation in classrooms, and independence (Bouk et al., 2011; Sanchez & Aguayo, 2008; Sanchez & Elias, 2009). In Weem's (1977) description of AT for his physical science class, he mentions the difficulties associated with the cassette recordings that were part of his AT packet. It was challenging to clearly communicate symbolically rich content, such as isotopes, on the audiocassettes. Isaacson et al. (2010) tackled part of this issue of symbols by turning to a technique developed in the 1950s for clearly translating mathematical symbols and expressions into Braille, Nemeth Braille. They computerized this code into an audible speech output format called MathSpeak. The effectiveness of the innovation is unclear, however, because they tested the effectiveness of interpreting the MathSpeak on education undergraduates without disabilities (Isaacson et al., 2010).

AT for people with hearing impairments in STEM.

There were few studies about assistive technologies for people who are deaf / hard of hearing in STEM. Both of the two studies included here focused on students in STEM and addressed hurdles associated with the logistics of STEM classroom instruction. One study focused on creating opportunities for natural interactions between DHH students in science classrooms with hearing students and teachers (Pagano & Quinsland, 2007). Authors described the use of instant messaging technology to facilitate group classroom discussions, enabling hearing and D/HH students to work together (Pagano & Quinsland, 2007). Futhermore, the authors suggest that this technology could also enable mentoring relationships via Internet. A second study addressed the issue of STEM vocabulary required for instruction in STEM classes and the limitations of American Sign Language interpreters, who do not necessarily know specialized STEM signs (Andrei, Osborne & Smith, 2013). Authors described public school interpreters for D/HH students in STEM education from early childhood through grade 12 as being unqualified and unfamiliar with STEM concepts and vocabulary. In addition, though real-time English language captioning is a good alternative to unqualified interpreters, it poses challenges for D/HH students who, at high school graduation, read below a fourth grade level (Andrei et al., 2013). Based on evaluative feedback from ten deaf students and two sign language interpreters who piloted the Lamar University Signing Avatar (LUSA), Andrei et al. (2013) concluded that an American Sign Language Avatar can be used to provide interpreting services to D/HH students in computer science. Like the B/LV STEM assistive technology literature, these studies focused on increasing information access. However, the Pagano & Quinsland (2007) study also targeted increasing social interactions between DHH students and hearing students and teachers. There are too few studies to draw meaningful conclusions about assistive technology for people who are D/HH in STEM.

AT for people with mobility impairments in STEM.

There were two articles that described AT that supported students with impaired mobility, both upper and lower body, to use a microscope (Duerstock, 2006; Mansoor et al., 2010). These articles described the same technology, AccessScope, and documented the early implementation and later modifications and extensions. The primary goal of the first article was to establish user comfort and function. This “can they use it” orientation is also seen in the B/LV literature, with a task focus rather than learning focus. The second article included pre/post tests and attempted to compare the use of the scope to the use of a digital photograph (Mansoor et al., 2010). Their findings, however, were based on statistical analyses that violated statistical assumptions. Nevertheless, the inclusion of a content-based assessment is uncommon in the literature about AT, and is therefore noteworthy.

Burgstahler et al. (2011) provided insight into types of AT and roles that various AT played in the success of individuals with disabilities not addressed in other literature. Though Burgstahler et al. (2011) did not focus on STEM preparation or participation and offered limited information about AT specific to STEM, they provided a useful overview of challenges and solutions associated with AT related to computer and cell phone access. Information from interviews of three people with disabilities who use AT was provided. These individuals were affiliated with STEM fields: a geophysicist, an AT specialist and a student who plans to study sociology or psychology. A geophysicist had a spinal cord injury when he was 44 years old, and he continued to teach and conduct research at his university in Korea. He was paralyzed but could speak and had a large range of head motion that enabled him to use a computer successfully with a sip and puff Integramouse and a head-motion controlled mouse. He used speech recognition software for writing and could make telephone calls through a connection between his computer and his cell phone. An AT specialist had cerebral palsy, which required him to use a communication device for speech output and a motorized wheelchair for mobility. He was born in 1977 and was progressing through school during the first nationwide mainstreaming of students with disabilities. He reported that his parents and educators were interested in exploring AT, and they started him off with an Apple IIe to support schoolwork such as word processing and math. Eventually, he used a scanner that worked with computer software that read aloud the scanned texts. He also had various augmentative and alternative communication systems, which generated speech for him. He reported that the combination of these AT increased his inclusion throughout K-12. College proved overwhelming and he left. He was hired as a consultant for technical service research and development by the company that designed his AT. The third STEM interviewee in the Burgstahler et al. (2011) study was a college student who has muscular dystrophy, requiring her to use a wheelchair. She provided less information overall but did indicate that AT helped her attain a high level of independence. She discussed her iPhone in particular, which helped her with navigation and allowed for easy phone communication, especially important given her weak hand strength. While this study was unique in the depth of description it provided about the kinds of AT and roles that AT can play in the lives of people with disabilities in STEM fields, of the focus on access and facilitation of social interaction are similar to other studies of AT for students with disabilities (Burgstahler et al., 2011).

Conclusion

This literature review addresses the research relevant to the design and implementation of the current study. The two foci of the study are the choice and participation of people with sensory and/or orthopedic disabilities in their STEM fields and the roles of assistive technologies in their STEM participation. The review of definitions of disabilities identifies the medicalisation of disabilities that has informed much American disability policy. It also presents alternative ways to consider defining disabilities. These philosophies drive policy language and the enactment of legislation that classifies people as disabled and determines subsequent restrictions and accessibility. The examination of differences in federal definitions of disabilities presents various ways that our federal system requires people with disabilities to identify themselves. Different classification schemes reflect multiple perspectives about people with disabilities including what they cannot do, how their bodies deviate from a biological norm and what they have accomplished. These definitions and classification schemes describe the legislative context in which participants recruited for the study are embedded.

The review of research about underrepresentation of people with disabilities in STEM explicates the state of participation of people with disabilities in STEM at different points along the pipeline. The data quantifies the problem of underrepresentation. It is relevant to the STEM choice and participation of people with disabilities because it presents underrepresentation not simply as a phenomenon in the workforce but as a system involving many people and structures. This helped to inform the development of items for the instruments used in the study.

The self-efficacy theory and research situate the current study within a robust arena of exploration. While little STEM self-efficacy research has attended to people with disabilities, there has been a focus on underrepresented minorities in STEM. The review distinguishes studies of self-efficacy sources from those examining self-efficacy as a predicting, mediating and predicted variable. This helps to orient the reader to the research branch from which the current study stems and directed the development of methods and instruments for the study. The final section about assistive technologies (AT) for people with disabilities reviews the current state of AT in the research literature. It provides points of comparison for the upcoming data from the current study, which will provide information about the practical implementation of AT in the context of STEM pathways for people with disabilities. Together the four bodies of literature were important for the development of the study within.

CHAPTER 3

METHODS

Introduction

STEM professionals with sensory and/or orthopedic disabilities were the focus of the current study. The purpose of this research was to develop an understanding of the factors that this group of people identified as critical to their choice and participation of their STEM careers. The study was also designed to explore the roles assistive technologies have played in the career trajectories of these STEM professionals. Three research questions were developed to structure the process of this investigation. They were:

1. What are the characteristics of critical experiences science, technology, engineering and mathematics (STEM) professionals and graduate students with sensory and physical disabilities identify as integral to their participation in STEM?

2. What role(s) have these critical experiences played in the development of participants' self-efficacy beliefs about their STEM domain?

3. What is the nature of the role(s) ATs played in the STEM trajectories of these professionals and upper level students?

Methodological Justification

Research paradigms differ widely across research domains. They reflect the worldviews and cultural practices of individual researchers and their research communities. Doyle, Brady and Bryne (2009) describe four elements of paradigms associated with research design: epistemology, ontology, axiology and methodology. Researchers' beliefs about ways of knowing (epistemology) and conceptions about reality (ontology) identify what counts as knowledge and defines the scope of perceptions about reality that will be accepted and explored within a study. These dimensions of researcher beliefs, along with researchers' values (axiology) influence the process, direction and assumptions (methodology) of a research design. "In other words, paradigm differences influence how we know, our interpretation of reality and our values and methodology in research." (Doyle et al., 2009, p. 176).

The constructivist paradigm introduces the roles of participants' perceptions about reality and researchers' values, beliefs, biases, and experiences into the research. Under the assumption of multiple realities, rather than the presumed single external reality of post positivism, participants' experiences, beliefs and perspectives are gathered, analyzed and interpreted by researchers. Researchers do this to develop understandings about participants' perceptions and meanings associated with phenomena (Creswell & Plano Clark, 2011). Data about participant's beliefs and perspectives rely on participants' memories. These data are inherently biased because they reflect outcomes of participants' sense making and interpretations of their experiences. Their conclusions and ideas about experiences can differ from the perceptual outcomes of others involved in the same experiences. This paradigm fosters theory development through inductive processes rather than theory testing associated with post-positivist practices and is most closely aligned with qualitative research practices (Creswell & Plano Clark, 2011). The constructivist paradigm guided the development and enactment of the current study.

Researcher biases.

I must make note of my biases, though they cannot all be identified and captured in a single paragraph. I am a science educator and researcher without sensory / orthopedic disabilities. My career has, primarily been in the geosciences and geoscience education, though more recently it has included science education broadly. I do not have in-depth knowledge across STEM domains. While I have personal experience with one major topic of this study, participation in STEM, I have little personal experience with the other central topic of this study, assistive technologies. I taught public school science for nearly a decade and while I taught many students with learning disabilities, I taught only four students with sensory or orthopedic disabilities. I also do not have any close friends or family with sensory or orthopedic disabilities. Therefore my experience with people with sensory and orthopedic disabilities is limited and I do not know the day-to-day realities of living with sensory/orthopedic disabilities. Though I have researched innovations and practices that support the learning of students with sensory/orthopedic disabilities, I have not used them in my own classroom. I am therefore unfamiliar with them in a practical sense. I have also never worked with the many educational and career-relevant technologies available for people with disabilities let alone those for daily living.

I strove to exceed my limitations by engaging with colleagues with disabilities for feedback on instruments and procedures for this study. I also connected with professionals with disabilities alongside my work on this study. Issues of accessibility in the digital platform was one of many important points that I became aware of by engaging people with disabilities in the development of this study. These experiences also gave me insight into how accommodations are implemented in professional settings and the kinds of creative solutions these professionals developed to work within the constraints of their office technologies and physical space.

Sample

Approximately 15% of Americans living outside of institutions have some kind of disability; 4.3% have sensory disabilities and 9.4% have physical disabilities (Brault, 2008). People with disabilities are a minority in this country. Groups who are less represented in a given field than they are in the country's population are considered *underrepresented minorities*. This is the case for people with disabilities (aggregated) in science and engineering positions, representing only ~6% of jobholders (National Science Foundation (NSF), 2013). Gathering a sample of people with sensory and physical disabilities from science, technology, engineering and mathematics (STEM) fields proved challenging.

This study consisted of 18 STEM professionals from government (2), industry (5), non-profit sector (2) and academia (9). Those from academia included active faculty (3), PhD students (4) and professors emeriti (2). Table 7 provides data about participants' demographic and STEM fields. Participants' self-identified STEM domains are also included. Most participants identified only one STEM domain. Of the five participants who identified more than one STEM domain, four listed both science and technology. Participant occupations fell into three categories: 4 in Science (S), 7 in Engineering & Computer Science (ECS) and 7 in Disability Service/Assistive Technology/Research (DAR). For three participants, Cera, Lina and Harold, their occupations overlapped with two occupation categories.

Recruitment technique.

This study employed sequential *snowball* or *chain* sampling. This method entailed gathering participants through the recommendations of other participants and key

Table 7
Demographics and occupation information about participants

Participant	Sex	Age	Ethnic.	STEM	Occupation (Category)	DIS*	Region
Bernadette	F	28	White	S	Biology PhD Student (S)	O	West coast
Carlos	M	25	White	T,E	Software Engineer (CSE)	V	South
Cera	F	28	White	S	Science Ed PhD Student (DAR) / (S)	V	Mid west
Harold	M	27	White	STEM	Comp Sci PhD Student (CSE) / (DAR)	V	North east
Herb	M	49	White	E	Medical device engineer (CSE)	V	Mid west
Hillman	M	64	White	T	Incl. Consultant/Public Speaker (DAR)	V	West coast
Karl	M	70	White	T	University Prog. Coord. for teachers of the blind (Emeritus) (DAR)	V	Mid west
Kumi	M	44	Asian Indian	S,T	Professor of Information and Computing Studies (CSE)	H	North east
Lars	M	32	White	T	Vocational Rehabilitation / Assistive Technology Instructor (DAR)	V	South west
Lina	F	42	Hispanic	T	Software Engineering Professor (CSE) / (DAR)	V	North east
Marco	M	24	White	S,T	Assist Shepherd / Young Stock Manager (Dairy Farmer) (S)	V	North east
Marton	M	50	Biracial	T	Policy Analyst /AT Project Leader (DAR)	V	Mid-Atlantic
Milo	M	39	White	T	Assistive Technology Project Director (DAR)	V	Mid-Atlantic
Seal	M	64	White	T	Coordinator of University Info and Computer Access Program (Emeritus) (DAR)	V	West coast
Tina	F	24	White	T	Software Engineer (CSE)	V	West coast
Viktor	M	67	White	S	Professor of Marine Ecology and Paleoecology (S)	V	West coast
Wyatt	M	36	White	E	Civil Engineer (CSE)	V	West coast
Wilhelm	M	26	White	S,T	Chemistry PhD Student (S)	V	West coast

*V = visual disability, O = orthopedic disability, H = hearing disability contacts (Teddlie & Yu, 2007). It was chosen because of the small population of people with sensory/orthopedic disabilities in STEM fields. I used the following criteria: STEM undergraduate degree (preferred), 3+ years post-undergraduate, disability onset occurred before the completion of undergraduate studies and current engagement in STEM field. STEM is broadly defined. I included people in professions associated with assistive technology under the umbrella of STEM fields. Only two participants lacked STEM undergraduate degrees. At the time of the study, they were both heavily involved in the community of assistive technology professionals. All other criteria were met by the participants in the pool.

The Arizona State University Institutional Review Board permitted me to identify the people who made the recommendations for participants. This was beneficial because my recruitment came from a trusted connection, rather than from an unknown researcher. To begin the process of the snowball sampling, I sought to establish connections from those around me with whom I worked directly. Dr. Hedgpeth is blind professional in the disability education community. She has a large network of students and colleagues with disabilities that she has fostered through her years as a professional and her tenure as head of the ASU DRC. Dr. Hedgpeth provided the names and contact information for 15 people with sensory and/or orthopedic disabilities that she knew were in STEM fields. From her contacts I was able to engage 6 people in the study. My work with the geology education community connected me with another participant. Together, this group of seven served as the first group of participants in my snowball method. Most participants from this group made suggestions of other people for me to contact for the study. I emailed the recommended individuals. There was some overlap in recommendations.

Some recommendations connected me with organizations with large networks. One participant suggested that I contact Sheryl Burgstahler at the University of Washington DO-IT program. Dr. Burgstahler agreed to share the study invitation with relevant students. Another participant's recommendation for a possible subject resulted in not only the successful engagement of the suggested person but also provided an unexpected a connection with the National Federation for the Blind (NFB). The NFB then shared the study invitation through their listserv and this led to additional participants. Through the direct recommended connections with individuals and through the recruitment emails sent out to the DO-IT and NFB communities, I was able to engage 11 additional people in the study, bringing the sample to 18.

The sample of participants is biased in disability type and in STEM domain, reflecting the nature of the snowball method. Sixteen of the participants came from the blind / low vision (B/LV) community. Only one participant was deaf, a college professor, and only one participant had orthopedic disabilities, a PhD student. Participants from the computer science and assistive technology fields dominated the sample. This was a natural consequence of following participant recommendations for more subjects. Dr. Hedgpeth, was involved in assistive technology and was part of Arizona State University's Center for Cognitive Ubiquitous Computing (CUbiC) before assuming her current position as head of the DRC. Her contacts reflected her experiences in assistive technology and computing fields. The listservs I was connected to through participant recommendations of DO-IT and NFB are for people with disabilities in general and are not domain specific so I was able to invite people from different domains to increase the diversity of STEM domains represented by participants in the study.

Instruments

This study employed two instruments to gather data. The first instrument was administered as a brief online survey following participant consent obtained by email. The second instrument was an interview protocol administered by phone call / Skype. Following the interview, participants received an email from me expressing my thanks for their participation and requesting recommendations for potential participants.

Participant selection survey.

The survey, called the Participant Selection Survey (PSS) was designed to identify people appropriate for the study who expressed interest. Though the original survey was developed in Google Survey, Survey Monkey was ultimately chosen because the program was accessible to screen readers, a critical tool for most of my participants. This survey was designed to gather data about respondents' STEM careers, academic degrees, demographics and disabilities. It also served to provide information about participants before I conducted interviews with them. There were ten questions on the PSS and they are listed in Table 8. The link to the Participant Selection Survey was sent by email following participants' consent to take part in the study.

PSS reliability and validity.

Creswell and Plano-Clark (2011) explain that reliability is said to play a minor role qualitative instruments and is focused on the inclusion of multiple people in the process of establishing and assigning codes for qualitative responses (Creswell & Plano-Clark, 2011). Reliability by these metrics poses challenges for this survey instrument because responses were not processed through coding. Instead I turned to a resource

Table 8:
Questions from the Participant Selection Survey, administered online

PSS Item #	Question
Item 1	Please provide your first and last name
Item 2	Please indicate the phone number or email address that is best for correspondence about the study
Item 3	What is your current field and occupation? (i.e. Field: biomedical engineering, geology; Occupation: research scientist, graduate student, engineer)
Item 4	Please check the most appropriate box(es) that best characterizes your current occupation. • Science • Technology • Engineering • Mathematics • Other (please specify)
Item 5	Please identify your academic degree(s) and year of completion. (i.e. B.S. Geological Oceanography (1985); M.S. Chemistry (2004) etc…)
Item 6	Please identify your gender • Female • Male • Other
Item 7	How would you describe your ethnicity?
Item 8	What was your approximate age when your disability was first identified?
Item 9	Do you use any assistive technology in your daily work life? Assistive technology device (Tech Act, 1988) refers to any item, piece of equipment or product system, whether acquired commercially off the shelf, modified or customized, that is used to increase, maintain or improve functional capabilities of individuals with disabilities. • Yes • No
Item 10	In your own words, please briefly describe your disability (~100 words).

focused on the development of effective surveys. In this resource, the preamble is identified as important to ensuring reliability of qualitative and quantitative questions (Thayer-Hart, Dykema, Elver, Schaeffer & Stevenson, 2010). The preamble serves as the portion of the survey questions that explains to the respondent what he/she needs to do for each question, such as “Please check the most appropriate box(es)”. The preamble also provides definitions that the participant must understand to answer the question. This helps to minimize opportunities for alternate understandings of questions, which can negatively impact reliability (Thayer-Hart et al., 2010). The PSS included preambles with explicit directions, such as “provide your first and last name” rather than “provide your name”. They also included examples of responses of formatted responses for items requesting more than one piece of information such as “Please identify your academic degree(s) and year of completion. (i.e. B.S. Geological Oceanography (1985); M.S. Chemistry (2004) etc…)”. The definition of assistive technology was also provided to minimize confusion over what was meant by the phrase. In addition to the role of the preamble in ensuring reliability of the instrument, the nature of the PSS questions focused on historical and current information about participants. Information about participants including academic degree(s) and year(s) of completion and approximate age at which disability was identified are historical and factual in nature. Other questions, including participant name, sex, current occupation and field and whether or not AT is used in daily work life are changeable in the course of a participant’s life but reflect the participant at the time of the study. The final question in the survey asked participants to describe their disability. It was designed to elicited responses that included information about etiology, impact on work and the physiology of the disability to inform my sampling process. The online software used for the survey was accessible to screen readers, which enabled participants to have a consistent user-experience, increasing reliability of the instrument.

Validity is an indicator of meaningfulness of participant responses to a measured construct and is assessed by experts external to the study (Creswell & Plano Clark, 2011). Content validity addresses the relevance and appropriateness of instrument items in the context of their constructs while construct validity assesses the alignment between the intent of the measures and the measures themselves (Creswell & Plano Clark, 2011). Content and construct validity of the PSS was established with input from the head of the ASU Disability Resource Center who is blind and from a working professional from our community with a degenerative orthopedic disability.

Interview protocol.

The interview was adapted from the protocol from Zeldin & Pajaras (2000) self-efficacy study of women in mathematics-oriented professions. The instrument was designed to serve four roles: (1) foster participant ease and engagement (Bogdan & Biklen, 2007) and clarify participant information (2) target the major theoretical building blocks of task-specific self-efficacy beliefs (3) collect data on critical experiences participants identify as related to their participation in STEM and, (4) allow participants to articulate their perspectives about the role(s) assistive technologies played in their pathways to their STEM careers. I engaged two working professionals with disabilities to review my instruments and the design of this study. Dr. Terri Hedgpeth and Kenny Brosch, a community member and professional who I met during a course specializing in assistive technologies. They shared their ideas and perspectives on the interview questions. This helped me to make changes that better aligned with their perspectives. Through these helpful and, at times, very intense conversations, I started to develop a theoretical model about how assistive technologies fit into the realm of Bandura's Self-Efficacy model (1977). This, in turn, informed a final question in the interview protocol.

The interview protocol had three sections: background, self-efficacy and assistive technologies. Part of the background questions and all of the self-efficacy questions were modeled after Zeldin and Pajaras (2000). In the Zeldin and Pajares (2000) protocol, they asked first about participants' background information and then went on to ask for descriptions of participants' current occupations. I adapted these first two questions of their instrument for the background section of my protocol by disaggregating them into a set of 12 structured background questions. I added questions about the disabilities of participants and their parents. The section of background questions includes items 1 through 12 in Table 9.

Background items 1, 5 and 7 (Table 9) which requested information about participants' age, size of their high school graduating classes and names of their undergraduate institutions were asked to assess the diversity of participants' backgrounds. Item 2 reflects an issue identified by Kenny Brosch with whom I consulted with on the development of this instrument. He felt that the customs and culture of his rural Midwestern community made it particularly challenging for his family to cope with his disability, both medically and socially. He posited that there was a potential relationship between American geographic regions and success of people with disabilities. Item 3 was included to determine where people who are successful in STEM careers went to school from kindergarten through twelfth grade. It directly addresses a comment that was made to my research team by an assistive technology specialist in Arizona with whom we consulted for a study we were conducting alongside the current study. She explained that people with children who are blind and whom they expect to go to college would never send their children to public school, only to specialized schools for the blind. Items 4, 8 and 9 ask participants to comment on their age at high school graduation, the number of undergraduate institutions attended to achieve the undergraduate degree and the number of years required to complete the undergraduate degree. These questions were included based on findings from the 1998 report by Seymour and Hunter in which they identified a “stop and go” pattern in the college attendance of students with disabilities because of issues with time. Participants from the Seymour and Hunter (1998) study missed classes for reasons related to ongoing medical treatments associated with their disabilities. There were also logistical issues associated with being dependent upon, for example, unreliable public transportation. In addition, participants from that study reported that they simply needed more time for learning because of their accommodations and compensatory mechanisms. While Seymour and Hunter (1998) found that students would eventually complete college programs, they did so in more than four years. Seymour and Hunter termed students with disabilities as being “time-disadvantaged” (1998, p173). Item 6 was added after the first six interviews were conducted. High school enrollment in advanced placement and/or honors courses was mentioned in several of the first six interviews. Through email exchange, I was able to ask this question of the participants that I had interviewed before item six was added. Item 10 was included to understand if cultural capital had a role (Bordieu, 1986) in the success of participants both as STEM professionals and as STEM professionals with disabilities. Item 11 is from the Zeldin and Pajares (2000) study, adapted to include graduate programs given that my sampling protocol made it possible to include graduate students. The final question in the background section, asking participants to describe their disability, is repeated in the interview after participants responded to it in the PSS. Here, it enabled me to ask clarifying questions to most accurately capture the demographic picture of each participant.

In the self-efficacy portion of the interview, items 13 – 19, I included the remaining seven questions from the Zeldin and Pajares (2000) instrument. The first four self-efficacy questions were designed to address the major theoretical contributions to the development of self-efficacy beliefs: mastery experiences, vicarious experiences, social persuasion and physiological / affective states (Bandura, 1986, 1977). Mastery experiences were addressed by item 13. They are identified as the most effective mechanism for developing self-efficacy beliefs (Bandura, 1994). Item 14 targeted the occurrence and role vicarious experiences through the observation of others may have had that contributed to participants' self-efficacy beliefs. The value-neutral nature of the question allowed for positive and/or negative experiences to be identified. Social persuasion was addressed in item 15, which was designed to elicit information about the level of social support participants experienced through responses about encouragement and/or discouragement. Item 16 focused in on participants' physiological experiences as proxies for their emotional experiences (Bandura, 1994) along their pathways into STEM fields. Item 17 did not target any particular self-efficacy belief source. Instead, Zeldin and Pajares explained, this question "guided respondents to tell their own stories and allowed them to provide their own interpretations of what they perceived to be meaningful events to their academic and career success" (2000, p.224). Item 18 was developed by Zeldin and Pajares (2000), and also included in this study because it was relevant the context of the current study. I, the researcher, am not coming from the disability community. Asking participants about their beliefs and understandings about why people with disabilities are underrepresented in STEM fields and what could/should be done about it gives a voice to this underrepresented group, reflecting perspectives from their own experiences. Finally, item 19 was included “to enhance the participants’ analysis of their own personal histories” (Zeldin & Pajares 2000, p 123). I believe that this question directly addressed issues of broadening participation because it is designed to elicit lessons learned by participants who, by their very presence in their fields, broadened participation.

Some changes were made to the Zeldin and Pajares questions to tailor them to the current study. Two of the seven items in the self-efficacy section of the interview protocol were adapted, from the Zeldin and Pajares (2000) protocol. I will only mention questions that were modified. I replaced “mathematics (science or technology)” with “your STEM field” for items 15 and 16 and I used “people with sensory/orthopedic disabilities pursue STEM-related careers” in place of “women in mathematical careers” for question 18. All other language in the items in this section was retained from the Zeldin and Pajares (2000) interview protocol.

The final section of question items in the interview protocol focused on assistive technologies (AT). These questions were designed to probe participants’ experiences and perceptions of the role(s) AT played in their participation in STEM. This group of questions was placed at the end of the interview protocol for two reasons. First, this research study was designed to minimize chances of a deficit approach to this study of people with disabilities. The AT questions focus on technologies designed to support people with disabilities. Inclusion of these questions needed be treated carefully to avoid participant perception that the I was attributing participant success in STEM to the use of AT. Asking first about the individuals’ experiences, relationships and perceptions employs a person-centered approach to the study, since the study was not about how technologies support people, but rather about how people use and perceive the roles of technologies in their endeavors related to STEM.

The questions in the AT section were developed for this study. They asked participants to provide historic/factual data in addition to reflective and perceptual information. The first item in the AT section, Item 20, asked for historical data about whether or not participants used AT in their pre-college years. With item 21, I sought to identify lists of technologies that participants believed were important to their learning in science and math, specifically. Item 22 asked participants to reflect on the role AT played in their participation in their STEM fields. It was designed to illuminate participant perceptions of AT in their professional success. Technology abandonment is a problem in assistive technology. The quality and usefulness of assistive technologies as well as the state of integration between assistive and mainstream technologies are probed in item 23. Item 24 was designed to identify specific technologies. The focus was on AT that successful STEM professionals with disabilities were using at the time of the study. Items 25 and 27 targeted issues of access associated with AT both in the past and the present. Items 26 and 28 asked participants to look toward the future both for children with disabilities and for people following a trajectory similar their own to identify technologies not yet invented that could be useful in supporting learning and success in STEM. These questions were designed to build towards an understanding of needs that are not being met by AT today. The final question, Item 29,was developed as I interacted with people in the disability community in preparation for this study. Kenny and Dr. Hedgpeth said, in their own ways, that there is interplay between personal motivation, social supports and assistive technology, associated with the successful choice and participation of STEM career for the participants of this study. They explained that, in their experiences, the relationships among these factors and their impact on academic and career outcomes is complex.

Interview protocol reliability and validity.

Reliability identifies test dependability, stability, and consistency upon repeated applications (Worthen, Borg & White, 1993) and it plays a minor role in qualitative research in which the focus is on coding in the analysis (Creswell & Plano-Clark, 2011). In order to maximize dependability for the interview, I have provided explicit descriptions of the rationale and decisions that I made throughout the study design, analysis and interpretation to ensure that my process is transparent, understandable and reproducible (Zeldin & Pajaras, 2000). I targeted stability by developing questions for the interview protocol with questions that I felt comfortable asking that were conversational. I also practiced asking the interview questions and I listened to every interview recording to ensure that I was following the protocol. I noted the occasional digression to limit

Table 9
Interview Protocol for current study including questions from Zeldin and Pajares (2000)

Interview Item	Question
Background information	
Item 1	What is your age?
Item 2	Where were you living during the initial onset of your disability (Geography?)
Item 3	What kind of K-12 school type(s) did you attend? (a) Regular public school, (b) private school, (c) independent school, (d) specialized school
Item 4	What was your age at high school graduation?
Item 5	What was the size of your graduating high school class?
Item 6	Did you take advanced placement, honors courses in high school? If so, in math and/or science?
Item 7	At what institution did you complete your undergraduate degree
Item 8	How many undergraduate institutions, including community college, did you attend for this undergraduate degree?
Item 9	How many total years did it take to complete your undergraduate degree?

Table 9 continued

Interview protocol for current study including questions from Zeldin and Pajares (2000)

Interview Item	Question
Background information continued	
Item 10	Family history a. Were you raised by one or two parents? Or by guardians? b. What is your father's / Guardian 1's highest education? c. What is your father's / Guardian 1's profession? d. Does your father/ Guardian 1 have a disability? If so, what is it? e. What is your mother's / Guardian 2's highest education? f. What is your mother's / Guardian 2's profession?
Item 11	Please describe your current occupation / graduate program.
Item 12	Just to refresh my memory, could you briefly describe your disability?
Self-Efficacy Questions	
Item 13	What experiences contributed to your decision to pursue your occupation?
Item 14	How were you influenced by others?
Item 15	What did people (family / teachers / peers / culture) say to you as you were pursuing your STEM (i.e. geology, mathematics) field? What sorts of sociocultural messages did you get?
Item 16	How would you describe your feelings and beliefs about [your STEM field] (i.e. geology, mathematics) as you were pursuing it?
Item 17	Tell me one memorable story that would really help me understand how you came to do what you do?
Item 18	Why do you think that so few people with sensory / orthopedic disabilities pursue STEM-related (i.e. geology, mathematics) careers? What could be or should be done to alter that?
Item 19	Considering your academic and career history, if you could have done anything differently, what would that be?
Assistive Technology Questions	
Item 20	Did you use (AT) before undergraduate college?
Item 21	What specific assistive technologies did you use that supported your learning in science and math at any point?
Item 22	How would you describe the role(s) AT played in your participation in (your STEM field) (i.e. geology, mathematics)?
Item 23	Were there technologies that proved unsupportive for (your STEM field)? That provided obstacles or were counterproductive?
Item 24	Now that you are in your career, what career-specific assistive technologies are you using?
Item 25	Were there any barriers to accessing some technologies that would have been helpful?

Table 9 continued
Interview protocol for current study including questions from Zeldin and Pajares (2000)

Interview Item	Question
Assistive Technology Questions	
Item 26	Thinking back to your experiences as child in school, what kinds of AT would you like to see invented that would have facilitated your learning connected to (your STEM field)?
Item 27	What AT exists today that you wish you had access to currently to support your work in your (your STEM field) career?
Item 28	What kinds of AT can you envision in the future that would make a difference for a person with the same disability as they were preparing and pursuing their (your STEM field) education and career goals?
Item 29	Weigh the relative importance of your own motivation, the social supports that you have experienced and the assistive technologies you have used in your successful choice and participation in (your STEM field)

being off track in the future. Consistency was ensured by the detailed list of questions in the interview protocol that were asked of every participant in the same order for every interview. In qualitative research, validity, like reliability, is established in the analyses conducted by the researcher (Creswell & Plano-Clark, 2011).

Interview Techniques

Participants were invited to schedule a time for the interview following the completion of the online survey. The structured interview was administered by telephone call or web-based communication platform in the winter and spring of 2014. I asked additional clarifying questions as needed to refocus participants. Some participants provided very extensive responses and at times, stopped and asked, "what was the question again?" Some participants answered questions they thought I asked rather than what I actually asked. Analysis of each question across participants revealed that single participants would respond to multiple questions within the interview by answering what they thought I was asking rather than what I was actually asking. There were no questions in the interview protocol that were consistently misinterpreted across participants. This indicated that the misalignment between the questions I was actually asking and what some participants thought I was asking reflected individuals' misinterpretations of questions rather than a lack of clarity on the part of interview questions. Most of the interviews were conducted by telephone call. Two of the interviews were conducted through alternative formats. The participant with orthopedic disabilities preferred to be interviewed through Skype. The participant who was deaf requested that we used the Video Relay System (VRS). At the time of the interview, this participant engaged the VRS system at the participant end, which entailed connecting with VRS through computer and using sign language to communicate through computer-based video with the interpreter at the VRS office. This interpreter then engaged with me verbally on the phone.

All interviews were recorded using two devices and I also took notes. The primary device was a hand-held digital recorder (MP3). I also used the audio recorder within Microsoft Word (MP4) as a back up. The MP3 audio files were clearer because the handheld recorder was placed directly at the speaker of the cell phone while the MP4 recording device was in the computer. The handwritten notes I took during the interviews enabled me to refer back to key information participants had already mentioned during the interviews.

There were challenges associated with the interviewing process, some of which I expected. I anticipated challenges associated with the interview including (1) coping with the logistics of interviewing people with disabilities via phone or Internet and (2) dealing with flaws in the interview design that did not elicit the kinds of data sought in this study. The first concern proved to be unfounded, as participants were easy to contact through phone calls as well as through the VRS system and Skype.

Analysis

I conducted the analysis for this study following Creswell's (2013) outline of the process for qualitative data analysis. This process included: (1) dealing with the raw data, (2) organizing and preparing data for analysis, (3) reading through all the data, (4) coding the data, (5) establishing themes and writing descriptions, (6) assessing interrelating themes and (7) finally interpreting meanings of themes (Creswell, 2013).

To start the process, I gathered the raw data. Participants provided data through their online survey responses and their interview responses. Survey data was collected through the online survey, transferred to a spreadsheet and participant names were changed to their pseudonyms. I sent 16 of the 18 interview audio files to a professional transcription service to be transcribed. I transcribed two of the interviews. I was concerned about how much they would cost because two audio recordings were difficult to understand. I had a poor phone connection with the interpreter during the interview using the VRS system and in another interview, the participant's speech made it challenging to understand. Upon receipt of them, I saved the transcriptions and recoded them with participant pseudonyms.

In preparation for the analysis, I conducted a question-based examination of participant responses to each question in the interview. This process enabled me to familiarize myself with participant responses, preview *a priori* themes and to start identifying emergent themes. Participant interviews ranged form 35 minutes to 2.5 hours.

As a result, some participant interviews included responses to single questions that took many minutes to deliver, which translated into multiple pages of transcribed responses to single questions. Participant responses varied widely in length and detail. I used Microsoft Excel spreadsheets for the organizational infrastructure of the data for the study. This program enabled me to create and save related spreadsheets in single workbooks to facilitate information retrieval and referencing.

Due to the small sample size, n=18, neither inferential nor descriptive statistics were used. Instead, all data is presented in actual numbers. Qualitative analyses for this study were focused on seeking emergent themes and assessing *a priori* self-efficacy themes. Demographic data from participants' survey responses and interviews were used to connect participants' responses and demographic data to illuminate patterns and groupings.

Emergent theme analysis.

Following the question-based examination, I conducted close readings of responses and focused on identifying participant responses that answered the interview questions. During the interview process participants often provided responses to previously asked questions as they remembered information and experiences. Participants also offered information that was not directly related to interview questions. To isolate answers to interview questions, I highlighted direct quotes from participants' responses on hard copies of the transcripts and then entered the direct quotes into Microsoft Excel spreadsheets, organized by participants' pseudonyms. Each question was given a separate spreadsheet within an Excel workbook. I created a separate spreadsheet within the emergent theme Excel workbook for direct quotes that did not address the question but rather answered other questions or provided information that participants chose to share through stories that were unrelated to the interview questions.

To start the process of developing codes, I printed out participant quotes for each question and cut them apart into individual quote slips for sorting. I reviewed and coded individual quotes based upon descriptive wording. A corkboard and tacks were used to organize and reorganize the quotes for each question, compiling similar codes and seeking themes. This ultimately led to identifying themes and subthemes. During the sorting process, I bundled the coded quote slips according to category, paper clipped them together with labels and stored the bundles in envelopes dedicated for each interview question. Within the Excel spreadsheet, I added code columns alongside all participant quotes and I populated them with the category names and color-coded the category cells. The color-coding allowed for the identification of category patterns and enabled me to ensure that all quotes were categorized. I recorded notes about the codes and categories that I had generated from the quote slips along with participants' demographic data. Throughout the sorting process and the review of the color-coding patterns in the spreadsheet, I wrote summaries of the categories. The number of individuals that fell into each category was captured during the note taking process. Those categories containing the codes from the most participants were identified as being the most important.

After the question-based analysis, I revisited my research questions and compared them to the responses that participants had provided for the interview questions. Not all the interview questions elicited responses that were relevant to the research questions I had identified for this study. This included questions 7-10 of the Assistive Technology

(AT) portion of the interview protocol. I set aside participants responses for these items for future work.

Using the initial set of categories, the themes and subthemes were identified. My next steps were to simplify and condense the categories I had developed in the question-based analysis and seek evidence of these simplified codes across other interview questions. I pooled the categories that emerged for the self-efficacy questions together and categories that emerged for the assistive technology questions were also grouped together. After establishing a condensed series of categories, I reviewed the participant responses again to identify the common theme for each grouping and to seek disconfirming evidence of the established themes.

Themes that included responses from three or more participants, across questions, were identified as those that would be considered for inclusion in the findings of this dissertation. My resources for qualitative research did not provide guidance about how many people constituted a good number for establishing a theme given my sample size (n=18). However, a natural break emerged from the data set such that major themes included responses by three or more people. This also provided the opportunity for one person with each kind of disability included in this study (visual, hearing and orthopedic impairments) to have representation within a theme. As part of the note-taking process, descriptions of each emergent theme were recorded.

Finally, I sought relationships among emergent themes. I integrated participants' demographic information into this assessment of interrelatedness. This process supported my interpretations of the meanings of themes.

***A priori* theme analysis.**

The four themes from the theory of self-efficacy served as *a priori* themes for this study: mastery experiences, vicarious experiences, social persuasion and physiological indices (Bandura, 1986). Triangulation of data was possible within this study in two ways. First, there were two sources targeting related data: the Participant Selection Survey and the interview protocol. Content from the survey questions was reviewed and expanded upon during the interview. Second, while the interview questions were designed to target the different sources self-efficacy, there was much overlap of content, which allowed me to develop a broader picture of the stories, examples, people, and experiences that participants chose to share.

Bogdan and Biklen (2007) explain that reliability, in qualitative research, is about finding a match between what is actually going on in the context of a study and what is recorded. This study is focused on the context of participants' experiences and their interpretations of these experiences. Participants provided information about different sources of self-efficacy throughout their responses to the self-efficacy interview questions. Therefore it was necessary to examine participant responses to all the self-efficacy interview questions in order to look for representation of each *a priori* self-efficacy theme.

To begin the *a priori* analysis, I examined interview items 13 through 19 for evidence of *a priori* self-efficacy themes. I sought evidence of one *a priori* theme at a time and identified each by highlighting direct quotes relating to each theme on hard copies of participants' responses. I entered the direct quotes for each *a priori* theme into

Microsoft Excel spreadsheets, organized by participant pseudonyms. Each *a priori* theme was given a separate spreadsheet within an Excel workbook.

The coding process for the *a priori* themes was conducted in the same fashion as the process for coding emergent themes. The final stage of the analysis entailed a review of themes seeking relationships among the *a priori* themes. Participants' demographics were considered in this assessment, enabling me to seek groupings and patterns. The interrelations supported the development of findings and conclusions.

CHAPTER 4

FINDINGS

Introduction

Findings from the analyses of participant interview responses are detailed in this chapter. The three sections of this chapter are (1) sources of self-efficacy, (2) assistive technology types, uses and roles and (3) barriers to participation in STEM by people with disabilities**.** Table 10 presents participants' descriptions of their occupations at the time of

Table 10
Participants' occupations

Participant	STEM Career / Studies
Bernadette	Ph.D. student biology; relationships btwn flower scents, pollinators and evolution
Carlos	Computer software developer for AI applications in insurance software
Cera	Ph.D. student science education; working with geology department to improve teaching contexts; developed and teaching a course on inclusive design
Harold	Ph.D. student in computer science; artificial intelligent (AI) applications for wearable computers that support social interactions for people with VI
Herb	Senior principal engineer and proj. manager; designs medical equipment software
Hillman	Keynote and public speaker and consultant on inclusion, AT and diversity
Karl	Professor Emeritus; formerly ran training program for teachers, rehabilitation specialists and mobility specialists for VI people
Kumi	Assistant Professor of computer science (instructor and researcher)
Lars	Assistant Technology Instructor at State Association for the VI, teaching blind adults entering workforce, preparing students for applying AT in college settings
Lina	Associate Professor in software engineering and instruction
Marco	Assistant Shepherd and Young Stock Manager on family dairy farm; also preparing for post-baccalaureate program in dairy science
Marton	Policy analyst at federal agency and project leader for communications AT
Milo	Manager of a partnership for employment and AT in a professional organization for disabilities and technologies; manages partnerships with employers, consumers and technology providers to improve accessibility of corporations and to enhance employment of people with disabilities
Seal	Retired Coordinator of the Information and Computer Access Program and Expert Level Instructional Technology Consultant; ensured that info and comp access available to all people with disabilities at his University
Tina	Computer programmer, specializing in JavaScript
Viktor	Distinguished Professor of paleobiology, researcher, publishing and teaching
Wyatt	Federal government civil engineer, managing water resources
Wilhelm	Ph.D. student in chemistry, researching various relatively large organic formulae; outreach activities engaging blind students in science; founded a nonprofit for chemistry camp

the study. Differences in the experiences of participants by sex, ethnicity, parent education and geography were not identified.

Sources of Self-Efficacy

Mastery experiences.

Mastery experiences were identified as those in which participants experienced success at STEM-related tasks and the outcomes associated with the successful completion of these tasks. All participants in the study identified at least one STEM mastery experience in their interview responses. Three themes emerged from analysis of the transcripts: (1) using resources and learning in STEM; (2) creating and self-teaching in STEM; and (3) STEM mastery experiences in the context of disabilities. The first theme, STEM mastery experiences using resources and learning, is comprised of participants' recollections of their successes in STEM as they engaged with resources to build and practice their STEM knowledge, skills and expertise. Participants' experiences with learning in STEM are also included in this theme. The second theme, STEM mastery experiences in creating and self-teaching, is populated by participants' creative endeavors of research, engineering and technology development as well as their experiences with self- teaching. The third theme emerged from participants' descriptions of mastery experiences in the context of their disabilities. Participants shared how they were able to enact particular STEM tasks in ways that specifically accommodated their disabilities or in ways that capitalized on their strengths. Some participants returned to graduate school later in life. All mastery experiences that were reported to have occurred prior to the completion of participants' terminal degrees were included.

Mastery experiences using resources / learning in STEM.

Twelve participants, males and females with vision disabilities, reported on their mastery experiences of using resources and learning in STEM. Participants from across STEM domains discussed mastery experiences of this nature. Reports of mastery experiences using resources and learning in STEM were categorized into two groups: those unaffiliated with formal education and those affiliated with formal education. For those mastery experiences unaffiliated with formal education, participants reported successful STEM tasks that they conducted outside of formal education settings and that were unrelated to school. The second group of mastery experiences was connected to formal learning in different ways.

Mastery experiences using resources / learning: unaffiliated with formal learning.

Seven participants across STEM fields, six men and one woman, reported mastery experiences of using resources and learning unaffiliated with formal learning. These experiences occurred mostly during childhood years, however two participants reported on experiences later in life.

Hillman, Tina, Harold, Milo and Herb reported mastery experiences with electronic technologies unaffiliated with formal learning. Hillman shared his successes with electronics, saying, "I've built crystal radio sets and other radio things… when I was seven, eight, nine years old". Hillman went on to explain, "In the Boy Scouts, I always got the merit badges that dealt with signaling and electronics and so on" and "I got a ham radio license when I was fourteen". Tina described her early connection to technology, saying, "I started using technology at a really young age". Harold shared, "The biggest one [experiences related to STEM participation] was just my inordinate amount of time spent playing video games as a teenager and preteen". Milo had an opportunity in his youth that led to mastery experiences for him. He shared,

> When I was a junior in high school I got the opportunity to go to the University of State to be part of a research project that was at the Environmental Research Institute there in X State… That's really when I began to delve really deeply into computers. Before that I used computers in school … I had never really used a PC until this research study. It just opened up a whole new world to me. It's when I really learned about the nuts and bolts of computers, operating systems, things like that.

Herb's mastery experiences with electronic technologies were situated in his college years. He explained, "Going through college, I always had some computers to play with, an old TRS-80 and one of the first VT2".

Wyatt and Viktor also shared early mastery experiences of using resources and learning unaffiliated with formal learning. Their experiences were not connected with electronic technologies. Viktor shared the origins of his life-long passion for invertebrates, saying, "I certainly picked up shells, saving them and got into that really early, even before we moved [to the U.S.]". Viktor went on to say, "I got really – really, really, really interested at age ten, approximately, and started collecting shells". Wyatt explored engineering and had mastery experiences through play. He explained, "I really enjoyed playing with LEGOs and building things".

Mastery experiences using resources / learning: affiliated with formal learning.

Eight participants in the study reported mastery experiences using resources and learning that were affiliated with formal learning. They were men and women from technology and science domains. This theme has three subgroups: mastery experiences through the use of school resources; mastery experiences that occurred in preparation for school learning and tasks; and mastery experiences in formal STEM learning settings.

Lina and Carlos recounted their mastery experiences with school resources, specifically those that did not necessarily focus on meeting the requirements of the school curricula. Lina explained, “So I had access to a computer when I was in high school, and I really enjoyed learning about programming and just thought it was very interesting”. Carlos shared his earlier introduction and experiences with computers, saying “… around seven years old, I started messing around with the computers at school and stuff like that”. Carlos went on to say, “Yeah, started messing around with the computers and stuff like that and doing mischievous stuff on the school computers, much to their dismay”.

Tina, Milo, Lars and Karl shared mastery experiences with tasks using electronic technologies that were not necessarily enacted in school settings or using school resources. They were, however, geared toward preparing these participants for school learning and tasks. Tina shared, “So I learned how to type in kindergarten”. Tina said that before she got her first Braille note taker in elementary school, “I’d been using the computer for a little while before that with JAWS”. Milo explained, “I learned to type when I was in the seventh grade, which was a huge benefit for me because it allowed me to do homework and everything else on my own”. Lars had an internship at an assistive technology center during high school and explained that he had experience with AT prior to starting the position. He said, “Had been using a computer for many years already at that point and a screen reader and screen magnification”. Karl took additional courses in methods and analysis during his masters program. Karl explained, “Part of that was learning to use a learning program and so I learned a language called Fortran”. Like Karl, Seal worked in assistive technologies for his career and reported mastery experiences from his masters program. He also shared experiences prior to graduate school when he was preparing for the program. Seal explained, "… I went to community college after work, in the evenings. They had what they called the High Tech Center … they had adapted computers. I learned how to use those". Seal went on to say, "I ended up working part-time in the evenings in the [High Tech Center] lab cuz I seemed to learn more than anybody else about it". Later when he started his graduate program, he sought resources to support him in his program. Seal explained,

> One of the things that I did when I started my graduate program at State University, where I ended up working for 22 years, was I went to the directory of disability services and I said, basically, "Hey, where' the stuff? I know it's supposed to be here. There's adaptive technology on campus here somewhere, because, basically, I know enough to know that's required now." He said, "Well, we just got some but we don't know how to put it together. Do you know how – do you know anything about putting it together?"… Over the next couple of weeks I unboxed it and hooked it up. I knew enough about doing it. Let's just say I knew about 50% of doing it. Not knowing how to do something completely has never stopped me, in my life, from doing something… My success in life, up to that point had been pretty good. Most things I had taken apart I could put back together and make some things better. I had a pretty good level of confidence and also some experience, so I put it together. Then he offered me a part time job…

Lina and Cera reported mastery experiences using resources and learning that were affiliated with formal school settings. Lina shared her mastery experience with electronic technologies and working in groups in her computer science program, saying, "I think that over time, I guess, as I went through coursework, especially as an undergraduate, it went from having individual competence in various areas to being able to bring that skills etc… into working with others". Cera experienced successes learning in the field at geology field camp. Cera shared,

> We were out in basin and range…. It was really that collection of walking around and constantly – in the field, constantly mapping and walking and looking and being confused and figuring it out. It all came together at once. The light bulb goes off and you're like "oh. It's… it all makes sense. I see how it fits now." I ran

> over to [Professor]. I was like "[Professor]! [Professor]! – I get it!" She's like, "Okay. Great. There's no going back." I remember that. That was wonderful.

Mastery experiences of creating and self-teaching.

Fourteen participants, including males and females with vision and physical disabilities, reported on their mastery experiences of creation in STEM in the contexts of research, engineering, development of technologies and self-teaching. Their experiences were facilitated in both within and outside of formal learning settings.

Mastery experiences with research and engineering practices.

Nine participants from science and technology fields reported mastery experiences with research / engineering practices. These experiences provided participants exposure, experience and practice with research/engineering-related tasks. Formal learning settings of high school and undergraduate programs provided few opportunities to develop mastery of research. Participants' responses indicated that they engaged in little to no research at these levels of formal education. Also no engineering mastery experiences were reported in these formal learning settings. More mastery experiences were afforded for participants in graduate programs. Internships and fellowships also provided opportunities for research/engineering-related mastery experiences. Some participants did not provide details about the tasks they engaged in during their internships, fellowships and programs. Since the information about what was accomplished during these internships, fellowships and programs was not clear and could not be inferred, it is not included in this section. This discussion is limited to participant responses that provided adequate details about their internships, fellowships and program experiences.

Eight participants discussed mastery experiences with research in formal learning settings. Bernadette went to a vocational/technical high school where she completed a biotechnology program of study there. She described her high school program, saying "I calculated it was 600 hours in high school of biology… It was like…This is giving me skills, which is nice 'cause it made it easier to go into research". She shared an example of her mastery experiences with research during her high school program saying,

> For my junior year in high school – we had to do an independent research project every year - and I had been doing some work on bioinformatics… so just looking at genes involved in alcohol preference in fruit flies 'cause I had bred these fruit flies the previous year that liked alcohol over water.

Harold and Cera had the experience of presenting their work at conferences in association with their undergraduate programs. Harold worked with a supportive math professor during college and presented a poster at an undergraduate mathematics conference. He explained, "….he kept encouraging me and eventually I did it. It turns out my presentation [at the math conference] was the best one there". While Cera's presentation was not focused on research, it was delivered at a major science society meeting. She explained,

> We also had a, basically, month and a half field course all over the western U.S. led by Dr. X that was really fabulous for me. We did a presentation back in 20XX … [at Major Geology Conference]… on being visually impaired and being in the field. That was fantastic.

Harold and Cera both indicated that they had more research experiences during their undergraduate programs but they did not provide enough detail to be included here.

Five participants from computer science and technology described the research that they conducted for their graduate degrees. For two of the participants, this included their theses as well as additional research. Although they provided little detail about the specific tasks they engaged in for their research, their discussions focused on what the mastery experiences did for them. Lina explained,

> Besides my thesis, I was able to be involved in some research and that really was very appealing to me to be able to think about, "Hey, I can examine or try to move forward and try to make improvements", or whatever you would happen to describe it as, in different things that I think are interesting or important.

Seal shared his controversial thesis topic, saying "They let me do my thesis on information access in the State community college system. Then I hit some resistance when I was doing my research….". Herb briefly recounted his work and the benefit he experienced, saying, "We had to do thesis projects and doing other research on that was just ….the visual impairments never came up". Only Karl provided details about a task of his research. He explained,

> You sat and made this great big list of – these boxes of cards, and you take it over to where the giant computer was, hand it in. They'd run it for you. Then you'd get your printout back out and then it'd have a dollar sign over every mistake you made. Then you have to go back and correct these mistakes, pick out the card. Oh god it was difficult, but I enjoyed it.

Bernadette, Wyatt, Marco and Harold engaged in one or more STEM internships, fellowships and/or programs that involved the creative endeavors of research or engineering. These opportunities were outside the track of their formal education. Bernadette had a science internship during high school that afforded her mastery experiences. She explained,

> I ended up working at the Human Genome Sequencing Center….This is still when we were finishing the human genome…I worked with a couple of postdocs and my P.I. I gave a couple of talks in front of my lab groups. I gave a poster at a poster session. I got to learn programming language and just a lot of interaction….

Marco had a science research-related fellowship one summer during undergraduate. It was not affiliated with his college program. Marco said, “I did a summer fellowship at Name University with the Institute of Accessible Science…I learned more about this format of structuring experiments, grant writing…”. He went on to explained, “I worked like a graduate student on a project…it was actually swine nutrition this time…it gave me an opportunity to do a little bit of the grunt work and also to put together a presentation to summarize results and procedures”. Marco also conducted an experiment on his own near the time of his fellowship and an internship in dairy technology he did not detail. Marco explained,

> …I did a field trial. It was the first field trial of my family farm’s calves…it was hypothesis testing…I was trying to see how much they [calves] drink. That’s very – I mean if you can imagine going out to the barn to feed calves six times a day, it’s a little bit much. A lot of farms feed twice or three times a day. I was testing how much could calves consume when fed twice a day as much as they could drink. It was just a very simple growth trial. That also taught me a little bit about planning studies and how much work there can be when there’s one person running the experiment.

Though few details were included, Harold shared his mastery experience with summer computer science research unaffiliated with his college work. He said, “I spent some time with NASA doing a fair amount of research on machine learning”.

Herb was one of the few participants who worked during college and between undergraduate and graduate school. He shared several mastery experiences with research practices that he had in these work capacities. He said, “Basically the job was to help the graduate students with their research projects, as well as work with the primary investigator to work on her – the primary research projects for the lab”. He went on to explain how important computers were in the research tasks he was required to perform. Herb said,

> We did a lot of non-linear modeling in the biology field, fitting growth equations to data and stuff. You don't wanna do a non-linear regression by hand. You wanna have a computer do that. We do a lot of analysis of using parametric and non-parametric statistics. Again, you don't wanna do that by hand. Yeah, we did a lot of stuff back then on the mainframe with… SPSS …"

Wyatt provided details of tasks he did during his engineering water resources internship with the state. He explained,

> … while I was doing my internship, where we actually did the sort of project planning of coming up with a handful of different alternatives, and ranking them as their best feasibility, their cost, their cost-benefit ratio, and their environmental impact…

Wyatt traced his mastery experiences with engineering back to his childhood. He said, "I enjoyed playing with Hot Wheels cars, and not just playing with the pre-made sets, but actually designing my own. He went on to say, "Then I used to have enough vision to … using markers and large sheets of my dad's drafting paper…. drawing and designing my own cities".

Though participants described some rich mastery experiences with research practices, only half of the participants identified that they had these kinds of experiences. Also, these experiences were more available to students late in their STEM education trajectories, after important decisions about persistence in their STEM fields had been made.

Mastery experiences with technology development and self-teaching.

Seven participants, men and one woman all with visual impairments, described their mastery experiences of creating technologies. These participants were four computer scientists, one technologist and one physicist. Two of this group also explained that they were self-taught in some aspects of technology.

Harold and Hillman focused their development efforts on systems of hardware and software for new technologies. Their mastery experiences with technology development emerged from their realization that they did not have access to assistive technologies that met their advanced STEM education needs because these technologies did not yet exist. Harold explained,

> I'm taking high level math classes and then starting to realize that I can't supplement three hours out of class for one hour in class by looking up stuff in a textbook cuz said textbook doesn't exist, or copy 12 plus boards in 45 minutes and I can't keep up with the monoculars and head mounted camera system… [I came] to the conclusion that I can actually build something that is better than what's out there, and that can actually work for my needs…

Harold linked this experience to his STEM trajectory by saying, "I think this was really what got me into this [computer science research] … what really put me over from just writing code and playing around with computer to, yeah, I can do higher level things". Harold went on to say, "Eventually I ran with that and started thinking about it and asking for $3,000.00 to build a prototype". Hillman went through college decades before Harold. Hillman explained, "I've always been involved in technologies. I was involved very much in some of the early pioneering technologies-type products". Hillman shared, "I actually worked with someone to build an experimental calculator so that I could have access to a reasonably sophisticated calculator that would produce Braille in a way that ended up not being what most people use today". Hillman went on to say, "I actually worked with someone at the college to develop a computer terminal that printed Braille so that I could be able to access computers".

Carlos, Marton, Tina, and Herb all engaged in mastery experiences of developing software. Carlos shared his experience from childhood,

> There was this one particular game I played with I was 11 , and I absolutely loved this game like nothin' else. I said, "Man, I would really love to make a website about this or do something about it." One of my friends told me about this way that… you could technically make websites cuz it was sorta like a drag-and-drop thing. I had no knowledge of this stuff and just started getting into that. From there, that spawned my branching off into slowing getting more and more technical.

Marton, Tina and Herb shared mastery experiences associated with their creation of technologies supporting the engagement of people with vision disabilities. Marton got a scholarship in graduate school for a computer, which enabled him to begin exploring and creating. Marton explained,

> I started with writing screen reader macros to do some things with the screen reader more quickly… starting out with a menu driven database system and seeing how I could configure it for tracking different kinds of information. Then getting into actually programming database systems.

Marton went on to say, "Over the years, I've written a dozen or so free open source computer programs that I make available over the Web for people to download and use". Tina designed a program to enable her electronic Braille writer output math-specific Braille language. Her discussion of this is found in the assistive technologies findings of this study. Herb shared his development work, saying, "Technology makes all that [screen reading] accessible. I've done a lot with embedded stuff. A lot of the embedded tools are really, really accessible and pushing the boundaries there…".

Harold, Herb and Seal shared their mastery experiences with teaching themselves technology. Harold took a semester off of community college to try to determine what he could pursue in college that would be feasible and enjoyable. He worked his way through a bookstore, reading about all kinds of topics. Harold explained, “Eventually I gravitated back towards the computer science section and the computer section, and from there, taught myself programming, and the rest was history”. Herb was also self-taught in facets of technology. For his jobs during and after his undergraduate degree in mathematics, Herb worked for researchers and the job required work with data. Herb explained,

> … I never had a formal degree in computer science. I had Fortran but I taught myself C and C++ and Assembler cuz a lot of those first two jobs at the cardiology department with Dr. Z [required me to] write customized software for data collection. Before you can analyze the data, you have to collect it, obviously. Writing software to collect the data from different hardware and so forth. Then, obviously, putting the data in some sort of usable form.

Seal started with electronic technologies later in life. Before he decided to go back to school for a graduate degree, he acquired his first computer. Seal explained, “He [blind acquaintance] sold me his Apple IIe with the speech synthesizer and basically held my had for about six months while I learned how to use it – self-taught, so to speak”.

Mastery experiences in STEM affiliated with disabilities.

Eight participants from across STEM domains, men and one woman, reported STEM mastery experiences in the context of their disabilities. Two groups of experiences emerged from the transcripts. They were reports that emphasized the good fit between the participants and their STEM tasks. There were also reports that emphasized the accommodations enacted by others to support participants’ STEM mastery experiences.

Seven participants, all men from technology and engineering, shared mastery experiences that focused on how STEM tasks worked well for them in the context of their disabilities. Harold, Carlos, Wyatt, Marton, Herb and Kumi shared similar stories of success with computers and their disabilities. Harold explained how he excelled with computers as a youth,

> … the computer screen, on the monitor, was one of the few areas where my vision and my disability was least affecting my performance. There were times as a child where we'd play these shooting games and there's 60 other people on the same game. Sixty other people. It wasn't unusual for me to come out in first place without any assistive technology or cheating or anything.

Carlos shared, "It was one of the things that I could really do that was uninterrupted by just the visual disabilities and stuff like that". Marton explained, "I did find that I could do computer programming independently [unlike other aspects of math and science]." Wyatt used computers heavily during his internship and explained,

> I got an internship with the State … Department of Water Resources … mostly working with water quality data and building off some of the required education that I had to take … and found that it was something I could do.

Kumi left physics and medical imaging for computer science, explaining,

> That's when I changed my type of research to computer science and access technology … feel like the environment was much better and there was more to pursue – the interest was the same but there were less barriers, if that makes sense."

Herb shared his process for working with data for his laboratory job prior to graduate school, saying,

> One of the weird things – it's strange to have a visually impaired person doing, but a lot of the initial stuff with Dr. Z was image processing. You treat that as a matrix and do some matrix arithmetic on it and there you go. Yeah and I could see the black and white images if I got close enough, put my face right on the screen … Since it was an image I could manipulate, I could mask out some things I didn't wanna see …

Herb went on to say,

> … the thing about being successful with a visual impairment is being creative. If the standard ways don't work, ok. Then I'd think, well, how in the hell can I do this and not bother anybody and get it done myself?

Wilhelm also shared a mastery experience but it was different in nature from the rest of the group of experiences focused on participants and their successes with STEM tasks in the context of their disabilities. He shared a mastery experience he first had in high school that was later reinforced in college that was conceptual in nature, rather than STEM-task focused. Wilhelm said,

> What I realized is, “wait a minute, I am using the same skill as in organic chemistry that I’ve used for my whole life as a blind traveler” – because I am visualizing everything around me. I need to make these visual images because I can’t see the streets that lay out the State University campus, for instance. I have to keep it in mind. If I have different things in my mind in miles and kilometers and whatnot, there’s no reason why I can’t shorten those distances down to angstroms and really tiny distances, and apply the same knowledge to atoms and molecules.

Cera and Wilhlem shared STEM mastery experiences that integrated accommodations that were made for them. Cera provided details about two specific experiences. After being granted permission to sail on a research cruise during her marine geology fellowship, she joined the research team on the vessel. Cera explained, “We had a system, a buddy system that worked out, and it took a couple of days before they [captain and crew] were like, ‘She’s fine. I don’t know why we were paranoid’”. Cera also shared her perspectives on having gone to geology field camp, saying “They really took on a big risk, I think, taking me out there and we made it work. It was fun.” Wilhlem shared his experiences with the chemistry lab that he was working in at the time of this study. Wilhelm said,

> … I met my current boss in undergrad. He said, “Just come try doing some research in my lab.” They made the laboratory accessible to me. Just one thing led to another and I realized, “Wow, I can go to grad school in chemistry….”

Wilhelm went on to say, “The things that we’re doing now with the scripting that we’re writing for the 3-D printer and with the stuff that I’m able to compute with the accommodations we’ve made that I never thought was possible”.

Conclusions.

Table 11 provides an overview of contexts in which participants had STEM mastery experiences. Participants in the study reported a variety of STEM mastery experiences that occurred in several different contexts including childhood informal situation, formal learning contexts, internships / fellowships / programs and other settings of independent work and the job setting. Many of the mastery experiences reported by participants in this study were in some way

Table 11
Overview of context for STEM mastery experiences as reported by participants

Participant	Childhood (Unaffiliated with formal)	K-12 (Affiliated with formal)	College (U/G) (Affiliated with formal)	Internship / Fellowship / Program (Unaffiliated with formal)	Other (Unaffiliated with formal)
Bernadette		X		X	
Carlos	X	X			
Cera			X	X	
Harold	X		X	X	
Herb			X		X
Hillman	X		X		
Karl			X		
Kumi			X		
Lars		X			
Lina		X	X		
Marco				X	X
Marton			X		X
Milo		X		X	
Seal			X		X
Tina	X	X			
Viktor	X				
Wyatt	X			X	
Wilhelm		X	X		

affiliated with the formal learning environments of K-12, undergraduate and graduate school. One-third of participants identified STEM mastery experiences in childhood outside of formal school. Some participants detailed how their disabilities were involved in their success at particular STEM tasks. It was evident from participant responses throughout the interviews that participants valued the role of their STEM mastery experiences in their choice and participation of STEM career.

Social persuasion.

The theory of self-efficacy includes social persuasion as a source of information that supports individuals in their development of beliefs about their abilities to successfully complete tasks or performances. Social persuasions are messages that come to a person from those around them in response to their choices and attempts to engage in activities. Participants received a variety of messages from those around them. All the messages participants received were classified as either supportive or unsupportive. Various types of persuasion were identified within the groups of supportive and unsupportive messages. Participants received these social messages from three groups of people in their lives. These were undefined groups, individuals outside of STEM and individuals in STEM. Overall, participants reported more supportive messages than unsupportive ones.

Unsupportive messages.

The three types of unsupportive messages that participants received were restricting (R), skeptical (Sk) and corrective (Corr). Restricting messages were those in which participants were told that, because of their disabilities, they were not permitted to engage in activities, they were not welcome, and/or they were not capable. Messages of skepticism came from those who doubted the participants' ability to be successful in particular activities. Doubt was linked to participants' disabilities. Individuals also questioned the value of things the participants expressed interest and/or they did not understand what the participants were trying to do. Finally, participants received corrective messages from those around them. These messages indicated that the participants needed to make changes to their decisions and actions. Individuals communicated that they had a better understanding about the participants' limitations and the types of activities in which the participant should or should not engage. Participants also received messages that they were making wrong decisions and/or that they were not conducting themselves appropriately given their disabilities.

Supportive messages.

Supportive messages came to participants in the forms of acceptance (Acc), membership (Mem), encouragement (Enc), high expectations (HE) and advocacy (Adv). Messages of acceptance were those suggesting that people had come to accept that the participants were following their own paths. Acceptors permitted participants to be in classrooms, upheld required accommodations and allowed participants to have experiences in various contexts. Messages of membership came from individuals who indicated that the participants should not only be engaging in the tasks and activities but also that they belonged to the group in the context of the tasks. Messages of encouragement came to participants through support and praise. Some participants reported that individuals held high expectations for them. High expectations were distinctly different from other supportive messages. High expectations demanded actions and outcomes on the part of the participants to meet various challenges. Finally, participants received messages of advocacy. Messages of advocacy went beyond expressions of confidence in participants' ability to be successful. Those who gave participants messages of advocacy also took action to remove obstacles related to participants' disabilities that could bar them from engaging in activities and tasks. Advocacy included messages that blended encouragement, high expectations and membership along with actions to remove barriers. Table 12 shows the types of social persuasion that participants received about their choices and attempts to engage in STEM.

Table 12
Types and quantities of social persuasion participants received in response to their STEM engagement

Participant	Unsupportive			Supportive				
	Res	Sk	Cor	Acc	Mem	Enc	HE	Adv
Bernadette		x			x	xxx		
Carlos						xx		
Cera	x	x	x		x	xx		xxxx
Harold				xxx	x	xxx		
Herb	xx		x	x	x	x	xxx	x
Hillman	x					xxx	x	x
Karl	xxx	xx	x		x	x		
Kumi						x		
Lars			x		x		x	
Lina			x		x	xx		
Marco		x				xxx		x
Marton				x		xxx		
Milo				x		xxx	x	
Seal		xx	x			xxxx		
Tina						xx		
Viktor	x	xx		xx	x	xxxxx		x
Wyatt						xx	x	x
Wilhelm	x	x			x	xx	x	xxx

Individuals who provided messages of social persuasion to participants.

There were three groups of people who provided messages of social persuasion to participants about their engagement in STEM. Messages came from undefined groups, individuals outside of STEM and individuals in STEM. I could not discern from the context whether those from the undefined group were from STEM fields or from outside of STEM. Participants referred to them as “everybody”, “people” and “anybody”. Individuals from outside of STEM included friends and family, professors and teachers as well as professionals from the disability community. Individuals in STEM who provided messages to participants were teachers, college faculty and peers, those participants met in STEM research experiences and individuals associated with STEM work. Participants reported few messages from other individuals with disabilities.

Messages from undefined groups in participants’ lives.

Participants discussed social messages that they received from groups they did not explicitly identify. Thirteen participants, males and females from across STEM domains, shared messages they received undefined groups. Messages from them were more negative than positive.

Participants received a range of unsupportive messages from the undefined groups including corrections, skepticism and restrictions. Herb explained, “Some people have told me that because I’m visually impaired, ‘You need to do this. You need to do that, and get a cane,’ and all this”. Cera and Karl also described messages they got about the “shoulds” and the “should nots” they were supposed to be adhering to because they had disabilities. Cera explained,

> So often, with good intentions in mind, people will try to tell your story for you. They'll try and tell you what you are and are not capable of doing. They'll try to judge that, and with the best of intentions, try and basically impose some situation on you, as opposed to telling a story with you or really making decision together in a way that is more open, and allows me or whoever the individual may be to decide for themselves and figure out for themselves what they can and can't actually do alone and with the help of other people. It's a very tricky balance, and it's different for everyone. It's very important that that's not decided by somebody else. It robs you of your autonomy if that happens.

Lars said,

> Actually, there was a lot of disappointment from a lot of people when I decided to choose this career [assistive technology trainer]. I was supposed to do something different, I think, according to a lot of people. That didn't work out. I think a lot of people wish I had been a lawyer so I could have taken – more of a front line role in blindness issues…I think there were a lot of people in my life who really wanted me to go to Washington and argue with people.

Disability is not the only aspect of participant characteristics that came under scrutiny. The issue of the intersectionality of sex, disability and STEM participation was raised by Lina. She said,

> ….I think for the culture and all that a lot of it is, "Oh, there aren't very many women and women really aren't into technology, " and things like that. It's just like, "That's not really true. You just think it is."…..well, you kind of have to work a little harder kind of thing [being female], which for me, actually, I had to work even more hard to go over the issues of accessing information and that.

These messages differed widely in their content, but the message was consistent. Participants were being told that they were not behaving appropriately as blind individuals. They needed to be redirected and corrected by those without disabilities, often with good intentions.

Karl and Seal, who were both over 60, experienced skepticism and restriction from this general group of others. For Seal, skepticism was based on ignorance. Seal was pioneering in the field of information access. He explained,

> Other people, I think they had not idea what I was doing. Well, they didn't understand the magnitude of it, in a sense…I think they were a little puzzled by it because, sometimes, I think people expect, if you're gonna be an engineer, we know what an engineer is. This is, well, I don't 'know exactly what it's gonna be because it's not there yet.

For Karl, unsupportive messages were related to both ignorance and his blindness. He explained, "I grew up [where] almost nobody had a college education – they had no idea what college was about". He went on,

> For the most part, I was discouraged from going to college and discouraged from this and discouraged from that. Told no, don't do that and don't do this…I was discouraged because I was severely visually impaired. You can't do all that stuff because you're blind.

Karl also said, "Ok, I never got an encouraging word…This was years ago when everybody thought that blind people couldn't do anything".

Six participants shared supportive messages from undefined groups. Tina recalled, "Well, most people were, you know, supportive and encouraged me to do it". Wyatt shared his experience, "I got a lot of very positive [messages]… even if they weren't sure that they knew the answer of how I would do something, or may not have even known the best method". Viktor, Marton and Milo received messages of acceptance of their STEM choice. Viktor explained, "I never had any significant pushback from anybody" and Marton said, "Honestly, I can't say that I recall anybody discouraging me". Milo said,

> Back when I grew up in Michigan, a lot of people were just going to work in a real blue collar area. Go to work for one of the automakers, that kind of thing. I was different just because of my disability. People knew that I was gonna have to go on a bit of a different direction at that time.

Messages from individuals outside of STEM.

Individuals outside of STEM provided messages of social persuasion to participants about their choices and attempts to engage in STEM activities. Messages were largely supportive, though there were some reports of restriction, skepticism and correction. Family, friends, pre-college teachers and those from the disability community provided the most supportive feedback.

Family and friends.

Thirteen male and female participants, across STEM domains, reported on social messages that they received from family and friends outside of STEM. In general families and friends were supportive of participants' choices and efforts to pursue their STEM trajectories. In contrary cases, it appears that family members expressed skepticism because they were unsure about where their children's STEM pathways would lead.

Three participants experienced skepticism from their families, specifically their parents. In each of the families, the participants' parents did not understand what it was their child was seeking to do or striving toward. Since they did not have experience within the fields and careers that their children were seeking to pursue, these parents expressed concerns, disapproval, and skepticism about their children's abilities to be successful. Karl, now 70, explained that his mother, by this time a widow running a farm in a small Midwestern community, was anxious about him applying to college. He said, "My mother didn't exactly know what I could do. She was kinda reticent about it – I mean she didn't know." Bernadette's father worked in the oil industry and expressed concern about her choice to pursue a STEM academia career, like her mother and stepfather. She explained, “My dad is still very concerned about my ability to get a job in academia. He keeps asking me about alternative careers that I might pursue”. At the time of the study, Marco was 24 and was struggling with his parent’s skepticism. He told me,

> My parents were – and still – questioned my decision to do that [study dairy science in college] but they tend to question a lotta things just as to my ability to be able to do it because they’re kind of of the opinion that if they don’t know how it works, they’re skeptical. I’ve come to realize that.

Nine participants described supportive messages they received from family and friends outside of STEM. Participants received messages of encouragement, high expectations, advocacy and acceptance of their efforts and choices to follow STEM pathways. Some participants received general encouragement such as Herb who recalled, “My mom and dad were always, ‘Do what you want. Whatever you want, go for it and do it’”. Kumi’s family encouragement was less about computer science than it was about higher education. He said, “…within family, everything was very positive, they were very supportive…. Growing up it wasn’t really clear what job I would get but they said don’t worry – always think about college”.

Three participants received messages of high expectations and advocacy for their choices from family members. Milo and Lars’ described the expectations their parents held for them and their impact. Lars explained, “I mean, expectations have always been high – when your parents have those expectations of you, it helps, obviously…”. Milo shared, “…my mom raised me as a really independent child as well as adult”. Harold described an incident in which his vice principal denied his request for early graduation despite completing all high school graduation requirements and success in community college classes. He had a number of individuals who advocated for him, including his parents,

> The principal said, "Harold, I have no doubt that you could do this or can do this, but I'm worried that it will set a bad example, an example that other students will not be follow, and so I'm going to accept these credits, and I do not want you to do this. We will not take them." Yeah. Basically, I reported that to my parents and to my orientation and mobility instructor, to a couple of my teachers. By the next day, we had an army of seven people, including myself, marching into the principal's office demanding that this be resolved.

Alongside advocacy, Harold 's family provided messages of acceptance about his decisions. He explained,

> There was this perception that college was just probably going to happen. Family would support what I did, but it wasn't them who were taking the initiatives to propel me forward, if that makes sense. It was this feeling like, the only person that can make this happen is me, and people in my family – I became increasingly aware that people in my family didn't actually have a very strong model of academia, right? I realized that although my family supported me, not only were they not the ones driving me forward – I had to come within myself – but also that they couldn't really advise me well on how best to proceed.

Seal, Wilhelm and Milo mentioned supportive messages they received from friends. Messages from this group were strongly positive. Karl shared his experience with messages of membership in his academic community during college. He said, "Those are my buddies [academic fraternity brothers] and they treated me really well". Wilhelm talked about the encouragement he had from his friends, saying,

> Really close friends…that I've known since I was like six years old that I live with now. ….they're supportive of whatever I want to do. The truth is, your [closest] friends and your family are just as important as your NSF grants…They keep you going just as much as every other positive resource you have.

Professors and teachers.

College professors and pre-college teachers outside of STEM differed in the nature of their social persuasion, according to participants. Messages from non-STEM college faculty were largely unsupportive but messages from non-STEM teachers were dominated by supportive feedback.

Three participants shared the kinds of social persuasion they received from college professors and it included messages of skepticism, correction and acceptance. Seal was met with skepticism from the Dean of the education program where he applied following his realization of his dream to advance access to information for individuals with disabilities. He shared,

> I explained to him [Dean] what my vision of where I wanted to go and what I wanted to do. He was a bit reluctant, I think, because he didn't even know what to make of this. This had never been done.

Karl and Seal experienced instances of correction. His fraternity advisor, a man Karl greatly admired because he held academic achievement in the highest regard, tried to convince Karl to change his major,

> Doc tried to talk me into – he thought that mathematics would be too difficult for me. Now he had his heart in the right place. No worries about that. He was gonna do a favor and go put together a kind of social studies – Yeah, a major. Kinda like you'd do history and little science and little sociology and that kinda thing. I said no. I was very polite and told him I appreciated his thinking, but I was gonna be a math major.

Seal received a message suggesting that he was wrong in his thinking and needed to be corrected. He did his graduate thesis on information access in the State University system. As he sought to connect with individuals he met with resistance to his ideas about equitable access to information. He said,

> What good is it if you get in the door [of the library] but you can't access the content – had a number of people – matter of fact, the chair of the department of special education flat-out told me, when 504 says access to programs, services and activities, they didn't mean that [accessing the content].

Harold received messages of acceptance but little else from his professors. He shared,

> By and large, the professors that I had…saw me as a capable individual, but doing my own thing or unique because I often had these accommodations requests that I would ask of them. They granted them graciously and without …ever any rancor or issue, but I don't think that I had really substantive relationships with most of my professors.

Five participants shared messages they received from pre-college teachers outside of STEM. The teachers provided participants with messages of high expectations, encouragement, acceptance and a message of restriction. Karl recounted a story of the restrictive message he received from his high school English teacher who announced aloud in class the names of students he felt should go to college. Despite his high achievement in the class, Karl was not named, he said, "He didn't name me. I was, if not the smartest kid in class, the second smartest kid in class…well that's because he thinks that I can't go to college because I'm blind".

Other messages from teachers were supportive. Herb shared, "I had a couple really awesome teachers in high school, never treated me any different than any other student. Always expected the same, never expected anything different." Milo told me, "I had some really excellent teachers early on in life that were really enabling for me – just really good at learning and keeping my confidence high and just encouraging me…the sky's the limit kind of stuff".

Viktor and Harold met with acceptance from their teachers. Viktor explained, "I had a lot of teachers who certainly had no problem with it [being in mainstream environments]". As with his college professors, Harold did not find that teachers were unsupportive, they were simply accepting. He explained, "… most teachers …never held me back or got in the way, but I would say they didn't really propel me forward or inspire me, except for a couple".

Disability community.

Three participants talked about supportive messages of advocacy and encouragement that they received from individuals associated with the disability community. Herb and Wilhelm shared their experiences with special education assistants. Herb recalled the support he received from the special services reader with whom he worked after he pushed to be mainstreamed for high school after being in a resource room in prior years. He shared about the reader, saying "[He was] Just was always supportive…always there and helped". Wilhelm discussed his assistant in college, saying, "She really became such a wonderful assistant. She is so brilliant…taught herself to Braille in a month so she could Braille [for me]".

Marton said that over the course of his college and career pathway, he received the most encouragement from the National Federation of the Blind. Shortly after he lost his vision, he found support in NFB. He explained,

> The leader of the organization (NFB) at that time was a very inspiring speaker. I used to listen to recordings of his speeches about blindness and the capabilities of blind people and how, if we could change attitudes in society, then we could have much better opportunities as blind people. That first actually made me even believe that I could succeed at a school like Princeton and take on a subject like engineering.

Messages from individuals in STEM.

Eleven male and female participants across STEM fields reported messages of social persuasion from individuals in STEM. While there were messages of restriction and skepticism, individuals in STEM provided overwhelmingly positive feedback and messages to participants.

STEM teachers.

Four participants, from across STEM domains, described messages they received from STEM high school teachers. These messages were primarily supportive. Tina shared, “My AP computer science teacher was pretty amazed when he saw some of the stuff I did”. Wyatt experienced high expectations as well as advocacy from his teachers. He explained, “[There were] A handful of teachers throughout the years in school and teachers who encouraged me to take challenging math and science courses and who gave me the opportunities to do that”. Wilhelm received complex feedback from his high school chemistry teacher. He explained that at first she gave him restricting messages, saying,

> …she always told me, ‘Chemistry is impractical and you shouldn’t study chemistry as blind guy. But it’s so much fun and I’m trying to tell the class, you should all do chemistry’ I loved the subject but I was being discouraged by her.

Halfway through the school year Wilhelm explained to his teacher that he was uniquely qualified to study chemistry because, at a molecular level, it is not visible to anyone. Therefore the skills that he used to understand spatial relations and distances for daily navigation had trained him to think about spatial relations and distances on a molecular level. Once she understood his reasoning, she shifted to being supportive, he explained, “She got that and became a huge ally of mine”.

Individuals in STEM college departments.

Eight participants shared messages from their STEM college experiences. Messages came from college faculty and peers from STEM college departments. College faculty who provided messages of social persuasion to participants included college professors, advisors and a dean. Few participants made distinctions between graduate and undergraduate faculty therefore, the discussion of messages from all college professors was combined.

While messages from college faculty were primarily supportive, three participants reported messages of restriction and skepticism. All of the unsupportive messages were delivered in the context of science. Herb, who was majoring in mathematics and Hillman both faced messages of restriction. Herb reported, "I remember the [chemistry] professor saying to me…'I don't want a blind person in my lab. You take my class, I'll flunk you". Hillman shared, "I learned later that one of the professors at U State wrote a letter and put it in my file, that said, 'A blind person couldn't possibly absorb the material to get an advanced degree'". Viktor explained the skepticism he faced as follows,

> That's when I was applying to graduate school. The director of graduate studies at Ivy University was obviously incredibly skeptical and he took me down to the museum and asked me what certain things were. I answered them and he said, "Ok, you have convinced me", and he was a major supporter thereafter.

Just as Wilhelm had to convince his high school chemistry teacher, Viktor had to convince the STEM specialist of his abilities. For both men, the specialists became supporters. Both Wilhelm and Viktor converted skeptics and restrictors to supporters more than once.

Messages of support from college faculty were reported by seven participants, four of whom were in science programs. Four participants were given supportive messages from college professors. Harold recalled how he was encouraged saying, "… with professors who took me under their wing and pushed me to do some [research]".

Cera, Wilhelm and Viktor received messages of advocacy from STEM college professors. Cera reported, “She [structural and tectonics professor] was awesome and just so creative in figuring out how to make things work with me and providing me with undergraduate research opportunities”. Wilhelm shared that he did not think graduate school would be possible because of the obstacles associated with his visual impairment and laboratory research. He told me about how he was connected with the researcher who changed his mind about this saying, “…[I had a] professor who I was taking a class from who said, ‘Listen, you can probably do computational chemistry if you want to. Let me introduce you to my friend”. Viktor experienced resistance from the State Commission for the Blind who would provide some funding for his college. He received messages of advocacy from his STEM professors once he was in college. He explained, “I hafta say particularly encouraging were these professors at Ivy University, who in fact wrote the State Commission a letter saying, ‘It’s our business – not yours – what he’s gonna major in’”.

Marco and Herb received supportive messages from their college advisors. Marco shared, “…my [biology] undergraduate advisor has been really, really supportive of that [his choice to go into research], even with my disability. That has given me – certainly instilled a desire to do it”. Herb experienced high expectations from his advisor. He shared,

> ...my advisor for my masters degree…Just a brilliant professor in her field, and did a lot of interesting stuff. We had to do thesis projects and doing the research on that was just – and the same thing. The visual impairments never came up. She said, “This is what we need to do. Go do it.”

Hillman told of the encouragement from the dean of his college who was a Nobel Prize winner,

> He and I had lots of talks about experiments, blind people doing stuff. He just naturally right from the start was absolutely in favor of my being involved in physics and technology and doing what I did…He said, "If I could do that, certainly you could do that".

Messages from STEM peers and friends were also mostly supportive. Four participants discussed what they heard from STEM peers and friends. Lina shared the sense of membership she experienced saying, "…good community and network of friends and that sort of thing – a lot of us were in the same major or similar majors". Harold also experienced messages of membership in college after finding his high school friends to be disinterested in academic pursuits. He made college friends who were interested in exploring computer science concepts in their free time, saying, "I cherry picked a handful of people during undergrad that started accumulating slowly and gradually that really were actually – if not pushing me forward, at least they were not holding me back."

Hillman shared two contrasting messages from peers. He shared the restricting message from his physics peers in graduate school. He said, "a lot of the other students had study groups and so on, but their perception was that if they had to describe things to me, it would have slowed them down in what they were studying". He explained that had he been able to break into those groups, it might have enabled him to be more successful in physics. Hillman also experienced a message of advocacy from a peer in computer science. Hillman explained,

> …the guy who approached me and said, "I heard you're trying to build an accessible computer terminal." He was in computer science. He and I worked

> together to do that. He did a lot of the work…and I was involved, of course, as the guinea pig. The fact that he did that, and was willing to be involved on that project was, I think, an influence on me going forward with it.

Wilhelm and Cera shared the messages they received from their college science departments. Cera talked about messages of membership, saying, "The whole department has this very close community family kind of, everybody takes care of everybody". Wilhelm had another experience in which he needed to convince people. This time they were skeptical. He shared, "…people were skeptical when I was starting in undergrad. They didn't think it would be practical or possible for a blind person to study chemistry". He went on, "I showed them little by little of what I could do. It was really exciting, because their opinions turned. I saw them shift slowly. Now, they're just such great supporters and allies, everyone I work with."

STEM research experiences.

Participants encountered individuals in STEM beyond their school and college-based STEM experiences. Through extracurricular research opportunities, participants were afforded opportunities to get to know STEM professionals. Like much of the feedback from the STEM community, participants received largely positive messages about their engagement in STEM.

Bernadette, Cera, Marco and Harold engaged in research experiences before completing their schooling. They met STEM professionals who provided supportive messages about their engagement in STEM research. Bernadette described the supportive messages of membership that she received during a summer internship in high school. "I was clearly a high school student but I was being treated like I was a productive researcher person and that was really – it was just really nice".

Cera received advocacy messages during her research experiences at geology field camp and an oceanography fellowship. She explained, "We…had a month and a half field course all over the western U.S.…that was really fabulous for me…. They really took on a big risk…taking me out there and we made it work". Cera and her field camp professor gave a presentation at a geology conference about visual impairment and field camp following her participation in the program. Following an incident in which NOAA denied her access to participate in a research cruise when her college professor sought to take her, Cera again faced resistance to her decision to go sea. This time, Cera was in a research fellowship at a major science institute and had two visually impaired researchers advocating for her. She explained,

> "Both [researchers] had been to sea multiple times…At first the captain was like, "No way." [The visually impaired researchers], the lead PI and the captain all got in a room. When you've got two established blind researchers sitting there telling you, "She can do it", you better take them out to sea. We had a buddy system that worked out and it took a couple of days before they were like "She's fine. I don't know why we were so paranoid".

Harold and Marco received messages of encouragement during their research experiences. Marco talked about the dairy nutrition consultant he met during his research internship. He said, "Dr. Professor has really been helpful well, really encouraging and really positive…in my decision to go on and do research". Harold had multiple research experiences during his undergraduate program and received supportive messages from individuals in each context. He explained that it started with a math professor, saying, "Through the … undergraduate research initiative I had some very positive interactions with a [math] professor…who encouraged me to publish – to submit a paper to an undergrad math conference… Then he kept encouraging me and eventually I did it…".

Later Harold conducted research with a computing group at his university and then at NASA. Their feedback was encouraging and gave Harold direction,

> …there was some of the mentoring that came from specific individuals…who were much more focused in saying, "Okay, you want to go to grad school? You need to publish. You'll need to do these things. You need to get grants." That was very good….

Harold developed an assistive technology to support his class work that he later brought to market. The STEM individuals he met through his research experiences provided supportive feedback that led to his decision to attempt a design solution. He said, "It was really just me stating difficulties and problems as staff members would have lunch with me and talk about how things are going. Eventually they said, "Why don't you try and fix it yourself?"

Individuals associated with STEM jobs.

Participants described experiences they had with individuals associated with their STEM jobs or jobs they were trying to get. Individuals associated with STEM jobs are supervisors, hiring specialists and work colleagues. Four participants shared messages they received from these individuals. While participants received messages that were mostly positive, there were some messages of restriction and skepticism.

Herb and Viktor reported unsupportive messages during their job seeking process. Herb described the interviewing process he experienced and the restrictive message he received, explaining,

> I've had interviews where it's great talkin' on to people over the phone. You see 'em in person and they see the non-standard way my eyes look and … Not being able to have the opportunity to even talk to somebody when they just give you lip service just to get you out and move to the next person.

In the job market for a professorship, Viktor again faced skepticism, as he did when he was entering graduate school. He shared,

> One was at the University of State and again, the chair of the department was, I think, quite reasonably skeptical. He said, “Okay, I’m gonna give you a chance and if you work out the first semester, you will be promoted to assistant professor,” and he was as good as his word so who can complain?

Herb, Hillman and Wilhelm were given supportive messages from supervisors and colleagues in the STEM work context. Herb experienced membership from his engineering work colleagues. He explained, “Mostly cuz my eyes….they look a little different. They have like a white over so it’s …[i]t’s very obvious, but my colleagues at work, it just hardly every comes up”. Herb, Hillman and Wilhelm all reported that their supervisors held high expectations for them. Hillman was hired for demanding work on the exciting collaboration between Ray Kurzweil and NFB, in which Kurzweil reading machines were to be installed and piloted across the nation for individuals with visual impairments. Hillman shared the message he received from the head of the NFB when he was being recruited. He said,

> [The head of NFB] said, “We want you to do this job, and what the job is gonna require is you literally travelling around the country for 18 months. You won’t be staying anywhere.” Literally, I lived in hotels out of suitcases for 18 months. I would never trade it for anything. It was a lot of fun. That was good too.

Wilhelm was hired to work in a chemistry research lab during his graduate work. He shared the message of high expectations he got from his supervisor, “My boss, when I joined the group, he had more faith in the fact that we could make this work than I did”.

Conclusion.

Every participant in the study shared instances of social persuasion that they experienced. Most participants received both supportive and unsupportive messages from those around them as they explored and pursued their STEM fields. No participants, however, reported that they received only negative feedback. Participants described how they overcame negative messages that they received. They persisted despite the lack of support from some individuals and groups. Though the undefined groups provided the least positive feedback, there were supportive messages provided from each of the three groups identified by participants. Individuals and groups provided participants with social messages at all points along the STEM pipeline, ranging from childhood to school to college and work.

Vicarious experiences: role models.

Vicarious experiences were hypothesized by Bandura to be one of the four sources of self-efficacy beliefs (Bandura, 1977). Unlike mastery experiences, which involved participants directly, vicarious experiences are those in which participants became observers. Role modeling provided the vicarious experiences that are addressed in these findings. In the context of this study, participants observed role models as they engaged in STEM tasks, practices, experiences, and careers that were related to those that participants would come to enact in the course of their own lives.

Participants rarely used the phrase "role model" to describe the people who have been identified as role models in this analysis. Instead, they described people in their lives who modeled STEM practices and undertakings that influenced participants' thinking, perspectives, understandings and decisions regarding STEM participation. I identified as role models people mentioned in participant responses when they were described as enacting STEM practices that were relevant to participants' STEM pathways. Many participants provided detailed information about role models. Some did not, so details such as when and under what circumstances participants encountered their role models are not clear. Even the number of role models was unclear for some who referenced groups of coworkers or supervisors. Experiences with role models that were reported by participants were consistently positive. There were no negative role models discussed by participants.

Fourteen participants identified role models in their interview responses. Participants found their role models in a variety of contexts. Four sources were most prevalent: teachers, professors, people they worked with in internships, parents, and people they met through the National Federation of the Blind. The four participants who did not identify role models were from computer science (i.e. Lina, Milo, Carlos and Herb). There were two computer scientists who did identify role models. However, the group of seven participants who identified three or more role models each was comprised of only scientists, engineers and non-computer science technologists. Table 13 provides the counts on the kinds of role models participants described.

Participants identified role models with and without disabilities, in and out of STEM domains, people from the same or different STEM fields and domains and people inside and outside of their families. They also identified disability specialists as role models and several described the need for role models. Two main groups of role models emerged, those from STEM domains and those from outside of STEM domains. From the group of STEM role models, I identified those who participants encountered prior to college and during college. In both of these groups, there were people with and without disabilities.

Table 13

Participant Fields, Domains and Role Models in and outside of STEM

Participant	STEM Field (Domain)	Role Models in STEM				Role models out of STEM w/ Disabilities
		W/out Disabilities		With Disabilities		
		Pre-College	During College	Pre-College	During College	
Bernadette	Ph.D. Student Bio (S)	3	0	1	0	0
Carlos	Comp. Sci. (T/E)	0	0	0	0	0
Cera	Marine Geo/Ph.D. Student Sci Ed.(S)	0	0	0	4	1
Harold	Ph.D. Student Comp. Sci (STEM)	0	1	0	0	0
Herb	Software Eng. (E)	0	0	0	0	0
Hillman	AT Consultant (T)	1	1	0	0	1
Karl	AT & Disability Professor Emeritus (T)	1	0	0	0	0
Kumi	Asst. Professor Comp.Sci. (S/T)	0	0	0	0	0
Lars	AT Instructor (T)	2	0	0	0	1
Lina	Associate Professor of Software Eng. (T)	0	0	0	0	0
Marco	Asst. Shepherd /Young Stock Manager (S/T)	1	1	0	0	0
Marton	Director Federal AT Program (T)	0	0	1	0	1
Milo	AT Project Director (T)	0	0	0	0	0
Seal	Coordinator of Info & Computer Access Program, Emeritus (T)	0	4	0	5	0
Tina	Software test engineer (T)	0	0	1	0	0
Viktor	Biology Professor / Researcher (S)	2	0	0	0	0
Wyatt	Civil engineer (E)	1	2	0	3	1
Wilhelm	Ph.D. Student Chemistry (S/T)	1	2	0	0	0

Role models in STEM.

Participants described the STEM role models they had throughout their pathways into their STEM occupations at the time of the study. Three themes emerged for role models outside of participants' families. First, it appears that the characteristics of the role modeling by people with disabilities in STEM was different from the characteristics of the role modeling exhibited by people in STEM without disabilities. Differing characteristics included where and how participants encountered their STEM role models and differed also in the content of the vicarious experiences. These role models operated along seemingly parallel tracks in the lives of participants, rarely intersecting. Second, there were differences also in the characteristics of the role models participants had before college and during college, both in and out of school. Prior to college, role models appeared to provide formative role modeling, serving to introduce participants to STEM and provide visions of what was possible for participants. There was not an emphasis on the logistics of STEM practices in the role modeling early in participants' lives. Role models that participants encountered during their college years provided vicarious experiences that were more practice and skill-oriented than their pre-college models. During college, participants were building their STEM-specific knowledge and developing STEM- specific skills and practices as they were progressing, so this kind of practical role modeling was relevant. Finally, participants seemed to build and sustain connections with their role models with disabilities throughout their STEM trajectories, which resulted in the development of networks of STEM professionals with disabilities.

In addition to the STEM professionals with and without disabilities that participants encountered outside of their homes, three participants identified their parents as STEM role models (i.e. Bernadette, Hillman and Lars, Lars provided little information about his father as a role model, however they both worked in assistive technology education and even worked at the same shop for a time. Hillman and Bernadette provided more information. During his interview I asked Hillman how he became interested in electronics after he explained that he stepped directly into a technology career when he completed his masters degree in physics. In response, Hillman explained his fluency and knowledge of technologies came from his experiences with his dad. He said,

> When I was growing up, I was always interested in electronics. When I was born, my father owned a store in Chicago doing television repair… back in those days, if a television broke, you went out to somebody's home and fixed it. I got to go with him. I got to see insides of TVs…Technology has always been a part of my life.

Bernadette's stepfather and mother were physics researchers who modeled aspects of life in academia that she came to value. She explained,

> I grew up in a family of higher education. I saw my stepfather….and my mom who worked in academia …. they could go to conferences. They didn't have bosses, per se. The pay was not as good, but they seemed really happy.

Bernadette's mother had cancer while she was working as a physics researcher and raising Bernadette. Her mother's role modeling went beyond exhibiting what life was like working and living as a researcher. Living with cancer, Bernadette's mother required flexibility in her schedule to cope with her disability. Bernadette explained,

> …with my mom being sick – I'd always wanted to go into academia and go into science ….it was this extra…the kind of stuff that my mom gets from her work, where she can work at home, and she can days off to go and get chemo and all that.

Bernadette shared that over time, as her own orthopedic disability progressed, she came to value the flexibility of academia even more. This kind of role modeling enabled

Bernadette to see not only a career path that would enable her to be happy and successful but also one in which she could function with her disability. Role modeling had provided insight into what was possible for her.

Pre-college STEM role models.

From childhood through the end of high school, participants had STEM role models outside of their families that included, STEM teachers and STEM professions who they encountered in out of school contexts. Bernadette, Wilhelm and Karl identified STEM teachers who modeled enthusiasm, thinking differently, excitement, and passion for their fields. None of their teachers had disabilities. Though Karl did not share much information about his role model, he did mention that, "I did have a math teacher in high school who – he was kind of a, you know, free thinker. He was smarter than the rest of 'em, and I wanted to, so, be like – well, I liked him". Bernadette had teachers in high and middle school as STEM role models. She shared her thoughts on her middle school teacher. She said, "He was really enthusiastic. Come to think of it, he actually also had a Ph.D….he cared about science". Wilhelm explained how his science teacher, who told frequently told her class how much fun chemistry was, impacted him saying,

> The one who got me into chemistry was my high school chemistry teacher, and that's why I want to teach chemistry eventually is because they are the ones that really influence people, the truth be told. They are the ones that can really pull people into a subject, whether it's high school or early college, just a first contact sort of thing

More than anything, these STEM teachers appeared to model their own interest and enthusiasm for their STEM fields.

Five participants mentioned STEM role models that they met outside of school. Two of these participants, Marco and Viktor encountered STEM role models without disabilities. Viktor did not share much information about the childhood surgeon or the two people that he met in his mid-teens who worked at the American Museum of Natural History as practicing anthropologists. However, he brought them up in response to questions about influences on the course of his STEM path. He said,

> I mean even at age three – since I had this surgeon who was known as Professor [XXX], I said, 'I wanna be a professor, ' not knowing a damned thing about what that actually meant. I mean I didn't know what I professor did. Even in high school, I only had a hazy idea, but yes. Academics was always gonna be what I wanted to do. No question about it. Whether it was a university or a museum – that didn't matter to me at all that much. But it was gonna be one those.

Viktor shared that the anthropologists he met were encouraging and that it was helpful. Given his later museum work for his career, it was likely useful for him to have the experience of encountering professional scientists working in a museum setting. Marco worked with an animal researcher from the State University during his senior year in high school. He explained, "….it was actually for a career class. He was helping me with my project about becoming a university faculty". These STEM professionals appear to have provided Marco and Viktor with some ideas about what people in STEM careers did. Their models seemed to provide introductions to academia.

Three participants discussed STEM role models with disabilities that they encountered before they graduated from high school. Tina, Lars and Marton all had vicarious experiences through STEM professionals with disabilities. In each case, the role model had the same kind of disability as the participant. These STEM role models with disabilities modeled different aspects of the STEM profession than those modeled by STEM role models without disabilities. Lars found a role model in the director of the

International Braille and Technology Center. Lars interned at the director's Center and explained his perspectives about the director,

> He really was an instrumental force, actually, in my development because he was – he was a blind guy, totally blind guy, who when he discovered at a job in the 1970s that he couldn't do it as a blind person, his solution was to write a computer program that would allow him to do it. Being able to witness that kind of inventiveness and ingenuity really helped…

Tina was a professional computer scientist at the time of the study and had developed software during high school that enabled her Braille notetaker to generate useful Nemeth Braille output, an important breakthrough in assistive technologies. Tina met her mentor and role model, a blind computer scientist from NASA, in affiliation with her participation in a National Federation of the Blind and NASA's Rocket-On camp for girls in computer science. He had been involved in the development of assistive technology for STEM application, the MathTrax graphing calculator. When Marton first lost his vision toward the end of high school, he was connected with a Ph.D. student in biology. Marton explained,

> ….something like my mother's hairdresser…knew of a graduate student at the University of Michigan who was blind. Because I had just lost my sight, she mentioned him to her in case he might be able to mentor me or something…He got me involved in the [NFB] organization. He was actually probably the very first influence and then in getting me involved and encouraging me that I could still do engineering [after becoming blind].

When I asked him about why there are not more people with disabilities in his STEM field of technology, Milo shared an interesting perspective that seems relevant to these findings about the unique characteristics of the role modeling by STEM professionals with disabilities. He said,

> There are challenges to the field, and that you have to figure out, thinking out of the box. I think that with the right development that people with disabilities have

> been proving that …one of the great skills that many have is to think around corners. Because they've had to do that in all aspects of their lives to get things done in new and innovative ways.

As Bernadette's mother did for her, role modeling gave participants the opportunity to understand what is possible. These role models exhibited the ingenuity, resilience and resourcefulness that would take for participants' to succeed.

STEM role models during college.

Seven participants with visual impairments described STEM role models that they met during their college years. They encountered these role models in their undergraduate and graduate departments, college courses, internships and research opportunities. Participants also found role models through professional conferences and the National Federation of the Blind. STEM role models without disabilities were primarily encountered in college departments, courses, internships and research. In general, these STEM role models without disabilities modeled the lifestyle, tasks and practices associated with the careers of STEM academicians and professionals.

Hillman shared his experience with the dean of physical sciences where he was an undergraduate in physics saying,

> He was the discovered of the subatomic particle, the neutrino and eventually got a Nobel prize for it. He and I had a lot of talks about experimenting, blind people doing stuff. He just naturally, right form the start, was absolutely in favor of me being involved in physics and technology and doing what I did because a lot of the experiments that he did, he conducted from thousands of miles away. They had to be done in a deep place. Typically, they were done in a diamond mine in South Africa… He couldn't be there. He was chairing a school. As he pointed out, he didn't need to be there because as long as he gave good directions, as long as he described to the people what he wanted done, it was his job to interpret the results 'cause he's a theoretician.

Harold came to know a role model through a community college math course he took. This calculus teacher had worked as an engineer, applying higher-level mathematics and he was the first person Harold had encountered who had worked in an applied mathematics field. Wilhelm, one of the few people to actually use the expression "role model", described a peer he had at the time of the study. He said

> My friend…who I met in the graduate program, he started the same year that I did. He is just a fantastic ally and a role model. He's a few years older than me, and so wise but in the same year. He's always there to talk about chemistry….he just loves to make things accessible.

Marco, Cera, Wyatt and Wilhelm each talked about their research and internship experiences and role models they encountered there. A college professor of Wilhelm's knew that he was interested in pursuing chemistry but Wilhelm thought that graduate research was not possible because of his visual impairment. The professor connected Wilhelm with a chemistry researcher who responded enthusiastically to having Wilhelm in his lab. Wilhelm was working for this researcher at the time of the study, pursuing his Ph.D. Marco did not provide details about the role model he was connected with through his internship in dairy nutrition. However, he did explain that the role model has also been very encouraging and supportive of Marco's decision to pursue a research track in dairy nutrition. Wyatt did not provide many details about the people he worked with and was supervised by during his two-year long civil engineering water resources internship for the State. However, he did say that they were very influential in his decision to specialize in water resources for his engineering career.

Cera's research experience at an oceanographic institute brought her into contact with two women who would become role models. The two oceanography researchers she met were both visually impaired but unlike Cera, their vision loss started after they were well established in their careers. It was not clear whether they were formally part of her fellowship program. Cera did not provide details about the role modeling these women provided. However, she explained, “We would have these blind science coffee hours, and just hang out and talk…Even outside of this whole science research side of doing things, they’ve been great friends and very supportive people for me”. These role models became Cera’s mentors and friends and she remained connected with them.

Mirroring pre-college experiences, participants only encountered STEM role models with disabilities when they reached out to the STEM disability community or were connected to this community through others. Four participants, Cera, Wyatt, Hillman and Seal, mentioned STEM role models with disabilities and three of these participants mentioned more than one STEM role model with disabilities.

Wyatt had many STEM role models. He talked about a physicist he met through the National Federation of the Blind. They met as the physicist was nearing retirement and as Wyatt was making the transition from high school to college. Wyatt explained that “seeing him as an example and knowing how he did things” was important even though he was in a different STEM domain. Wyatt also met a blind electrical engineer through NFB. He explained,

> Also, I got to know pretty well and still keep in touch with him pretty regularly, a guy who…had just gotten his master’s. He actually now has his Ph.D. in electrical engineering. He’s worked for a number of defense contractors on communication-type stuff, probably some stuff that requires a security clearance”.

During his engineering undergraduate experience, Wyatt encountered an accomplished biology faculty who was also blind and a faculty member at the same university. He shared,

> I did get to know a little bit of a professor at State University, who's actually somewhat well-known…Again, getting to see him as an example has been a little bit in line, knowing how he did things, even though it's not the same as what I do, but to know –

Cera also identified this same biology faculty member as a role model. She was told about him by her department head as an example of a blind person who was not just capable in science, but successful and accomplished. During her graduate work in geology in 2009, Cera went from having low vision to being blind. She sought ways to continue with her passion by looking beyond her program and university. She found another role model in a blind geophysics researcher across the country. She explained,

> There's a few others that I found back in 2009 when I had that sudden loss of vision. David Engebretson…. He does a lot in sonification, and that was a really huge discovery for me to say, maybe I could still look at data by listening to it, or maybe there's still an alternative research path for me where I could still access this somehow.

Seal encountered assistive technology specialists as he sought to supplement his graduate program in special education with self-developed assistive technology expertise. He went to disability technology conferences, introducing himself, building a network and over time became part of the assistive technology community. He found role models in the people with and without disabilities who were working to develop and improve upon technologies that positively impact the lives of people with visual impairments. Seal described eight role models who were, he explained, "some of the early pioneers" in the assistive technology field. He identified a creator of JAWS screen reader, a founding member of California State University, Northridge (CSUN) International Technology and Persons with Disabilities Annual Conference, several people who were instrumental in the development and success of the Project Equal Access to Software and Information (EASI) among others. Some of the role models had disabilities, some did not, but none of them had formal education training in assistive technologies because the programs simply did not exist at the time.

In general, role models that participants encountered through formal channels such as internships, research opportunities, college courses and within college departments, modeled the practices and roles of STEM research faculty and professionals. Participants encountered few people with disabilities in these contexts. Role models with disabilities were more commonly found in other ways, including being introduced by others and through societies and professional organizations associated with disabilities. Role models provided participants with the vicarious experiences of observing and knowing professionals with disabilities who successfully engaged in STEM practices and careers. They also appear to have exhibited contextualized innovations in adaptive strategies that provided insight into the logistics of *how* to engage in STEM practices for research and professions. These role models with disabilities seem to provide the kind of support that Wyatt indicates is most important in his statement below,

> I think it's because a lot of people – and a lot of people in society have really good intentions, and they can be very supportive and "Oh, certainly somebody with a disability can go into engineering" and really mean well. Actually finding and connecting and then taking it to the next level of, 'This is how you can make it work for you', whether it's …figuring out how to use a combination of Braille, and readers and tactile diagrams, and it's Braille and technology, figuring out how to – taking to the next level.

Building networks within STEM.

During their pre-college and college years, participants described STEM role models with disabilities with whom they connected and constructed lasting relationships. Some participants did mention people in STEM without disabilities. However, STEM specialists with disabilities were part of the STEM networks that participants created. These relationships ranged from childhood to professional careers and even into retirement. Though Milo did not provide enough information for me to determine whether or not his blind elementary school teacher was a role model, he shared this when he was describing his involvement in an impactful research institute. He said "I found out about it through one of my elementary school teachers that was also blind. Him and I had remained close and we actually still remain close till this day, which is really cool". Lars discussed his history with his role model and mentor, the director of an NFB Center, he explained,

> When I was interning at the International Braille and Technology Center, [I met] one of my very good friends there [the director]… I also met him while I was a child at a training program getting that training under sleep shade that I mentioned to you… those are the people – my parents and [the director] – probably between the three of them. Those are the reasons why I am where I am.

The National Federation of the Blind (NFB) emerged as a significant mechanism of connecting participants to their STEM role models and mentors. Lars, Tina, Marton, Wyatt and Hillman all described STEM role models met through the NFB meetings, initiatives, programs and networks.

Role models outside of STEM domains.

People outside of STEM domains were identified as role models because their approaches to their own disabilities were influential on participants' perspectives about disabilities. Role models from outside of STEM domains were found in similar contexts as those within STEM domains. Family members, with and without disabilities, and the National Federation of the Blind (NFB) featured prominently. Four participants with visual impairments identified role models in this group. All role models had disabilities.

Hillman, Lars, Cera and Marton identified people who influenced their perspectives on disabilities. Hillman and Marton both found role models through their connections with the NFB. Hillman knew the then-president of the National Federation of the Blind before he completed his master's degree in physics. He described this former president, with whom he worked saying, "I gotta say, even though he wasn't much of a technology guy, Ken Jernigan…was willing to step out of his comfort zone and even do this Kurzweil reading machine." Marton explained his experience with a leader of the NFB as follows,

> The leader of the organization at that time was very inspiring speaker. I used to listen to recordings of his speeches about blindness and the capabilities of blind people and how, if we could change attitudes in society, then we could have much better opportunities as blind people. That first actually made me even believe that I could succeed at a school like Princeton and take on a subject like engineering…

While Cera did not specify whether or not she knew Aimee Mullins personally, she shared her view of Aimee Mullins, an athlete whose legs were amputated when she was a year old and then became a spokesperson for revisioning prosthetic technologies. Cera explained,

> There's another level that I like to call opportunities of adversity, which I initially encountered from Aimee Mullins…. She's amazing. The opportunities of adversity are things that really challenge us into exercising an extraordinary amount of resilience and adaptability and growth that we otherwise, unless we're challenged into exercising those things, we don't develop it. I think that's been one of the most extremely valuable things for me in my path.

Lars also identified a role model who influenced his approach to disability, explaining, "My mom was blind and fully independent, and they had no reason to expect that I wouldn't be".

Lack of role models.

Five participants responded to the interview question asking why there were not more people with disabilities in their STEM fields with comments indicating that people are not well enough connected with role models. These participants included Milo and Lina, neither of whom mentioned role models in the interview, Marco, who identified two role models from college experiences and Kumi, who identified close family without disabilities as role models. Marco explained his dilemma in this way, "…because nobody knows how a blind person does biology. I don't know. I have not met a blind biologist yet. I know a blind chemist….the vast majority of blind professionals I meet are lawyers or something….in humanities". Kumi described his experience as follows,

> But the lack of role models is an important reason. They don't see – I don't see very many deaf, successful people. I mean my cousins are hearing and I thought, "if they can do it, then I can do it", but it depends on the role models form the communities or from the family and, you know, from anywhere".

Milo shared his view by saying, "Getting parents and obviously eventually the children with disabilities positive role models, positive goals to strive for, things like that". Lina made a comment that echo's Milo's that emphasized the importance of role models for parents when children have disabilities when they are young. Lina said,

> ….especially if the parents themselves do not have a visual impairment, they don't quite know what's possible. I think sometimes they're a little freaked out and try to protect their kids, you know, try to bubble wrap them to make things okay, because the child isn't challenged really as much or at least have the expectations of their peers.

Conclusions.

In summary, there were two major groups of STEM role models, those with and without disabilities. Role models also provided different kinds of vicarious experiences to participants during their pre-college and college years. In general, excitement and enthusiasm for STEM fields were modeled by STEM role models without disabilities during pre-college experiences for participants and this helped to foster interest in STEM fields for participants. These role models were generally encountered in school settings. Participants encountered STEM role models without disabilities during their college years in college class settings, internships and research contexts. These role models provided vicarious experiences focused on the lifestyles and practices associated with being STEM academicians and professionals. STEM role models with disabilities were generally encountered when participants looked outside of the standard school paths to people beyond teachers, professors and supervisors.

Physiological / Affective States.

Physiological / affective states are the emotions and physiological responses experienced by people in association with their engagement in particular tasks. Positive/negative emotions and responses are part of this self-efficacy source. Emotions are the focus of this section. As with other studies of self-efficacy sources, findings associated with physiological / affective states from participant responses were less abundant than those affiliated with other sources of self-efficacy.

Physiological / affective states are the least well represented source in the self-efficacy sources literature affiliated with choice and participation in STEM. The lack of attention to this self-efficacy source in the literature, provided little guidance about establishing the kinds of information that should be classified as physiological / affective states. I chose to exclude participants' mentions of their interest in STEM from the physiological / affective classification. This is because interest is affiliated with motivation in other constructs and is not explicitly connected to studies of self-efficacy. Mentions about how participation in STEM activities and practices made participants feel as well as those referencing how participants felt about STEM domains and activities were included.

Sixteen participants made comments in their interviews that were classified as physiological /affective states. Lars and Lina, professionals in technology fields at the time of the study, were the only participants who did not make comments that could be classified and included here. Two themes of positive and negative physiological / affective (P/A) states emerged from participants' responses. Nearly twice the number of participants reported positive P/A states than negative. Seven participants reported only positive P/A states while one participant reported negative P/A states. The remaining individuals reported both positive and negative P/A states.

Positive comments regarding P/A were classified into two subthemes. The first subtheme was composed of reports about positive emotions associated with STEM, STEM applications and STEM practices. The second positive P/A states subtheme consisted of participants' comments about their feelings of belonging and the right fit they found in their STEM fields. Participants' negative comments about P/A states were grouped into three subthemes. The first subtheme reflected participants' anger and frustration about issues of accessibility associated with their STEM participation. The second subtheme was comprised of comments expressing feelings of isolation and loneliness in association with their STEM participation. The final negative P/A states subtheme was composed of comments about feelings of uncertainty, insecurity and being overwhelmed also in association with their STEM participation.

The context of positive and negative P/A states differed. Participants generally reported positive P/A states in association with various aspects of STEM. However, participants generally reported on negative P/A states in association with their disabilities and their participation in STEM.

Positive physiological / affective states.

Fifteen participants, men and women across STEM, reported positive P/A states in their interview responses. Twelve individuals reported on these positive P/A states without references to their disabilities. The first subtheme of positive P/A states was comprised of participants' shared feelings about various aspects of STEM. The second subtheme captured participants' sense of having found the right fit for themselves in their STEM fields.

STEM / STEM applications / STEM practices.

The first subthemes of positive P/A states reflect participants' feelings about domains, applications and practices in STEM. Herb, Milo, Wilhelm and Viktor shared their feelings about STEM domains in general. Herb, a computer science engineer said, "… always enjoyed and loved sciences". Herb also shared, "I've just always liked math". Milo, an assistive technology specialist, shared, "I was always just excited. I was just a curious kid, child … I enjoyed technology, music, just audio, things like that …". Wilhelm, a chemistry researcher, explained, "I always loved learning how things work and how things fit together". Viktor explained his feelings, saying, "I've always liked natural history and always liked science".

More intense emotions were expressed by the participants who shared their feelings about their specific STEM fields. Viktor, a paleobiologist, shared, "It was all complete curiosity and excitement … For me it's all curiosity and fascination – A to Z. It's never waned". Cera and Wilhlem fell in love with their fields. Cera explained, "… geology is one of those things you just fall in love with it the more you learn about it". Carlos and Marco also expressed strongly positive feelings. Marco said, "I was always the most passionate in biology and biology-related classes" and Carlos shared, "This [computer science] is what I'm really passionate about". Though not as strong as some other comments, Kumi and Bernadette also shared their feelings about their STEM fields. Bernadette said, "I've always really liked biology, " while Kumi and Tina, computer scientists, identified their fields as fun. Kumi said, "I really enjoy computers" and "[Computers] is something that is just fun for me".

Eight participants shared their feelings about applications and practices in their STEM fields. Harold shared, "I really just started to fall in love with the concept of, I don't know, just this bettering society and humanity through the use of computers". Marco also found the application of his STEM domain to be impactful, saying, "I was fascinated … about how ag[ricultural] research can be used to help farmers". Computers and their challenges were a source of positive feelings also. Karl explained, "Oh god, [using the punch card computer] was difficult but I enjoyed it". Carlos shared, "I just found [messing around with computers] really fun". Carlos also said,

> From there [his first website design], that spawned my branching off into slowly getting more and more technical. I feel like honestly that just wanting to be able to do more than drag –and-drop and slowly getting more and more…advanced, it was almost like a thirst. I was like, I need to know how to do this next cool thing and it kinda kept it going.

Bernadette and Cera shared positive P/A states that they experienced in association with learning in their STEM fields. Bernadette said, "I was like … I love everything we're studying [in the high school biotechnology program]" while Cera shared, "When it started to make sense, I was just totally hopelessly into the field". Wyatt and Herb had positive feelings about their experiences in real STEM work settings prior to completing their terminal degrees. Wyatt shared, "I really enjoyed [my water resources internship with the State]" and Herb explained, "That [job in the research lab] was a lotta fun cuz basically my job was … they give you problems and you figure out how to do things".

Feelings of belonging and finding the right fit.

The theme of STEM community membership that participants experienced was identified in the findings section on social persuasion and the experience of finding the right fit in a STEM field was identified in mastery experiences. Emotions overlap with the other self-efficacy themes therefore the sense of belonging and of right fit will be addressed here as well. Participants expressed P/A states they experienced in association with sense of belonging, connected to membership, and having found the right fit in their STEM fields. Cera, Bernadette and Kumi, three participants with different categories of disabilities, shared information about their positive P/A states in this regard. Cera shared, "That [geology field experience] was an early, pretty strong commitment to geology. After you have an experience like a good field course, you just – you know. It's like that's it. I found my place". Kumi explained his P/A state associated with his STEM pathway change,

> I'm still talking about the…medical imaging: PT scans, MRIs…from doing that and then I still liked that and doing that but the environment wasn't great – I didn't feel very comfortable in the environment. After I changed research at the same graduate school, then I felt a lot better.

Bernadette's quote was one already presented in the social persuasion section of findings. I am including it here because it not only reflects the messages from other people, but it also explains how Bernadette felt about her participation in an impactful STEM context. She had an internship at the Human Genome Sequencing Center and Bernadette said, "I was clearly in a high school student but I was being treated like I was a productive research person and that was really – it was just really nice".

Negative physiological / affective states.

Seven participants shared information about negative P/A states associated with their STEM participation. They are all related to participants' disabilities. The first subtheme contains comments about participants' emotions associated with the challenges of accommodations and access as they sought to engage in STEM. The second subtheme is a collection of comments about feelings of isolation and loneliness in association with their STEM participation. Finally, participants' mentions of feelings of uncertainty and insecurity are captured in subtheme three.

Issues with access.

Four participants shared their negative P/A states that were associated with access issues in relation to their STEM participation. Three were related to formal education contexts. Feelings of anger and frustration dominate this group. Harold had two incidents associated with challenges of accessibility that induced negative P/A states in him. The first related to Harold's practice of working out accommodations with his individual teachers without involving disability services. His community college math professor insisted that Harold get formal paperwork for the accommodation he requested of changing from his assigned seat in the back to a seat in the front row for class because of his vision impairment. Harold shared, "That [professor] infuriated me cuz it seemed so completely unreasonable". Harold also shared his feelings about his experience struggling in an upper level math course with no textbook. Harold said,

> For me, that was just a slap in the face because previously I didn't feel especially academically challenged, at least to the point of exhaustion or inability…The depth of impact it had on me, this idea, oh I actually have to withdraw from classes…because I can't see the materials or because I'm not understanding the material was very poignant to me…When you're trying to really work at the higher capacity and everyone around you is too, you actually run into a problem of finite hours in the day. It became clear to me that even if I could push through these particular classes, right, without some assistive technologies, it wasn't a sustainable strategy because hours that I had to spend compensating, even if it could work out in this case, were not going to help make me competitive in the future.

Carlos and Marton also reported negative P/A states associated with access in formal learning settings. Carlos shared,

> Trying to sit through a math class or a chemistry class or something like that when you can't follow along with the whiteboard is an absolute just monstrous nightmare. I can easily see why a lotta people would just kinda give up and go towards something with less resistance.

Following his vision loss in late high school, Marton tried several different engineering majors in college before settling on one that he found to be less visually demanding. Marton said, "Even then, unfortunately, I still was frustrated with accessibility issues [in the engineering major]". Cera shared negative P/A states she experienced during college. She was denied admittance on a research cruise with NOAA and Cera explained, "I was pissed". Cera went on to share, "There were several points where I became pretty frustrated with myself and even accessibility and all those little things that come up".

Feelings of loneliness and isolation.

Four male participants with visual disabilities, who all worked in technology, shared how they felt as they engaged in various aspects of STEM. Seal and Harold described negative P/A states they experienced before they made their academic STEM choice. Prior to Seal's success with computers and assistive technologies, his wife expressed interest in getting a computer for the family. Seal said, "I was quite resistant, initially, to getting a computer…I was negative on it cuz I honestly thought… this is gonna separate me from the rest of the family, cuz they'll be able to use it and I won't". Before college, Harold lived with his family out on his mother's horse ranch in the rural countryside. He did not have peers who were interested in college and computers like he was. Harold shared,

> The idea of wanting to get out of that isolation and being able to effect my own transportation and be able to have the intellectual company or

> companionship that I really felt that I desired and lacked in these rural settings. Those were some of the negative interactions that propelled me towards the career in science technology – into the STEM field.

Hillman and Marton related negative P/A states they experienced in college. Hillman shared the exclusion he felt during the comprehensive exam preparation process in graduate school in which other students were working in groups to prepare. Hillman commented, “I didn’t even know about some of the study groups for a while”. Marton shared his experience with isolation, “There weren’t any other blind students in STEM when I was there, so it did feel lonely that I – any accessibility issue I had, I had to mainly figure out the solution myself”.

Feelings of uncertainty, insecurity and being overwhelmed.

Four participants shared negative P/A states they experienced. They all referenced situations in college that elicited these feelings of uncertainty and insecurity. Cera explained her perspective on her participation in geology field camp,

> … it’s risky. You’re taking a blind girl – visually impaired at that point. I still had a lot of functional vision, I guess. In the field, I had Casey the dog with me and a bunch of my friends were there and two professors.

Cera also shared her concerns in college generally, saying, “I wasn’t convinced that I could do it at many points”. Marton shared his situation in college and his feelings, saying

> Well, at first, I was really optimistic. I pictured that I could get really good at Braille and using a talking calculator and things that would just allow me to perform independently in STEM. Unfortunately, I then did start getting discouraged when I found that I, try as I might, could no get up to a fast speed with reading Braille.

Harold struggled with feelings of inferiority, sharing his P/A state when he was being encouraged to do mathematics research during his undergraduate program. Harold said that he was thinking, "Oh I'm not worth of this. My skills are clearly not adequate for this. You guys have the wrong person". He went on to describe how he became involved with a research-computing lab. Harold said,

> I basically, at the time, was reading a book, like a graduate level book in machine learning – trying to read it, I should say – and just said, "I want to volunteer my time here and just try to get involved." I still had this huge inferiority complex of, "I'm not worth of you guys' time. If you guys spend time with me, it is because you're being charitable".

Carlos and Wilhelm shared their feelings of being overwhelmed. Carlos said,

> My thought for the majority of it [undergraduate in computer science], the first few years was "Holy crap, I'm in over my head here. What did I get myself into?" Then as it got more into the Masters stuff I kind of went towards, "I'm in over my head" again".

Wilhelm shared his experiences with feelings of being overwhelmed in relation to his work as a researcher in a chemistry laboratory during his graduate work. Wilhelm said, "I know oftentimes things felt impossible that we hadn't done yet. They really did. They were a struggle. They were difficult…".

Conclusions

Physiological / affective states are the least well-represented source of self-efficacy in the self-efficacy literature regarding choice and participation in STEM. In the current study however, P/A states were mentioned by more participants than those who discussed their experiences with role models. Participants communicated more positive than negative physiological / affective states associated with their participation in STEM. Positive feelings were centered on how participants felt about various aspects of STEM along with the sense of belonging they felt when they had found their STEM niche. Negative feelings reported by participants were associated with participants' disabilities as they engaged in STEM. While there were relatively few comments about physiological / affective states compared to comments about other sources of self-efficacy, participants communicated strong emotions associated with their choice and participation in STEM.

Assistive Technology Types, Uses and Roles

Participants were asked to identify assistive technologies that they used in their STEM careers for learning science and math. They also described the role assistive technologies have played in their participation in their STEM domain. Participant responses to these questions yielded extensive lists of technologies and descriptions of how participants used them. Their responses also provided insight into when various technologies were most relevant along their STEM trajectories. Overall, STEM-specific technologies were not commonly mentioned by participants for learning or their STEM careers. Instead, general assistive technologies were used for STEM applications as a student and professional.

Five themes emerged from this analysis. First, accessible technologies were mentioned alongside assistive technologies. Second, aids and sensory substitutions emerged as the most commonly used assistive technologies for STEM applications. Third, assistive technology was identified as a necessity and an equalizer for both STEM learning STEM career applications. Fourth, the types of assistive technologies used by participants were similar throughout their STEM trajectories from learners to professionals. The variety of assistive technologies, however, decreased as participants transitioned from student to professional. Fifth, the ways in which assistive technologies were used differed as participants transitioned from STEM learners to professionals and creators of content, technologies, frameworks and infrastructure. Participants also identified barriers to accessing assistive technologies.

Assistive vs. accessible technologies.

In this study, the phrase "assistive technology" reflects the federal definition within the Tech Act (2004) referring to an assistive technology device or assistive technology service. According to the Tech Act (2004), an assistive technology device is "any item, piece of equipment or product system whether acquired commercially, modified or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities". These include visual aids and sensory substitution technologies among others. Assistive technology service is "any service that directly assists the individual with a disability in the selection, acquisition, or use of an assistive technology device." (Tech Act, 2004). Assistive technologies includes interpretation services for people who are deaf, readings services for people who are blind in addition to other assistive services.

Participants in this study also identified accessible technologies in their responses to questions about assistive technologies. The Center for Accessible Technology defines accessible technology as technology that is designed with the diverse abilities of users in mind. (Center for Accessible Technology, n.d.). This means that features that would have, in the past, been considered assistive, are now being integrated into technologies as standard features. Accessible technology includes built in zooming features in Microsoft Word, Windows 7 built-in magnifiers, and built in digital recorders. Accessibility is also enabled by the designing features to be interoperable with assistive technologies. An example of this is the design of computer operating systems that enable compatibility with assistive screen reader technology such as Job Access with Speech (JAWS).

Sixteen participants identified accessible technologies as important to their participation in STEM fields. The accessible technologies they identified served as aids and provided sensory substitutes. Seven participants, including the four participants who were Ph.D. students at the time of the study, identified accessible technologies as important for STEM learning and their work as students. The accessible technologies they identified served as aids and provided sensory substitutes. Four participants identified computers as related to their STEM learning: three specified laptops and one mentioned the text-to-speech rendering feature on the Apple IIe. Bernadette explained the role of her computer, saying “I would have a lot of trouble, if I couldn’t use specifically my laptop. I can’t handwrite more than a little bit. If I had to handwrite every day for my lab notebook, I would not be getting very much done.” Six of the seven participants who identified accessible technologies had visual impairments. Cera gave an extensive list of built-in features that she used including her computer’s digital audio recorder and zooming capabilities as well as the iPhone VoiceOver feature that Wilhelm also mentioned. Wilhelm used it to listen to chemistry PDFs in addition to basic phone function.

Twelve out of the thirteen professionals in the study identified accessible technologies as important for their work. iPhones were mentioned by seven visually impaired participants with some identifying the VoiceOver technology and others mentioning the GPS feature. Only Hillman and Marco explicated how iPhones related to their work. Marco, uses a herding application to help him on the farm and Hillman travels extensively, so the GPS feature supports his navigation, which is integral to his work. Four participants mentioned computers in general, including Kumi, who is a computer scientist with a hearing impairment. Three participants specifically mentioned Windows. Carlos shared,

> Windows 7 and up, the magnifier that they have built into Windows is absolutely phenomenal. I use it all day, every day now pretty much. It's one of the most useful thing that I've found to really make the screen bigger in a way that isn't obtrusive and that doesn't hinder your work.

Three professionals with visual impairments from different STEM domains identified spreadsheet software, which are compatible with screen readers, as important for managing data and calculating. Tables 14 and 15 list the types of assistive and accessible technologies participants identified were relevant to their STEM participation.

Assistive technologies and participation in STEM: a necessity and an equalizer.

Thirteen participants described assistive technologies as a necessity. This group included males and females from across STEM domains, ranging in ages from 20s to 70 but was limited to participants with visual impairments. The four participants who did not identify AT as a necessity still spoke positively about the role of AT in their lives. They made comments about the importance of AT such as Kumi, who said “those things [interpreters and captioning] helped me and how someone else could benefit”. These participant comments expressed that they valued AT, but not with the sense of necessity of other participants. Viktor proclaimed, “I could never do what I do without Braille….likewise all the fieldwork I’ve done, the museum work I do – I mean that’s my

Table 14

Assistive technologies and accessible technologies (italics) used by participants in association with STEM learning

Participant	Assistive and Accessible Technology Types
Bernadette	Electronic multifunction ergonomic pipette; Eppendorf tube levers; ankle/ wrist/ finger braces; stool; giant trackball; lab assistants: *Laptop; Linux*
Carlos	Monocular; human note taker
Cera	K12: none; College: Braille; Braille display; screen reader; data sonification; Clarity desktop (CCTV); magnifiers; lighting; enlarged print; high contrast; enlarged stereonets; laptop; digital recorder in laptop; zooming and magnification in laptop; *iPhone with VoiceOver*
Harold	Monocular; notetaker technology; monitor arm; lighting; *GPS*
Herb	Braille; Nemeth Braille; reading tapes; human readers; white paper and thick marker; Kurzweil machine; reading tapes; inverted text; OCR scanning; screen reader; *Apple IIs; VT displays; TRS-80; Fortran*
Hillman	Braille; tactile models; Brailled figures and graphics; Braille books; circular Brailled slide rule; raised line drawing kit; resource professionals; extra time in lab with professors and the lab equipment; learning ally; *accessible monitor*
Karl	Braille; inverted screen calculator; audio recordings
Kumi	One-on-one instruction; captioning; interpreting; human note taker
Lars	CCTV for diagrams/charts; tactile graphics – tooling foil and drawing kits; tactile models; JAWS; Braille; Braille embosser; Braille note takers
Lina	Human note takers
Marco	Braille notetakers; Braille; enlarged and bolded graph paper labeled with Braille; tactile science diagrams labeled with Braille; Nemeth Braille; embossing printer for tactile diagrams; resource professionals; JAWS; *laptop*
Marton	Learning ally; audio recordings; cassette recorder; human and screen readers
Milo	Microcassette recorder; OCR; Learning ally audio books; Braille textbooks; Braille; *early laptop; Echo2 for Apple IIe*
Seal	Braille; audio recordings; NLS talking books; reel-to-reel tape recorders; cassette recorder; CCTV; large felt-tipped markers with big writing surface; writing on chalkboard; tape; Arkenstone reading machine; text-to-speech; JAWS; *notebook computer*
Tina	MathTrax; models; Octaves command-line calculator; program for Braille writer to output Nemeth Braille; Nemeth Braille; BrailleNote; JAWS; BrailleLite; *Laptop*
Viktor	Tactile science drawings and models; raised line drawing for graphics; tactile graphing with stylus scraping; Braille reader; modified dial calipers; Perkins Brailler; slate and stylus; sighted field assistant
Wyatt	Large print / screen magnification; Braille; Braille writer for math; refreshable Braille; Nemeth Braille; screen readers; *Excel*
Wilhelm	Braille; learning ally; tactile graphics (pictures in a flash); molecular models; JAWS; Braille notetaker; human reader; 3-D printing models with Braille labels; *VoiceOver tech for iPhone*

Table 15
Assistive technologies and accessible technologies (italics) used by participants in association with STEM careers

Participant	Assistive and Accessible Technologies
Bernadette	N/A
Carlos	*Windows 7 magnifier*
Cera	N/A
Harold	N/A
Herb	Screen reader (JAWS); CCTV; oscilloscopes with people to help; lighting; *magnifying software*
Hillman	Guide dog; cane; screen reader; Ultrabook computer with JAWS; Dragon naturally speaking with J-Say to work with JAWS; talking calculator; K-NFB reader on Nokia N86; BrailleNote; Braille embosser; *iPhone with GPS*
Karl	JAWS; refreshable Braille display; Braille notetaker; car service; *Apple IIe with Text Talker; iMac running Windowns and Mac; Windows 7*
Kumi	Captioning; interpreting by qualified interpreters; *computer*
Lars	Braille display, screen reader – all kinds of AT for B/LV for work; *iPhone*
Lina	Color inversion; magnification; handheld magnifier for grading student work; *Large monitor*
Marco	JAWS, Herd; TapTapSee; *iPhone; spreadsheet software; computer; laptop*
Marton	Screen reader; human reader; *iPhone; desktop computer*
Milo	Screen readers (JAWS); cane; *Computer; windows; Bluetooth keyboard; Apple VoiceOver and GPS on iPhone*
Seal	JAWS; *computers; spreadsheet software*
Tina	Braille display; screen reader (JAWS); *iPhone*
Viktor	Sighted field assistant; human reader for emails; human reader for papers and math; Braille; modified dial calipers; Perkins Brailler; slate and stylus; *iPhone*
Wyatt	Braille displays; screen readers;*MS Office; Adobe software*
Wilhelm	N/A

scientific life". Wyatt explained, "I mean, it [assistive technology] was a tremendous equalizer…that allows me to work effectively alongside my sighted co-workers" about the role of AT in his work as a civil engineer. Carlos situated the necessity for AT within science and math learning saying, “I think that in terms of being able to use that technology to make science and math learning easier, it was critical because that let me leverage that knowledge to really go forward with this [career in software engineering]”. Herb, a, software engineer shared, “Well, screen reader, vital. I wouldn’t be able to do my job without it. It was absolutely vital”.

Types and roles of assistive technologies in STEM learning and careers.

Participants identified the types of assistive technologies they used to learn science and math, technologies they used at work at the time of the study and they also identified assistive technologies they used as they explained the roles assistive technologies played in their STEM participation. Science and math learning includes participants’ K-12, undergraduate and graduate education. Two types of assistive technologies emerged from participant responses, aids and sensory substitutions. Aids included visual and orthopedic groups. Visual aids supported participants by augmenting participants’ senses and by assisting with services such as note taking. Orthopedic aids provided physical support or assistance. Sensory substitution technology devices and aids provided sensory input that is typically routed through one sense, such as aural input, into alternative senses, such as the sense of sight. There were three main groups of sensory substitution technologies used by participants in this study. Tactile resources substituted for vision and included technologies for tactile reading, writing, math and graphics including graphs. Vision substitution also included aural renderings of written text. Aural substitution included captioning and sign language interpreting.

Participants described the roles assistive technologies have played in their participation in STEM. Three distinct roles emerged. The first role was relevant to students. In this capacity, assistive technology was the facilitator of interactions with STEM content in the learning process. Second, and relevant to both students and professionals, was the theme of assistive technologies as providers of access to STEM content. The final theme that emerged was relevant to both STEM professionals and some participants who emerged as creators before they had completed their schooling. The role of assistive technologies for these participants was providing access to the creative process as well as to basic job tasks.

Types of assistive technologies used for STEM learning.

Vision aids.

Six participants identified vision aids as assistive technologies that they used during their STEM learning. These included note takers, magnifiers, distance viewers, large format text and graphics, text inversion and lighting. Note taking entailed other people taking notes in class for the participants. Notes were then provided to participants following the class, which was useful for some. For Kumi, who is deaf, a note taker was very important for logistical reasons. Kumi said, "With math and science, you know, I really needed to have a note taker because it's impossible to watch and take notes at the same time. Um…some classes would give notes and some would not, that was a challenge". The services were not useful for everyone. Carlos reported, "I had a vision aid who would essentially take notes for me in class and just get me the notes. That wasn't really helpful because I'd only see the stuff when it wasn't relevant anymore".

Magnification can be effected through a range of low and high tech solutions. Lars explained, “I used a CCTV [closed circuit television] because boy, I just couldn’t see the diagrams of the charts and stuff”. Augmentation of distance viewing came in several forms. Harold and Carlos both used monoculars to see the classroom board. Harold recalled, “I’d hold it up to my face, and it’s a shaky view, but I can at least zoom in to the board, but I wouldn’t be able to take notes very well…the back and forth thing.” During his undergraduate program Harold created a technology that improved on the hand-held monocular. He developed and used this specifically for his STEM courses. The core functions of his innovation enabled the user to optically zoom in on the board or the professor with a camera and to have the video output feed into a split screen monitor in near real-time. The monitor enabled the user to annotate on the screen as the camera captured the professor’s notes on the board and movements at the front of the classroom. He explained,

> The whole point of that was, not only do you want to eliminate this going back and forth between the board and the notes, but you also need to have handwritten notes because you really got to have them for science and math…math notation and diagrams etc…The [technology] is all about getting you to see the board in roughly the same amount of time that your sighted companions could, and being able to take notes better there.

When he was not in the classroom, Harold also used a monitor arm to bring his monitor within inches of his face so he could see the computer screen when he worked in his office.

Some participants with visual impairments could read and write using ink as long as it was in large format. Seal explained his use of large format in school as follows,

> I have enough sight…. if I have a dark felt-tipped pen and good light and something big write on, I can draw it on the wall. That was more readily available

> and portable and good enough for me to get the job done, to demonstrate how I solved problems and worked equations and wrote out the expressions and all that kind of stuff.

Marco described his experience with enlarged resources. He said "… so this is what I felt was more helpful [than specialized software], was the enlarged graph paper. Enlarged and also was bolded. The lines were bolded. …. it was actually printed on regular photocopy or copy paper". High contrast was important for Marco, Cera, Seal. Harold, Seal and Cera mentioned environmental lighting as part of the conditions that best support their learning.

Orthopedic Aids.

Bernadette was a graduate student at the time of the study. She was working in a laboratory located in a historic greenhouse. Her research required her to be able to stand and walk around the lab, walk and work in field settings and occasionally come into the lab at all times of the day for running specific experiments. Bernadette identified orthopedic aids that she used including STEM specific assistive laboratory equipment such as an Eppendorf tube lever and an electronic multifunction ergonomic pipette that she used during her time as a lab technician. She also identified general assistive technologies that she used such as braces to lend support to her joints and canes and crutches that she used for mobility in the lab during times when joints were injured. She frequently had joint injuries. She also used a stool saying,

> …at my desk and in the greenhouse 'cause most of us work standing up but I can't work standing up, and in the field, the same thing. Yeah. I actually carry a foldable stool with me everywhere. It fits in a standard Nalgene bottle slot and it's maybe about 18, 24 inches long when it's folded.

In addition to physical resources, Bernadette used laboratory assistants to do repetitive pipetting work that was very hard on her hands and for intensive lab work requiring early morning hours. She had sleep issues associated with her disability. Bernadette explained, "…she [lab assistant] got up at hours that I couldn't get up for to do experiments". These laboratory assistants were only able to support Bernadette because they were knowledgeable in the biology domain and also in lab practices, so they too were STEM specific.

Sensory substitutes.

Participants with blindness / low vision used tactile and auditory resources that provided information to them that people without these disabilities would sense visually. The participant in the study who was deaf used visual resources to provide information to him that people without hearing impairment would sense aurally. The sections below detail the types of sensory substitution technologies participants used for their STEM learning.

Tactile formats.

Tactile formats for sensory substitution came in the forms of Braille languages and tactile graphics including raised line graphs. Twelve participants indicated that they used Braille in association with their STEM learning. Six explicitly named resources for tactile mathematics, namely Nemeth Braille and tactile graphing. Seven participants described their use of tactile graphics in their science and mathematics learning. Only four of the 16 participants with visual impairments never used Braille as a tool for learning or working

Braille was used primarily as a reading tool but was also used for learning mathematics in the form of Nemeth Braille. Mathematics poses significant challenges for people who are blind for two key reasons. First, mathematics characters are not restricted to a linear single-line representation. Simple fractions, for example, take up three lines including the numerator, the fraction line and the denominator. As math increases in complexity, so does the challenge of representing it with Braille, which is presented in a linear format. The second major mathematics obstacle for people who are blind is that they cannot view mathematical expressions as a whole, as sighted people can, looking at an entire expression or series of expressions on a page. People who are blind can listen to audible mathematics renderings or read Braille mathematics expressions. However, the cognitive load is extreme, requiring users to keep track of the math they have read or heard. Nemeth Braille is a common mathematics Braille language used in the United States that works to solve some of these challenges, specifically the lack of single line format of mathematics. Herb explains, "Yeah, it was the Braille and all the – I guess it's the Nemeth…All the math symbols, it's not just standard Braille. You have to figure out how to write integrals and differentiation signs and all that." Learning Braille can be challenging. Marton, who lost his vision at age 16, struggled to learn Braille and Nemeth Braille. He said "Then I got material from XXX School for the Blind. It's an online-correspondence course for blind people. I would take my Nemeth learning materials, and it was self-study". Technologically, Nemeth Braille was not always congruent with Braille technologies. Marco explains,

> "They [Braille writers and Nemeth] worked not well, yes. For the longest time, that was a huge disconnect. Now they have recently made – the new software on the BrailleNote actually takes – well, you can type Nemeth Braille. It will hook up

> to a printer. You turn your Braille file into a Word document, and it will print actual Nemeth."

Advances in electronic Braille notetakers have done much to reconcile the incompatibility between Nemeth and standard Braille. Braille use is not restricted to people with no vision. There are also low vision users including Marco and Cera who used Braille.

Six participants reported that they used tactile graphics as learners. Tactile graphics included tactile graphics and kits, raised-line graphing, tactile lab equipment and 3-D printing. Users ranged in age from 20s to 70. Tina was the only female in this group. Four of the participants held undergraduate degrees in science fields. Wilhelm was still in his Ph.D. program in Computational Chemistry at the time of the study, so his responses included resources he was currently using that were related to learning math and science. Lars, Wilhlem, Viktor, Hillman and Marco detailed their experiences with tactile graphics. They described raised line drawing kits that people used to create tactile drawings for participants. Tactile graphics were consistently reported to be low-tech classroom based solutions that participants used across science and math courses. "My [high school] geometry teacher was pretty good at making tactile drawings for me… I used the tactile stuff in science too 'cause I couldn't see too well under the microscope", explained Lars. Viktor, a paleobiologist, shared,

> …. in fact, my very first article that was ever published was on raised-line drawing…. You take a sheet of paper, put it on a piece of screening and take a stylus and scrape over it and then you get a mirror image on the other side. It's incredibly simple and works very well….

Marco's high school paraprofessional created tactile graphics with puff paints and Braille labels for Marco in his high school biology and anatomy classes. He said "It was absolutely amazing…maybe that's actually more to do with why I like biology [laughter]". All noted that these graphics were helpful for math and science courses.

Hillman, Viktor and Cera were the only participants who identified specific lab / field equipment designed for people with visual impairments. Cera used enlarged stereonets for learning in structural geology. Hillman shared, "The closest I had to any of that was a circular slide rule… There was a regular linear slide rule and then there was one that actually did everything in a circle, and there was a Braille version of that". Viktor had a tactile dial caliper for measuring invertebrates. Wilhelm, who used tactile graphics throughout his science and math learning, was delving into modeling using current technology. He said "Now 3-D printing and coming up with a script that writes Braille on the chemical bonds that we use. It's a full circle back to using Braille with that 3-D printing".

Auditory formats.

For people with visual impairments, auditory resources can be important. Thirteen blind / low vision participants indicated that audio resources were important to their STEM learning. Audio resources mentioned included audio recordings of STEM content, screen readers, human readers, cassette recorders and reading machines.

STEM content recordings are not recent innovations. They have been available to participants since the childhood years of the oldest participants. Seven participants reported that they used them to support their STEM learning. Seal's Braille training at school was discontinued early on. He told me that "When I got to about fifth or sixth grade, Braille kinda went away. I was given audio tapes." He was given "talking books" from the National Library Service for the Blind (NLS) when he was in school in the

1950s and 1960s. Milo, Marton, Hillman and Wilhelm recalled audio books from Learning Ally, which was formerly known as Recordings for the Blind and Dyslexic. Wilhelm shared, “[Learning Ally] record audio textbooks in a format, and I can listen to figures described by a professional. There are volunteers, thousands of volunteers all over the country….”.

Participants’ experiences with screen readers are reflective of the many changes in screen reader technology over the years. Ten participants with visual impairments discussed screen readers. Milo recalled, “The first screen reader I used was the Echo 2. That’s for the old Apple IIe, so it’s going way, way back.” Freedom Scientifics (JAWS) screen reader technology was named by most participants who were using screen readers. Marco had been working on his family’s dairy farm for the several years since he completed his biology undergraduate degree. At the time of the study, he was applying to post-baccalaureate programs at the time of the study to help him transition into graduate school. He was still entrenched in STEM learning and explained, “At present, I would say it’s really with JAWS that I’ve been able to read. That’s how I stay involved right now, is through reading”. His goal was to have a clearer idea of what he wanted to study before approaching a faculty member.

Four men in the study identified human readers as important for their STEM learning. The readers provided audible renderings of written course materials. Cassette recorders have served participants’ learning needs over time. Marton struggled to find an effective method of note taking in high school, when he first lost his vision. He said,

> Sometimes I would try taking notes in Braille. The trouble is it can be pretty noisy to do that in a classroom. Sometimes I would also try to sit in a corner of the room and whisper notes – onto a cassette tape.

In college, he had refined his method saying,

> Definitely through college, a tape recorder was of great benefit to me…. A reader would come to my dorm room... [and] read a few pages and then I would indicate for them to pause. My tape recorder would be cued up and then I would dictate a summary onto tape. Then, to prepare for an exam, then I would listen to my notes that I had recorded."

Cera was also using recording technology, "It's all on my laptop. I use a digital audio recorder that I love, especially for in the field and quick notes. It's like my version of pictures. I just love audio recording". Reading machines were identified by two participants, both over the age of 45. Seal used an Arkenstone reading machine when he went back for graduate school as an adult, Herb tried a Kurzweil machine in college.

Learning applications.

Interacting with STEM content.

Tactile graphics, raised line drawings/graphs, Nemeth Braille, large/high-contrast writing and assistive calculators were most commonly identified by participants as assistive technologies used in association with STEM during their learning in elementary, secondary and college experiences, including graduate school. These same technologies were missing in discussions of STEM careers. Twelve participants identified aid and/or sensory substitution technologies, which have been classified here as technologies for interacting with STEM content. This group of technologies provided participants with the means to interact with models and problems used for learning science and math. The twelve participants in this group engaged in working math problems, exploring structures in science and assessing relationships between variables. There was little mention of laboratory equipment. Only Hillman, whose undergraduate and masters degrees were in physics mentioned his experiences with lab equipment, saying,

> I think, for me, sometimes extra time in labs, getting hands-on with some of the equipment, and the professors taking some extra time, was helpful, but no other specific assistive technology because it wasn't available back them.

The list of technologies interacting with STEM content included both STEM-specific AT and general AT. Examples of STEM-specific assistive technologies tended to be mentioned by individual participants including enlarged graph paper, raised line graph paper, molecular model kits, Braille version of a circular slide rule, enlarged stereonets for plotting geologic structures and tactile dial calipers for field measurements of invertebrates. The latter two AT were used in undergraduate science programs.

Nemeth Braille and talking / graphing calculators were also a STEM-specific assistive technologies that participants identified. Karl, Tina and Marco discussed their experiences with calculators. Karl was 70 at the time of the study and discussed his calculator experience in graduate school. He was a married adult when he sought out graduate school for assistive technologies and ended up in a program for special education. He bought a piece of cutting edge technology for graduate school. He said,

> … to go to graduate school I had a hand calculator that even the professors, everybody just envied. Hell, it cost $400. I mean, it was amazing technology…. It had large numbers, light numbers on a black background so I could read it. Rather than sitting there with my paper and pencil and calculate things… I used it in the STEM courses. I asked the professor whether I could use it in his class, and he said absolutely. He was fascinated by it too actually…. A simple calculator, addition, subtraction, multiplication and division. That's all it did."

Tina and Marco were in their 20s at the time of the study and each shared their high school experiences with calculators. During high school Tina used a listserv following her involvement in a summer computer science program for girls to ask if anyone had suggestions for an accessible graphing calculator. A blind computer scientist from NASA replied to her with a suggestion of MathTrax, the free online accessible graphing calculator. This started an important mentorship between Tina and the NASA scientists that lasted through Tina's high school and college years. Marco was critical of accessible graphing calculator technologies. He explained that they seemed to be developed for high school-level mathematics and were difficult to learn, making them not worth the effort.

Aside from these few examples of STEM-specific AT, participants remarked on their uses of general assistive technologies for STEM learning applications. Braille was integral for the learning of math and science for eleven of the participants in this study. For some, including Marton and Seal, the lack of Braille was a detriment. Seal explained his experience and perspectives on the value of Braille in this way,

> When I got to about fifth or sixth grade, Braille kinda went away. I was given audiotapes. This is gonna sound kinda funny, but maybe it makes sense. As a kid I though, "Fine," I didn't see the big picture, in terms of having to do you Braille lessons. I was just, "Woohoo! I get to listen? Really?" I think it was one of those experiments that I think you talk to a lotta people mighta – I've talked to a few that have been in a similar situation to me. Later in life, they go, "That was a mistake. They should've made me learn the Braille." It gave me a tool to read and write with, and process in a way that is reading and writing and a form of literacy.

Participants mentioned Braille writers. Wyatt described how Braille writer technology was used for his math learning. Wyatt said,

> …certainly used Nemeth Braille in hard copy and in my own notes…. everything from being able to use a Braille writer to do things like linear algebra in hard copy to using a refreshable Braille for doing other math and equation writing …

Six participants with visual impairments, five males and one female, identified tactile graphics as important to their science and math learning. Participants ranged in age from 20s to 60s. This included four of the five people with visual disabilities with science degrees. Wilhelm explained, “Yeah, tactile graphics in a machine called a Pictures in a Flash machine which makes a raised line where you have lines on the page … I used them for biology, physics, chemistry, geometry. Very valuable.” Hillman, who was 64 at the time of the study, reported, “I also had a device called a raised line drawing kit…it was a board with a rubber mat on it that drew on plastic. People could make temporary, or just quick drawings of things as we needed to.” Marco, aged 24 at the time of the study, had the experience of his paraprofessional using puffy paints to render tactile images while Lars’ classroom teacher worked with his assistive technology directly saying, “….my geometry teacher was pretty good at making tactile drawings for me.” Marco explained what happened when he went to college for his biology degree,

> I explained to them how Paula [paraprofessional] made the diagrams. The document conversion specialist made my diagrams for the first chapter in *Domestic Animal Biology* with puff paint. He said, "That was really f*cked up. I am not gonna to do this the rest *[laughter]* of the semester."

As an alternative, given the specialist’s reaction to the puffy paint process, the disability services office at the college purchased an embosser to create the tactile drawings for Marco’s classes. He came to rely heavily on the embossed models. Wilhelm was doing research in a chemistry lab at the time of the study while working on his Ph.D. He was using a 3-D printer in the chemistry lab to generate models of all the molecules they were using. He explained that it also gave him a mechanism by which to communicate models he had in his mind.

Accessing STEM content.

Participants described assistive technologies as the key mechanisms by which they could access information. Access to information, specifically STEM content, was identified as a major component to participation in STEM. Seal shared his perspectives on information access,

> I remember thinking that if I could've gotten my first-grade education materials in a digital format, how much different my life would've been. If I started school with equal access to the information everybody else had access to, how much different my life would have been. That set me on this quest….

During their learning years, 17 participants identified that they used assistive technologies to access STEM content that was being delivered to them. Only Bernadette did not mention that AT was a means of accessing STEM content for her. The content participants were seeking to access during learning was generally from educators and textbooks. As learners, participants used aids and sensory substitution technologies to access what was happening at the front of the classroom and to access the content from schoolbooks.

Nine participants used visual aid technologies as learners. They employed the AT to help them read typed text in hard copy or on the computer, to increase visual access to the teacher at the front of the room and to improve their abilities to read the handwriting and see the drawings and modeling on the board. Wyatt along with four other participants with low vision at the time of their schooling used magnification technologies. He mused "…it's interesting, actually…Growing up in elementary and high school, I used mostly either large print or screen magnification". Herb expressed his view that "The best adaptive technology with low vision is white paper and a big thick marker." Carlos and Harold used telescopic technologies. Carlos explained how the visual aid he used provided access. He said that, "…the most useful thing was the monocular, telescope. That really let me – it wasn't the best solution, obviously, but it let me sit in class and actually follow along with the board somewhat. That was huge." Harold's video-system based Note Taker innovation enabled users to see writing on the board and everything the professor was doing at the front of the room. He explained "…that computers were able to help even mitigate lack of access in the physical world, as in the case of the Note Taker." People who took notes in class as an assistive technology service provided STEM content also. Carlos and Lina, who have low vision and Kumi, who is deaf, all used note takers. Kumi explained why note taking was so useful saying, "With math and science, you know, I really needed to have a note taker because it's impossible to watch [the interpreter] and take notes at the same time…"

Ten participants used sensory substitutes to access the teachers' spoken language in class, teachers' writings on the board and textbook STEM content. To accomplish this, Kumi relied on humans to interpret spoken language into sign language. Marton, Milo and Seal relied on cassette tapes to capture classroom lectures. Milo explained, "I also used a little microcassette recorder to record … through a good portion of high school but definitely through college. That was invaluable for note taking and just to review things and all that."

To access written resources, participants used Braille, human readers, screen readers and scanning technology to input hard copy print into reading machines or computers. Captioning was used by the one participant who was deaf to access media-based content. Wilhelm's response, "Braille is number one," is an apt summary of the role of Braille in science and math learning for people with visual impairments. Thirteen participants of the sixteen with visual impairments, identified Braille as an important AT for their STEM learning. Participants who identified Braille were from across STEM domains, from a wide age range and included males and females. Four male participants from across STEM domains explained that they worked with human readers to access STEM content as students. Screen readers were identified as important for accessing STEM content by five participants from across STEM domains. Four of these five participants are under 40. Only Seal, who was over 60 years of age and went back to graduate school as an adult and used a screen reader. Usage of this technology is possibly tied to the increased availability of screen readers over time. Three participants over the age of 45 identified reader machines as methods for accessing content. Herb shared his experience with a reading machine late during his college career saying, "…the university got… a great big old Kurzweil machine… I tried puttin' some books on it, and it had a speech synthesizers built in. It did an okay job." Participants often used a combination of technologies to access STEM content. Wilhelm, a Ph.D. student at the time of the study, explained, "Accessing material is so important. My computer that talks has a screen reader on it, JAWS… My Braille note taker, which I can read Braille off of and take notes whenever. Assistants, knowing when and how to use a live reader to get stuff."

Types of assistive technologies used for STEM careers.

The fourteen participants in STEM careers included those with low vision, blindness and hearing disability. Their representation across STEM domains includes: five AT specialists, four computer scientists, two engineers, one scientist and one farmer with a science degree. Marco, the dairy farmer, is straddling both career and learning, as he works on his family's dairy farm and is preparing for a post-baccalaureate program in dairy science. In general the AT used by professionals was less diverse, though both aids and sensory substitution technologies were identified. All fourteen working professionals described technologies that they identified as assistive, though most also identified accessible technologies that were useful. Carlos is the only participant who named only an accessible technology, Windows 7 magnifier, as a technology he uses today for his work. As with STEM learning technologies, professionals used few domain-specific assistive technologies and instead used general assistive technologies for STEM applications. The only STEM-specific assistive technologies mentioned include Viktor's continued use of the tactile dial calipers created for him in college and Herb's requests for assistance during his occasional use of the oscilloscope at work. Note that four participants were students at the time of the study: Bernadette, Cera, Harold and Wilhelm. Their responses are not considered in this section.

Vision aids.

Vision aids were identified as important for career work by Lina and Herb. These included magnifiers, text inversion and lighting. There were no mentions of telescopic viewers or note takers. This reflects the nature of the work professionals were engaged in compared to students. Lina, a research professor, used a hand-held magnifier for grading student work. Text inversion is also helpful for some participants including Lina, "Instead of it being black on white, I invert it to white on black…make it more comfortable for me to be able to read things on the screen." Herb mentioned that environmental lighting also supported his access to resources at work. Carlos mentioned the Windows 7 screen magnifier that he uses for his job but this is accessible technology, rather than assistive.

Sensory substitutes.

Twelve participants identified sensory substitutions including participants with vision and hearing impairments. Substitution technologies included tactile, auditory and visual formats.

Tactile format.

Braille was mentioned by six participants with visual impairments. It was the sole tactile format used in the workplace by STEM professionals. Braille is rendered tactile through hard copy embossing and refreshable Braille displays. Braille writers are used to enter content / data using Braille as the input. The tactile aspect is the Brailled keys for typing. For some, such as Viktor, Braille was a primary resource. He said "I read vast amounts of scientific work. I have an enormous – I mean gigantic Braille library of all the notes I've transcribed from these papers". Wyatt used a Braille display but he did not use any hard copy Braille in his professional career. Tina also used a Braille display but she did not use her BrailleNote Apex for work, though she loved it, because, "it has limited capabilities – so like you can't program on it".

Auditory format.

Eleven blind / low vision participants indicated that audio resources were important to their STEM participation. Audio resources mentioned were generally limited to screen readers and human readers though there was one mention of a portable reading machine. This group of participants came from across STEM domains and age ranges. Only one of the two females in careers used audio resources.

Ten participants identified screen readers as important for their STEM work. Most also specified JAWS though Herb explained that he found a free screen reader,

"….called [non-visual display adapter] NVDA….It's written by some – I think a team down in Australia. It is just absolutely wonderful for somethin' that's free". Human readers read aloud whatever writing participants needed access to including emails and scientific journals.

There were no mentions of cassette recorders, audio recordings of content or large stationary reading machines for use in professional settings. Hillman carried around an old Nokia phone with a Kurzweil-National Federation of the Blind (K-NFB) technology on it. He said,

> Kurzweil developed a reading machine and always wanted to get it portable. He and the NFB worked to eventually get it on a cell phone. It was on Nokia cell phones for a while. Literally, I could take a picture of a page using particular Nokia cell phones, and they would read it out loud…I carry a Nokia N86 phone that has the program on it in my briefcase so I can read wherever I go…When the K-NFB reader comes out on the iPhone, it will completely revolutionize doing optical character recognition on the iPhone.

Visual formats.

Kumi used visual resources for sensory substitution. He discussed captioning and interpreters, emphasizing that it's important to have qualified interpreters who have the sign language vocabulary and technical knowledge to be able to provide adequate services because "….a random person would not be able to understand and…successfully translate the information".

Career applications.

Accessing content.

During their career work, ten participants employed assistive technologies to access STEM content that was relevant for their jobs. This kind of STEM content included scientific journals, software code and company / agency / institution documents.

This STEM content was generally available on the computer. Consequently, audible renderings, by screen reader or human, were the main type of assistive technology for people with visual impairments to access content. For the participant with a hearing impairment, content was read or provided via interpreter.

Viktor preferred human readers to computerized readers. He said,

> I just do not have the patience, and certainly not the time, to try to worm my way through using these clunky programs… a lot of material I read is highly technical. It's full of peculiar names. Often there might be equations, symbols of all kinds. It's frankly - a sighted person is so much more flexible than these programs are, so there's just no comparison.

Creating STEM content

There were fourteen participants who were professionals at the time of the study, including the two who were working as emeriti. The remaining four participants were Ph.D. students at the time of the study. They were transitioning from roles as learners to roles as professionals as evidenced by their changing uses of their AT. The professionals were all engaged in career work that included the creative aspects of their work as well as the day-to-day tasks of the job. Lina distinguished between the creative aspects of her career and the related tasks of the job when she was talking about technologies on the horizon. She said,

> Things that augment reality and stuff like that where you're wearing something like a little glass and it just highlights things for you. That has limited value for the technical aspect of the career, I think, but it certainly can impact things positively in related tasks of the career.

With this distinction in mind, I approached participants' comments about the roles that AT played in their careers. I found that in their STEM career work, participants were using computers, Braille, lab equipment and assistants for both their creative career work and their job tasks. Career uses of AT differed distinctly from student uses of AT for interacting with STEM content. Job tasks included communicating remotely (emailing and phone calls), interacting with colleagues, navigating for work travel, keeping calendars, and grading student work. Participants used both assistive and accessible technologies to complete these tasks. Lina talked about grading student work, “I use a handheld, those digital handheld magnifiers sometimes. Yeah, especially when I grade student work that isn’t on the computer to try to decipher handwriting on tests”. Marton explained his uses, “I’ve used a desktop computer for writing, for keeping contact information about people, for keeping a calendar –“. Viktor’s assistant helped with all aspects of his work including job tasks as follows saying,

> I have a regular, non-specialized computer in my office, so when emails are read to me, I write up emails … which I type in Braille first and then I type and then she scans it in. She proofs them and so forth, and all this stuff – it really works very well.

The professional participants can be grouped into four categories: scientists, engineers, computer scientists and assistive technology specialists. While the job tasks, when they were mentioned, were comparable across participants, the creative work differed. Viktor, the only non-student scientist in the study, was a published researcher and therefore, a producer of knowledge. The engineers, Herb and Wyatt, developed solutions and innovations. The computer scientists designed and built software and applications. The assistive technology / disability specialists established infrastructures and frameworks for working with people with disabilities. In each of their own ways, the professional participants were creators. The professional participants had transitioned from being consumers of knowledge, users of technologies and software and learners of infrastructures and frameworks to being creators.

As with the students, there were few STEM-specific assistive technologies used by the professionals. Herb mentioned that he occasionally used an oscilloscope with the help of others and Marco used an iPhone application called “Herd” which helped him with his shepherding duties. Aside from those specific technologies, three participants mentioned that they used Braille, three worked with assistants and eight mentioned some aspect of computers (software, operating systems and/or peripherals). Viktor explained the role of Braille for his production in this way,

> I have an enormous – I mean gigantic Braille library of all the notes I’ve transcribed from these papers. Many tens of thousands of ‘em and I could never ever ever writer the papers I do or the books I do without having that library that I’ve accumulated reading. Likewise all the fieldwork I’ve done, the museum work I do - I mean, that’s my scientific life.

Tina, a Braille user, explained her application of AT, “I do a lot of coding and you need to look at the fine grain details so I also have a Braille display”. Kumi explained the role of the interpreter in his writing thus, “just being the way how the translation process – to help the interpreter and the deaf person capture the video or knowing the chapter is clear and easy to follow”. Hillman combined several technologies for his writing process saying, “Dragon Naturally Speaking and J-SAY which is a bridge between JAWS and Dragon, that makes the whole process a lot more accessible. I use that when I write longer articles….”. Three participants identified accessible technologies like MS Office, with applications that are screen reader friendly, important for writing and engineering. Two participants mentioned magnification features, enabling them to see the screen to work. Lars, who is a teacher of assistive technologies, must understand how everything works to not only teach his students about the logistics but also how the AT will work in their lives. He said "[I use] everything because again, I can't teach it if I don't use it."

There were four participants who became creators while they were still in school. Harold, Tina, Seal and Wilhelm each faced challenges in which the AT that was available to them was not sufficient to grant them sufficient access so they chose to innovate. Wilhelm, a Ph.D. student in computational chemistry at the time of the study shared, "There are things that we're doing now with the scripting that we're writing for the 3-D printer and with the stuff that I'm able to compute with the accommodations we've made that I never thought was possible." He chose to leverage the resources around him to push the boundaries of access into a new space. He was using the 3-D printer to both access the visualized models used by the people in his lab as well as to communicate the models and concepts he had in his mind. Harold invented NoteTaker technology as an undergraduate desperate to keep up in his advanced mathematics courses. The class that prompted his push to innovate was not beyond his reach cognitively, he was simply constrained by his ability to access the content the teacher was putting on the board. Tina was frustrated with the inability of her electronic Braille notetaker to produce a useful Nemeth output. She chose to innovate. She told me,

> …so in the summer between my sophomore and junior year… I basically shut myself in my bedroom for maybe month – a little more – and started writing with only one year of java experience, a program to basically take code if you wrote Nemeth on an electronic notetaker, it would output my text.

Seal started his graduate program as an adult. He was excited about assistive technologies which were relatively new to him and approached the director of disability services on campus to inquire about the AT they had available. Seal explained,

> [The director] said, “Well, we just got some, but we don’t know how to put it together - do you know anything about putting it together?” I said, “Yeah, I can put it together for you.” Then, he takes me a little room where they had all this stuff stored in boxes. Over the next couple of weeks, I unboxed it and hooked it up. I knew enough about doing it. …. Not knowing how to do something completely has never stopped me, in my life, from doing something…. Then, he offered me a part-time job running the lab. I said, “Okay, well, another door just opened.” …. Along the way, I met other students who were—they were kinda new to this, too, so I got to teach them. … There wasn’t any policies; there weren’t any rules. All that stuff came along the way. We developed hose things. … Because, in the sense, it wasn’t an accredited program, we could chat about stuff that wasn’t—there weren’t gonna be tests on it. There wasn’t gonna be exams on anything.

Each of these people engaged in creative practices of STEM careers while they were still students. And, subsequently, they were using assistive technologies – the very same ones they were also using for learning – for their creative endeavors. They were providing access for themselves.

Assistive technology inventory.

Along with the roles of AT, participants primarily specified the types of AT they had used in their responses to three interview protocol questions: (1) whether or not they used AT prior to undergraduate (2) which AT they used for science and math learning and (3) descriptions of the roles AT had played in their participation in STEM. Some also provided information about AT they used in early questions about self-efficacy and a later question about barriers to acquiring AT. Figure 6 provides an overview of the specific assistive technologies identified in the study. The AT are organized by those used for STEM learning, STEM careers and those that were used in both learning and careers. AT listed along the left edge of careers but primarily in learning reflect those mentioned by participants who are transitioning from learning to careers in their Ph.D.

programs. Note that few examples of AT were described in the passages above when fewer than three participants mentioned them.

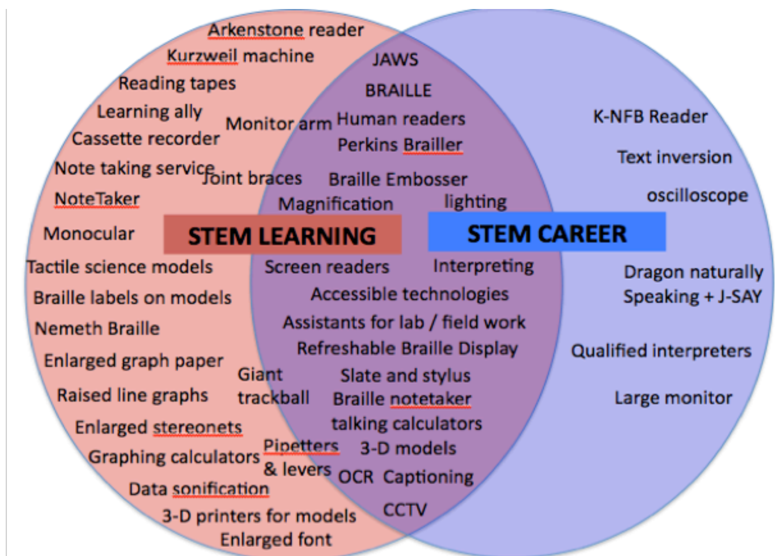

Figure 6. Assistive technologies for STEM learning and STEM career applications

Data in Table 16 provides an overview of categories of AT identified for learning and career work. Though participants were asked if they used AT prior to undergraduate school, I had not designed the interview questions to capture details about the years of use for each technology (elementary school, secondary school, before college, during undergraduate, graduate school). Many participants provided enough contextual information for me to connect specific technologies to specific pre-career timeframes. However, without enough data to establish that level of detail for each participant's experiences, I aggregated the technologies participants used prior to their careers as “technologies for STEM learning”. Technologies they used in their careers were categorized as “technologies for STEM careers”. These technologies were then classified

Table 16
Technologies used by participants for STEM learning and careers

	Sensory Substitution						
	Vision Aid	Ortho Aids	Audio	Tactile Writing	Tactile Math	Tactile Graphic	Interpret. / Caption.
AT for STEM learning	9	1	12	12	7	6	1
AT for STEM learning without student participants*	7	0	9	10	5	5	1
AT for STEM careers of working participants	3	0	11	6	0	0	1

*Note: four participants were students at the time of the study. This row does not include them to allow for an easier comparison between AT for learning and for career among the same participants.

according to their assistive technology types based on the groupings in the previous section: aids and sensory substitutions. Note that four participants included in this study were in graduate school at the time of the study. The AT they identified was grouped under tools for learning, though they were transitioning to careers.

Kumi and Bernadette were the only two in the study without visual impairments. Kumi identified technologies that substituted vision for hearing, interpreting and captioning. Bernadette identified orthopedic aids only.

Tactile writing, math and graphics were disaggregated to show the contrast between tactile math and graphics compared to tactile reading and writing. Tactile math (Nemeth Braille and raised line graphing) and graphics were identified by participants as STEM learning technology and were not used for STEM career work by the blind/low vision participant pool of this study. Braille was used by all blind and many low vision participants during their learning, though it was not used as frequently by participants in their STEM careers. Use of vision aids, tactile graphics and math as well as tactile writing decreased from learning to career applications. Use of audio resources increased between learning and career work for those in professions at the time of the study.

Changes in the assistive technology use are not based solely on differences between career and learning applications. Participants AT use changed over time because of changes in their disabilities and because of the evolution of technologies. Lars explained that he had “considerable usable vision in childhood”, enough to play sports and video games. Because Lars’ mother had the same visual impairment as he had, they knew that his vision loss would likely increase. His family was proactive. “I actually attended programs while I could still see to get training under a blindfold,” he explained. Lars learned Braille while he still had vision so he did not have an abrupt transition from large print and magnification to Braille and screen readers as his vision loss increased. Some participants reflected on what they used in the past when their disabilities were less advanced. Herb described how he used computers before he had a screen reader. He recalled, “At that time, fortunately, if I got close enough to the screen, I could read the white text on the black background”

People who started out with usable vision and experienced significant vision loss over time transitioned from visual aids to sensory substitution technologies. Seven participants with vision that was never usable throughout their lives reported using only sensory substitutions. Six participants used both visual aids and sensory substitution technologies. Wyatt, Herb and Lars, were three of the people who used both visual aids and sensory substitution technologies and they all had mothers with the same disabilities.

Most participants who used both categories of technologies shifted from visual aids to sensory substitutions as their visual impairments increased. Herb, however, learned Braille as a child though he still had usable vision. He did not use Braille at the time of the study. "…. I haven't really used Braille in 20, 30 years. I mean I'll go back and look up something out of a textbook. I kept my textbooks…. I don't' think I've ever used Braille in my professional career", he explained. He added, "Maybe in the next few years when my vision gets a little worse, I may have to switch over to that [Braille]". Wyatt took a training program for adjusting to blindness at the start of his undergraduate experience. He described his transition from visual aids to sensory substitutions and the value of the techniques he learned when transitioning,

> Growing up in elementary and high school, I used mostly either large print or screen magnification. It was when I actually started as an undergrad that I began to use Braille, and speech, and the use of readers more. That was a good transition to make, but it's something—but it's interesting, the sort of alternative techniques that I use today, I only started using just in my undergraduate program, at the beginning of it.

Participants also changed how they used technologies based on what was available at the time. Lina recalled that she did not use assistive technology prior to undergraduate other than a note taker saying,

> I graduated high school in '89. There wasn't a whole lot. We really didn't use computers in the classroom….a computer lab in my high school .... had Mac SEs. That' the ones shaped like a shoe box. I was just like – the monitor was so small, it was like, "Well I'm not using this."

Seal, who was 64 at the time of the study, recalled, "I had reel-to-reel tape recorders and then eventually cassette recorders." Hillman, also 64, described a Brailled circular slide rule that he used for math. And Herb, aged 49 at the time of the study, explained, "I think when I was a senior in college the university had got – it was a great big old Kurzweil [reading] machine. The thing was about the size of a desk – that would do some scanning." Marton did not lose his vision until at age 16, towards the end of high school. Therefore he did not have experience with assistive technologies prior to that. He tried learning Braille for several years after becoming blind but never mastered it enough to use for learning or career. He used audiotapes for textbook content and cassette tapes to record lectures and eventually moved to screen readers in graduate school because he was able to access one.

Cera, a Ph.D. student in Science Education in her late 20s at the time of the study, came from undergraduate and masters degrees in marine geology. She explained her own experiences with technological changes during her college years as follows,

> … because it changes and improves so quickly, as long as there's somebody in there who's thinking about people with diverse abilities and incorporating that accessibility into the technology, the rate at which we're more able to do more just accelerates, and it's quick…even from undergrad to grad school, I saw this immense increase in possibilities of things that I could do.

Her comments are particularly noteworthy given that it was during her masters degree program that she experienced significant vision loss.

Barriers to acquiring assistive technologies

Twelve participants described barriers they experienced in acquiring assistive technologies. The most common barrier was cost. Ten participants, with orthopedic, visual and hearing disabilities, mentioned that cost of assistive technologies could be prohibitive. Hillman shared his experiences as, "Cost. Cost would be the main one, now, especially because I'm not a client of the department of Rehabilitation. I don't have access to them just buying stuff". Karl added, "Everything in the area of blindness and visual impairment is incredibly expensive because the market is so small".

Availability of the resources and training were the next most common barriers, each were identified by three participants. Milo recalled a school experience saying, "I couldn't get a Braille textbook until I was a senior, so I was only able to take a year of French". Kumi ran into issues of accessibility also. He said "Oftentimes it is hard to find a qualified interpreter for a technology need…there are only a couple of people who are successful in making that kind of a job and they're able to… dig in with what we're talking about". Seal, Karl and Marton were all over the age of 50 at the time. They identified that the learning curve for new technologies was a major barrier. Seal explained, "…when you learn how to you is, you don't know – you can't remember everything". Marton added that,

> In terms of the learning curve, yes. That is an issue. I do find that sometimes its' an issue with apps that I hear about other blind people are using and it sounds really cool. I just haven't set aside – when I tried it initially, it seemed intimidating. I just haven't set aside the time to learn it. I do think for a sighted person, it's often more readily apparent how one operates something, but for a blind person, we have to learn about alternate ways of doing things – that has an additional complexity and additional cognitive load.

Harold and Bernadette mentioned that it is difficult to know which technologies will work for your needs. Bernadette explained,

> The really advanced, highly functional head tracking stuff that I'm interested in trying is about $1,000. That's something where I've demoed it in the access tech lab. It looks awesome, but $1,000 is a lot of money. It's like, if this worked really well, I would totall be willing to pay $1,000… If it didn't work really well, it would such to sink $1,000 on it…"

Barriers to Participation in STEM by People with Disabilities

Seventeen of the 18 participants shared their ideas about why there are so few people with disabilities in STEM. The remaining participant, Seal, said he did not realize that there was an underrepresentation. Because nearly all participants responded, there are no generalizations to make about participant or parent demographics. Almost every STEM professional in the group had distinct thoughts about this issue. Their responses were sorted into five themes: 1) barriers to success, 2) inaccessibility, 3) characteristics of STEM, 4) perceptions and decisions, and 5) missing support.

Barriers to success.

Eleven participants identified barriers to success. They identified inadequate preparation, low expectations, and college faculty and disability services as barriers to success in STEM. Participants who identified these barriers were males and females across STEM domains with different disabilities. Some participants had mothers with disabilities.

Inadequate preparation.

Inadequate preparation was identified as a barrier to success by six participants from computer science and engineering (men and one woman). Their comments about preparation addressed fundamental literacy skills, deficits in computer training, consequences of inappropriate mainstreaming practices and issues with the quality of educators. Hillman identified a disparity in literacy development,

> We don't teach Braille like we used to. We encourage people who have [blind] kids and [blind] people as they're growing up to use screen readers and recorded books, or listen to books through computers. We don't encourage sighted kids …to learn what they learn just by watching television and looking at pictures. We still teach them how to read and write. Why is it different for blind people?

In the K-12 setting, Lina pointed to a lack of participation by students with disabilities in mainstream environments, limiting students' opportunities to become engaged and have hands-on experience. Marco had two drastically different experiences with teachers of the visually impaired. One, with whom he worked from first to eleventh grade, was excellent, went above and beyond learning Nemeth code to work with him on his math and really pushed him hard. The other, who worked with him during his senior high school year was described in the following way, "she didn't really have the mental capacity to help a graduating senior take calculus….". Seal noted, "I know things are still not where they should be in K-12. In terms of preparing, I think, people with disabilities, in general, much less in the sciences."

Lars identified an issue he explained is pervasive in the lives of people with disabilities. He explained that it drives people's inaccurate perceptions of the inaccessibility of resources and impacts them throughout their lives, He said "The problem is you have a whole huge segment of people who have never really received appropriate training on their computer". Inadequate training impacts people throughout their lives, especially now when computer use is so commonly used in daily life. Wyatt addressed the larger issue of successfully working toward goals and achievements in STEM. He explained, "I think that's where there's a lot of disconnect between people who intend to do it and have people who are more supportive….[and those] that can't really get to that next level of figuring out the resources, what they need to make it happen."

Low expectations.

Five male and female participants with different disabilities cited low expectations for people with disabilities as a major impediment to their representation in STEM. Lina explained that people overprotect their children with disabilities, especially when the parents do not have disabilities. Their children are raised in environments that are less challenging than their peers, limiting their ability to be competitive. Bernadette recalled that she was in school with students with IEPs that were "perfectly capable of getting a Ph.D." but were counseled by the school to go to community college instead of four-year institutions. Both she and Cera explained that people with disabilities are advised to take easier academic paths. Marton thought that the advice to take an easier academic path is because people believe that individuals with disabilities are not able to be competitive. Kumi specified that because mainstream education is so heavily dependent upon spoken words that students who are deaf / hard of hearing do not have equitable access to information. This then leads to lower academic performance and lowered expectations by educators. Consequently, students who are deaf / hard of hearing end up leaving STEM paths for other careers.

Disability services.

Hillman, Bernadette and Harold expressed frustrations about their experiences with disability services. Harold avoided disability services, only engaging them when absolutely necessary and even then, only for specific services. He told me

> [Disability counselors] don't always know what they need. Oftentimes, they'll even suggest things that aren't actually helpful, that could be hurtful... [they can be] actually a little bit overprotective or think that they know what you need better than you do. I think there's times when that's true, but there are also times where someone has to really explore these things themselves and figure out what works best for them…

Bernadette, who has an orthopedic impairment that affects the joints in her body, has struggled to find and get assistive laboratory equipment. She has not found disability services to be helpful because their focus seems to be on computer-based innovations. She said "I can tell people about that [an accessible lever to open Eppendorf tubes in the lab] but when the accessible technology specialists at the universities that I've been at don't know about it, how are people supposed to know?" She went on to explain that she has seen more assistive technology available for people with sensory disabilities than orthopedic disabilities.

Hillman expressed his frustration with the lack of self-advocacy training exhibited by disability offices. He saw that the disability services do all the work. He believed it was critical that it should be the students connecting with professors who negotiate conditions for accommodations, only calling on disability services in circumstances when professors will not cooperate. Hillman said,

> …if I don't learn to do it in college, I will not be able to do it when I get out into the real world. Again, we're treated as a different kind of class and we're not forced, if you will, to learn the skills that other kids learn.

Harold reflected on his experiences seeking people to pilot test his Notetaker innovation for those with visual impairments. He sought to recruit participants from the disability services centers but the numbers were very low. Wondering where all the visually impaired people were, his team changed their recruitment tactics, using department listservs to invite people who struggle to see the board to participate. They received 75 responses. Harold suggested that perhaps people with low vision are managing to get by in classes by listening and using compensatory mechanisms. They are managing this without engaging with disability services. . However, they are unable to keep up in challenging STEM courses and, consequently, follow academic and then career pathways that are less rigorous.

College Faculty.

Three participants discussed college professors as barriers to success. Bernadette recounted an experience she had shortly before her participation in this study in which she realized that college professors did not understand issues associated with disabilities. She explained, “it was…like…they didn’t realize that…there were people with disabilities in their labs….and that access was a thing they should think about. Harold identified the central issue of tenure requirements for college faculty saying, “nowhere in there [requirements for tenure] is teaching an incentive… and especially teaching of the variety where the outcomes are not at all certain that they’re going to be better overall, and … contentious for the department”. Harold went on to say,

> There's no incentive … to customize these classes to each individual student… and I don't know that there even should be. I guess the point is, is just, I think part of … the under-participation, if you want to call it, in STEM majors is not just unique to the individuals with disabilities. It's probably amplified.

Cera acknowledged that some college professors have “old mindsets” about the capabilities of people with disabilities and raised the question of who would be able to fight that mindset if it was the prevailing attitude of a department. However, she also stated that faculty attitudes are shifting. Faculty want to teach their students in the most effective and fair ways possible but she said, “[t]hey just don’t know how or what resources are available, and so that really limits them in terms of their conception …. Of what human ability is and what people can do.”

Inaccessibility.

Nine participants shared their ideas about issues relating to inaccessibility. Wilhelm summarized his views saying, “The problem with anything facing people with disabilities, it’s just that it’s not in an accessible format all of the time.” Carlos explained challenges from his experiences,

> Trying to sit through a math class or a chemistry class or something like that when you can’t follow along with the whiteboard is an absolute just monstrous

> nightmare. I can easily see why a lotta people would just kinda give up and go towards something with less resistance.

Tina wanted to take a visual basic course in junior high but had to take one online because the class at her school was not accessible. Herb, Carlos and Karl discussed specific issues of inaccessibility and mathematics. Karl explained,

> The reason is that math is pretty inaccessible to blind people. In a nutshell, mathematics is actually very visual in nature and we still do not have good methods for studying mathematics, good ways of reading mathematics….

Karl added, "If you don't know mathematics you don't stand a ghost of a chance in chemistry, physics, whatever it might be." Carlos, a computer scientist, explained that computer science is a natural fit for people with visual impairments but that the math and science courses were a major impediment because they tend to be inaccessible. Herb remembered his challenges with mathematics access. He said,

> The math was sometimes almost impossible because, "What book are you using next semester?" "Well, I don't know. It's either this one or that one,"…. sometimes they'd be Brailling the book during the class and the teacher said, "We'll, we're gonna jump to chapter eight for a while, then we'll go back to…".

Cera suggested that the teaching of geology at the introductory level is unnecessarily "visually obsessed" and that this impedes people's abilities to think in terms of non-visual representations and learning. Harold introduced the particularly challenging issue of the social aspects of learn in STEM courses, "especially once it's really sophisticated". He explained that,

> It really helps to interact with your peers and other people who are at similar or even maybe higher levels of understanding than you are……[People with visual impairments and some orthopedic disabilities] can't naturally interact in these groups nearly as well….they're gonna be gesticulating to a paper. That paper, you can't see unless you hold it up to your face….even then, some people need magnification….You can ask them like, "Slow down"… "hold it up to my face"… but the situation doesn't always allow for it. They happen in all these

> myriad ways that impeded normal, natural social interaction, particularly with respect to studying and interacting with course material or concepts.

Wilhelm added the reminder that “The other problem is getting things from my mind onto paper, structures…”. The issue of inaccessibility is not unidirectional, only from a source to the participant. It is also related to the communication of ideas that originate with people with disabilities. For people like Wilhelm, who is working on a Ph.D., this is a major obstacle because he is at the stage of knowledge creation.

Laboratory spaces can also pose inaccessibility challenges. Bernadette, a Ph.D. student in biology, worked in laboratory located in a 1930s greenhouse at her university. She explained that while she can negotiate within the space, people in wheelchairs would not be able to do so. She also identified the issue of pipetting, which, she explained, is physically taxing whether or not someone has a disability. Finally, Tina and Marton raised the issue of compatibility between STEM technologies and assistive technologies. Marton explained,

> Just for example, a lot of sighted people will use a program called Mathematica to do all kinds of mathematical calculations. People do that, and they'll use…SPSS to do statistical work. Both of those are really challenging with a screen reader. It's a real shame because I do think that much more is possible technologically if only the software were written in ways that were very compatible with the assistive technology…they don't have a lot of incentive to do so.

STEM Characteristics.

Six participants identified STEM characteristics as a reason for the underrepresentation of people with disabilities. Harold, Milo and Herb noted that STEM coursework and fields are difficult and they are not well populated by Americans in general. Tina, Kumi and Cera addressed challenges in their specific STEM domains. Tina and Kumi explained that computer science is very difficult and people need to have solid and complete educations in order to be successful in the field. Cera cited the lack of exposure to geology, because geology is often not offered in high school, as a reason why there are so few people with disabilities in geology. She also identified poorly taught introductory level college geology courses as a deterrent to pursuing geology, which impacts all students.

Perceptions and Decisions.

Six participants identified perceptions held by people with disabilities and the perceptions of others as barriers. All participants represented in this theme are males and females from science backgrounds.

Participants suggested that self-perceptions heavily influence decisions. Cera explained that, "I know a lot of blind people who are just prisoners of their own fear and just don't really experience much at all in life, and that starts early". She goes on to explain that few blind students that she knows of have gone on in science because they are discouraged, being told that the field is too visual for them to possibly participate. Bernadette described the kinds of decisions people with orthopedic disabilities face when they are interested in STEM domains with fieldwork. She said,

> …it's gonna be hard to get into the field…You're limited and if you really want to go and work in the field, and you can't, it's like, do you want to settle for something – do you want to settle to be a collections manager, when someone else brings you the stuff they've collected…

Viktor explained his own participation, based on self-perceptions as, "Few people are, frankly, as obsessed as I am. I mean it's rare enough in the science community. It certainly is rare in the blind community, so it's an unusual trajectory for almost anyone."

Hillman and Marco discussed the impact of others' perceptions on the decisions of people with disabilities whether or not participate in STEM. Marco, a biologist, focused on chemistry, a domain he thought would be considered to visually oriented that chemists could not conceive of how to work with someone without vision. Hillman constructed his explanation for low participation rates of people with disabilities in STEM beginning with,

> The Gallup polling organization has done a number of surveys and blindness is typically one of the top five fears in America, and 76 percept of all people fear blindness over any other disability. That's a fear that's been created by so much that goes on around us.

He went on to explain he could not get life insurance until the mid-1980s because insurance companies presumed, without data, that blind people have higher mortality rates at lower ages than non-disabled people. He used these examples to explain that, "We don't teach people that blindness doesn't mean equality. We teach people that blind people are different and unequal in every sense of the word."

Missing support.

Four participants identified a lack of support as an important reason for low participation rates of people with disabilities in STEM fields. These participants were all male but had different disabilities and came from different STEM domains.

Milo and Marco, who both have visual impairments, as well as Kumi, who has a hearing impairment, identified lack of mentors with disabilities in STEM. Marco explained his own experience saying, "they're not encouraged because nobody knows how a blind person does biology. I don't know. I have not met a blind biologist yet." Milo speculated that people might not have good mentors or people encouraging them to get out of their comfort zones. He went further to explain, “we’re discouraged from doing it. We’re not encouraged to do it.”

Ideas for ways to foster increased participation in STEM.

Fewer participants had ideas for solutions about what could or should be done to increase participation of people with disabilities in STEM. Eleven participants, males and females and people across different disabilities, offered suggestions. More than half of these participants were in their 20s at the time of the study. While all the scientists and many computer science / assistive technology specialists shared ideas, engineers were not represented in this section. Note that there were only two engineers included in the study. Participant responses were sorted into four themes: education and training, empowerment, support and changes in perspectives.

Education and training.

Eight participants identified strategies and approaches to education and training that directly address ways to increase participation of people with disabilities in STEM fields. Seven of these participants had visual impairments and one had a hearing impairment.

Milo and Lars addressed issues of training. Milo emphasized that Braille is an important tool for success. Lars adamantly stated that quality computer training is currently lacking but necessary for people with visual impairments to be able to access resources. Milo and Wilhelm talked about the importance of having appropriate content-based resources like textbooks available in alternative formats. Milo emphasized that it is important to have the same resources as sighted peers.

Tina, who took an accessible computer course online because the one at her junior high school was not accessible, stated that there needs to be more accessible courses available in schools. Wilhelm met with resistance from his high school chemistry teacher about the feasibility of choosing a chemistry career but is now working towards his Ph.D. in Computational Chemistry. He explained that there are alternative ways to learn in STEM, "It's just the way that things are presented. Things are very visual. They don't have to be." He went on to say that in his work, he successfully conducted analyses of visual data numerically.

Kumi, who has a hearing impairment, and Harold, who has a visual impairment, both mentioned that smaller groups for schooling would be beneficial. Kumi identified this because in his experience, one-on-one education was most effective and smaller class sizes allowed for more individual attention. Harold explained that the social environment of the classroom could be difficult for people with low vision because they could not fully engage in the social learning aspects of the upper level STEM classroom such as discussions about data while referencing a visual representation on paper such as graphs. "I would say one strategy that can help is interacting with smaller numbers of people and getting to know them better", he explained.

Lina and Wyatt mentioned the importance of out-of-school learning experiences. Lina addressed the need for clear messages about inclusion in advertisement for school clubs and university programs and the importance of meeting whatever students require for accommodations, which can be overlooked in mainstream out-of-school learning programs. Wyatt explained that internships are extremely important for STEM trajectories, "I know that that can be challenging for any person with a disability to get that employment or internship experience, but I found that if you can get that, that makes a tremendous difference".

Empowerment.

Five participants, men and women, addressed the theme of empowerment through self-advocacy, involvement in decisions about oneself and equality in expectations. Four participants had visual impairments and one had an orthopedic impairment. None of these participants had parents with disabilities. Hillman addressed the issue of inequality in expectations for people with disabilities,

> I think that what needs to be done is that more stringent legislation needs to be passed that mandate that we be held to the same standard, and that people start to learn that it's appropriate to hold us to the same standard as anyone else. I think we need to do more to educate people that blindness isn't the tragedy that we think it is.

Harold and Milo identified the importance of people with disabilities to be able to self-advocate. Milo included that finding resources was an important component of self-advocacy and Harold added that disability counselors do not always know what people with disabilities need. Cera and Bernadette both discussed the importance of sharing in decision-making processes about themselves. Bernadette described the importance of being able to decide when work is not safe. Cera talked about the need to have a common language and structures in place to enable decisions to be shared among people with disabilities and those in the contexts in which they function (i.e. labs, classrooms).

Support.

Five participants, males and females all with visual impairments, identified various types of support as necessary for people with disabilities to be successful in STEM. Lina and Milo discussed the importance of bringing parents into the process by exposing them to success stories of people with disabilities so that they know what is possible for their children. Milo and Tina addressed having goals to reach for and learning how to reach them. Both of which, they explained, are fostered by role models and mentors. Lina and Tina, both women in computer science, identified the importance of verbal encouragement as significant in supporting participation of people with disabilities in STEM. In particular, Lina included, encouragement from people running robotics clubs and the like. Viktor provided a summary saying, “There’s no doubt that having good, supportive contacts makes all the difference in the world – absolutely all the difference in the world”.

Changes in Perspectives.

Four participants, two scientists and two people involved with computers and assistive technologies, identified the need for changes in perspectives. Their comments were directed to three communities: educators, institutions and society. Wilhelm addressed the issue of limited teacher perspectives about is possible for people with various disabilities, ending with the importance of keeping open minds. Cera explained that there is a need for more teachers / professors who are comfortable and open to having students with disabilities in their classes, seeing the experience as an opportunity to learn about how to do things differently rather than seeing students with disabilities as “trouble student[s]”. She added the reminder that, “Many of these approaches that we develop for students with diverse abilities turn out to be something that really benefits the whole classroom interaction system and community in some way.” Marco expressed his wish that there were information sessions available to college faculty on teaching people with visual impairments. He went on to say “the blind STEM community… just need[s] to spread the word that there are tools out there, tools and techniques”.

Cera and Marco also addressed issues of institutions. Including open-minded people [faculty] who are not afraid to fail and looking at models and examples, Cera explained, can enable college STEM departments to accommodate individuals with disabilities. This requires making changes within the department rather than relying on disabilities services to force / make the changes. Marco called for institutions to turn their attention to creating adaptive / assistive technologies specifically for laboratory practices.

Society in general was the target of some comments. Marton identified that “more efforts to get accessible technologies created and available and affordable” is vital for more STEM involvement of people with disabilities. Wilhelm addressed the issue of society in general as one where society convinces children with disabilities that STEM is too impractical. “Anyone in society can do whatever they want, they just have to want it bad enough,” he declared.

Findings Summary

Participants reported on sources for the development of their STEM self-efficacy, the roles and types of assistive technologies that were key to their participation in STEM and barriers to STEM participation for people with disabilities. STEM mastery experiences were found largely in the informal learning settings of childhood hobbies, self-teaching during high school and college years and internships / programs. Graduate school afforded participants the most STEM mastery experiences in formal learning contexts. STEM mastery experiences that related directly to accessibility and disability were common. Positive social persuasions were the most commonly reported self-efficacy source in the study. These positive messages were described in detail and revealed multiple types of support, which were acceptance, membership, encouragement, high expectations and advocacy. Family, friends, people with disabilities, teachers and people from STEM communities provided these different kinds of supportive messages. The nature of negative persuasions were restricting, skeptical and corrective and appeared to stem from ignorance about the capabilities of people with disabilities. Negative messages were largely provided by general undefined others, some family members and some college faculty. Vicarious experiences, in the form of role modeling, were identified as important by many participants. However, these experiences were reported by the fewest participants. Some individuals had multiple role models. In general, those who were connected with disability and/or STEM communities reported more instances of role modeling. When participants were young, role models with and without disabilities fostered interest, excitement and a sense of what was possible. Later, when participants were further along in their STEM trajectories, role models with and without disabilities modeled the logistics of STEM participation. Positive physiological / affective (P/A) states were reported by most participants and were expressions of their enjoyment and passion for STEM and their own STEM domains. Negative P/A states were associated with issues of accessibility, feelings of inferiority / insecurity and the sense of isolation in the context of their STEM participation. These negative P/A states were commonly the impetus for participants taking action to improve or manage issues, which led to mastery experiences.

Assistive technologies (AT) were identified as a necessity for participation in STEM and an equalizer for this community in STEM. AT served the role of providing access for participants in three categories associated with STEM participation. These were access to learning in STEM, access to STEM content throughout their lifetime and access to the professional STEM practices. Professional STEM practices were basic job tasks and creative endeavors, such as researching and engineering, building programmatic infrastructures and developing technologies. Although Braille was not commonly used in the professional work of the individuals in this study, Braille literacy was identified as critical to STEM learning for people with vision disabilities because it best supported access to the complex and technical terms in STEM and to mathematics. Consequently, Braille writers and refreshable displays were important. Braille also lends itself readily to labeling of three-dimensional models and lab equipment, common in STEM education. The participant with a hearing impairment emphasized the importance of captioning and technically trained interpreters. The participant with orthopedic disabilities highlighted the critical need for technologies and human aids to reduce the burden of repetitive and physically demanding laboratory practices that do not require high levels of scientific skill or understanding. Aids and sensory substitutions were most commonly cited as the critical types of technology for STEM participation. The focus was on using these kinds of AT to access STEM content.

Most participants discussed barriers to successful participation in STEM for people with disabilities and many suggested solutions. Barriers identified were (1) inadequate preparation in STEM of students with disabilities; (2) limited access to full engagement in mainstream STEM classrooms; (3) challenges of STEM courses themselves; (4) lack of STEM-specific AT knowledge on the parts of disabilities services professionals; (5) defeating self-perceptions of people with disabilities as well as negative perceptions held by others about people with disabilities; and (6) the lack of mentors and role models in STEM with disabilities. Participants suggested education and training solutions to increase the competitiveness and preparation of students with disabilities. Their suggestions were to ensure access to appropriate learning resources, high expectations upheld by teachers and professors, access to out of school learning experiences with appropriate accommodations and training for self-advocacy. Participants also stressed the importance of social support such as (1) verbal praise for students with disabilities when they are successful in STEM tasks; (2) providing parents of students with disabilities with examples of successful STEM professionals with disabilities to expand their conceptions of what is possible; (3) connecting students to mentors and role models with disabilities in STEM; and (4) fostering conceptual changes in educators, institutions and even society about the capabilities of people with disabilities.

CHAPTER 5

DISCUSSION

Introduction

At the start of this study, I developed three research questions to guide this qualitative study. Participants responded to the interview questions with rich details and personal stories of relationships, accomplishments, experiences and challenges. Their responses provided a wealth of information valuable to the goal of developing an understanding of the successful choice and participation of STEM professionals with sensory and/or orthopedic disabilities. Their responses did not, however, answer my research questions in ways that I anticipated.

The focus of the original research questions one and two had been on the identification of specific critical experiences that were integral to participants' choice and participation in STEM and the role of these experiences on the development of their self-efficacy beliefs. Through the analysis of participants' responses, it became clear that there were no single critical experiences that set the STEM trajectories of the individuals in this study. Instead, there were years of myriad instances of relationships, perceptions, experiences, roadblocks and triumphs that acted both incrementally and holistically to guide participants along their STEM pathways.

The answer to research question one, therefore, is that there were no identifiable characteristics of critical experiences. There were not single experiences that were integral to participants' choice and participation in STEM. Research question two also hinges upon the concept of critical experiences, and therefore was not answerable by the findings of this study. Research question three is unconnected to critical experiences and participants' responses were well aligned with this final question.

Participants shared information that was focused on the development of their self-efficacy beliefs in all of its manifestations. They provided details of how they used assistive technologies and the kinds of AT that was most beneficial to them as learners and as professionals. They also shared strong feelings and ideas about barriers to participation in STEM for people with their disabilities. Therefore, the questions that will be addressed at the close of this study's findings are:

1. How were self-efficacy beliefs constructed in STEM professionals and graduate students with sensory and/or orthopedic disabilities?

2. What is the nature of the role(s) AT played in the STEM trajectories of these professionals and upper level students?

3. What are barriers to the successful choice and participation of STEM careers by people with sensory and/or orthopedic disabilities?

Construction of self-efficacy beliefs in STEM.

The STEM self-efficacy beliefs of most participants were constructed, in part, by each of the four sources of self-efficacy. Social persuasions and mastery experiences were detailed by every participant. Social persuasions were not only prevalent in participant responses, with supportive messages being reported by every participant, but the content and nature of these messages were also highly detailed. The detail and prevalence of reported social persuasions suggest that they may be the most influential source of self-efficacy development for this community of STEM professionals with disabilities. Supportive messages may have served to make participants robust to the unsupportive messages many also reported, which were rooted largely in ignorance about the capabilities of people with disabilities. Generally supportive messages came to participants starting in childhood from their communities outside of STEM including family, friends, people around the participants, teachers and the disabilities community. STEM-specific support came from people in the STEM community such as college professors, peers, professionals and researchers, whom participants did not encounter until high school and later. Many impactful supportive messages came from people in STEM when participants were engage in STEM mastery experiences of STEM. Mastery experiences were common among participants and were encountered most frequently in informal learning settings. Childhood experiences with STEM resources outside of school, independent learning, self-teaching and internships yielded the most mastery experiences in informal STEM contexts for these individuals. Graduate school provided the most mastery experiences in formal learning settings.

Physiological / affective (P/A) states and role modeling were less common in participant responses and descriptions were less detailed compared to social persuasions and mastery experiences. These representations suggest that P/A states and role modeling were of less significance in the development of self-efficacy beliefs. Importantly, however, negative physiological / affective states were consistently linked to participants' disabilities and were also commonly connected to participants' decisions to take action to change or resolve the issues of access they were facing, which led to some mastery experiences. While role models were spoken of highly by some, many participants either did not recognize people they spoke of as role models or did not report having any. The importance of role models, however, was generally accepted in this group. Unsurprisingly, participants who were more connected with communities of people, whether disability-based or STEM-based communities, reported more exposure to role models.

Nature of the role(s) AT played in STEM trajectories.

Participants provided detailed descriptions about the roles assistive technologies (AT) played in their STEM trajectories. The prevalent message about AT was that it was critical to STEM participation for the individuals in this study. Participants explained that it provided access to their STEM learning and their STEM work. AT was also identified as an equalizer, enabling participants to be competitive, productive and keep pace with those around them without disabilities. Other humans were important in the system of acquisition, use, maintenance and applications of AT. In addition to supporting participants' use of AT, some people also acted as assistive technologies in their capacities as readers and interpreters. Many participants spoke highly of the professionals in their lives who supported their AT use in various contexts. Participants mentioned the importance of not only disability-specific technologies but also accessible technologies. Accessible technologies are standard technology features that were designed to support access for a broad range of people with diverse abilities, such as computers with built in screen magnification software and media with captioning. They were identified as important to STEM participation in both learning and career settings. They served to meet more access needs for participants in their careers than in learning contexts.

Participants used AT in STEM learning and career applications for three purposes. They used AT to interact with STEM content, access STEM content and to engage in creative practices in STEM. In primarily formal learning settings, AT facilitated participants' interactions with and provided access to STEM content. For participants with visual disabilities these AT were tactile sensory substitution technologies such as such as tactile graphics with Braille labels, Braillewriters/readers and raised-line graphing kits. AT used by individuals with vision disabilities to access and interact with STEM content also included auditory sensory substitution technologies such as audio books, readers and talking calculators. Participants with some usable vision employed vision aids to access STEM content in learning settings such as monoculars used to see the classroom board and screen magnifiers for computers. For the participant with a hearing disability, the AT were sensory substitutions including captioning and interpreting. The participant with an orthopedic disability identified orthopedic aids, such as finger braces and the use of a laptop, to support interacting with and accessing STEM content in learning contexts.

Interacting with STEM content is distinguished from accessing STEM content. Accessing content is a unidirectional process in which participants received information. Interacting with content involves an individual receiving information and also providing information back into the system. For example, while audio and Braille textbooks enable individuals to access the content in books, Nemeth Braille was a critical tool for participants with visual disabilities to be able to work through math problems. Screen readers render computer text audible, enabling individuals to access content on computers while raised line graphing equipment enables people to work with data to generate and analyze graphed data.

Accessing STEM content was also practiced by participants in career contexts. In career settings, participants with vision disabilities reported less use of tactile resources and a heavier reliance on audio-based resources, such as screen and human readers, for accessing STEM content. Interpretation and captioning were identified as critical for accessing STEM content by the participant with a hearing disability for career applications also.

AT also provided participants access to creative STEM practices. For learners, these creative experiences occurred in informal learning contexts in which participants were pursuing their STEM interests outside of formal curricula such as developing assistive technologies for learning and writing software. For professionals and upper level students, creative practices were inherent in their STEM work and required AT for access. Examples of creative career practices were research, writing, developing technology solutions and engineering. AT also supported professionals in their basic job tasks by providing access to tasks such as phone and Internet communications. AT was needed that enabled participants to engage in their creative tasks. For people with vision disabilities examples of these AT include Braillewriters, speech-to-text applications, humans aids acting as readers and scribes and applications employing number-based representations of data. The participant with a hearing impairment emphasized the importance of captioning and interpreting services that matched the high level of technical language and concepts he required to create in the rigorous academic research and teaching setting. The participant with orthopedic impairments identified many aids that she used to support the physical logistics of her research in the lab such as pipetting and opening lids of containers as well as braces for her joints and a stool to reduce load bearing on her joints.

Aside from the critical role that AT played in providing participants with access to their STEM learning and work, AT also played the role of an obstacle at times.

Participants did not always have access to AT they needed. The high cost of technology was commonly mentioned by participants and limited availability was also identified as a challenge. In addition, disability specialists with inadequate training or insufficient knowledge impeded participants' access to appropriate or current technologies. The gaps in the knowledge and training of disability specialists tended to be STEM-specific. These issues were impactful for participants because AT is integral to their participation in STEM.

Barriers to successful choice and participation in STEM

The two greatest barriers to successful choice and participation in STEM for people with disabilities identified in this study were inaccessibility of STEM resources and the perceptions of gatekeepers along STEM pathways who do not believe that people with disabilities can be successful in STEM.

STEM content for formal and informal learning and mathematics pose challenges to STEM participation for people with disabilities. Issues of access to STEM resources were most commonly discussed by participants with vision disabilities. Mathematics preparation is important for the foundation of participation across STEM domains. For people with vision disabilities, math is present challenges. Braille math languages have been developed but disabilities specialists were reported to be limited in their knowledge of these languages. Braille displays and writers do not support Braille math languages enough to work for upper level math. In addition, computer-based applications, including educational software and Internet-based resources, do not consistently present math in formats that are accessible to screen readers, which is the primary access point to screen content for people who are blind. Computer and Internet-based text- and image-based resources are also not consistently formatted to be accessible to screen readers. Lack of access to computer-based STEM resources can be mitigated through the use of Braille-based resources. Paper Braille, however, takes time to generate and can become outdated quickly. This poses major challenges to classroom textbook resources, especially when faculty members select multiple texts and jump around in the books. Brailling services cannot necessarily keep pace with this kind of faculty use of text-based resources. Although electronic Braille displays can improve upon some of the issues associated with paper Braille renderings, the lack of full-page refreshable Braille display with refreshable tactile graphics technology still limits access to STEM content for individuals with vision disabilities. Standards for formatting text and images online have been developed but they are not widely used by non-governmental entities.

Participants identified low expectations held by parents, teachers and guidance counselors for individuals with disabilities as a major impediment to students' entering STEM pathways. These expectations dictate what parents, teachers and counselors tell students with disabilities about their options and prospects for the future. They also dictate the decisions these gatekeepers make about the kinds of opportunities and experiences they will allow their children / students with disabilities have in and out of classrooms. Participants cited inadequate preparation of students with disabilities in fundamental literacy and computer training in addition to insufficient STEM content learning and skill training. Based on participants' comments, it appears that the inadequate preparation is linked to the perceptions of early STEM gatekeepers that people with disabilities cannot be successful in STEM. The consequences of inadequate preparation alongside limited access to learning in and out of the classroom creates gaps in the foundation of STEM knowledge and experiences that are important to engagement in upper level STEM learning and success in STEM later in life. These issues were identified by participants across disabilities. Participants also discussed college faculty perceptions. Unlike the hampering and low expectations practiced by people around students with disabilities in their pre-college years, college faculty were reported to have the perception that there is no room in academia for disabilities. This was represented by reports of college faculty having no idea about issues associated with disabilities and not believing that people with disabilities have any place in college-level STEM classrooms and labs. Participants expressed that these faculty beliefs were artifacts of assumptions faculty hold that people with disabilities are not capable engaging in STEM. Participants also suggested that a lack of personal knowledge of anyone with disabilities in STEM impedes faculty's abilities to conceive of how STEM participation is logistically possible for people with disabilities.

Contributions to the Literature

Research on sources of self-efficacy.

Bandura (1977) theorized that mastery experiences were the most important source individuals use to inform their self-efficacy beliefs. This idea was supported through studies of people in STEM classes and fields. Studies emphasized the importance of mastery experiences in the development of the STEM self-efficacy beliefs of people in general and of white males in particular (Britner, 2008, Britner & Pajares, 2006; Chen & Usher, 2013; Hutchinson et al., 2006; Hutchinson-Green et al., 2008; Lent et al., 1991; Lent et al., 1997; Luzzo et al., 1999; Miura, 1987; Sawtelle et al., 2012; Zeldin et al., 2008). Bandura (1977) presented social persuasion, vicarious experiences and physiological / affective states as other less important sources of self-efficacy. Throughout the years, research has shown mastery experiences important. However, studies of underrepresented minorities in STEM suggest that women and ethnic minorities do not weigh sources of self-efficacy as initially theorized. The development of STEM self-efficacy in women was found to be heavily and even primarily influenced by either vicarious experiences through role models alone (Hutchinson et al., 2006; Marra et al., 2009; Nauta et al., 1998) or through a combination of vicarious experiences and social persuasions (Lent et al., 1996; Zeldin & Pajares, 2000). Nauta et al. (1998) found that vicarious experiences were even more impactful for the development of self-efficacy beliefs in women who were in traditionally male fields. Studies of African American students (Gainor & Lent, 1998; Usher, 2009) found that social persuasion was a critical source of math self-efficacy beliefs. Like women and ethnic minorities in STEM, participants with disabilities in the current study seemed to weigh other sources of STEM self-efficacy more heavily than mastery experiences, specifically social persuasions. Vicarious experiences with role models were not consistently present in the stories of participants in the current study. For those who did report role models, it appears that role models with and without disabilities served different functions for participants. Role models with disabilities were key to modeling what was possible for participants when they were young. When participants were further along in their STEM trajectories, role models were instrumental in modeling the logistics of engaging in STEM practices in the context of disabilities. STEM role models with disabilities were not necessarily in the same STEM domains as participants. Role models without disabilities seem to have fostered excitement and interest in STEM when participants were young. Later, when participants were pursuing STEM pathways, role models without disabilities provided critical information about the details of being successful in particular STEM domains, unrelated to disabilities.

Usher (2009) detected differences in social persuasions received by African American and non-African-American students from their teachers and parents. These differences included attention to the importance of African American students' believing that they have a right to be successful (Usher, 2009). Teachers and parents also told African American students that they needed to be better than students around them to prove their worth (Usher, 2009). The author concluded that the kinds of social persuasions given to African American students served as immunization against negative social messages that they received from others beyond family and school (Usher, 2009). Similar to Usher's (2009) findings, participants in the current study reported generally negative messages from undefined others around them but generally positive messages from parents, teachers and STEM specialists. This indicates that the positive messages from the "local level" (Usher, 2009, p.300) could also serve to immunize people with disabilities against negative messages from the wider community around them as they engage in STEM trajectories.

Jenson et al. (2011) conducted a study of STEM two and four-year college students with a range of disabilities. Authors found that participants identified encouragement from family, peers and most importantly instructors was key to the development of their self-efficacy beliefs (Jenson et al., 2011). Though participants in the current study did not prioritize the importance of social persuasions from instructors over those from family and friends, they did provide details that allowed for distinctions in the kinds of positive feedback provided by those in and out of STEM. Teachers and parents were reported to have provided encouragement, acceptance and high expectations for success in general. They provided positive launch pads for STEM success. However, people from STEM communities including college professors, STEM professionals and peers in STEM provided messages of membership, and advocacy in addition to encouragement and high expectations. The STEM community members provided welcoming landing pads where participants could pursue their STEM fields.

Chen and Usher (2013) conducted a study of science self-efficacy sources of secondary students. Their findings supported Bandura's (1977) view that negative physiological/affective states are strengthened when people have less access to other sources of self-efficacy beliefs. Chen and Usher (2013) found that for individuals with few to no science role models or mastery experiences in science /science achievement and little exposure to positive feedback about math, students exhibited high levels of anxiety and depression associated with science. These negative physiological/affective states were not present in students who reported multiple self-efficacy sources and science mastery experiences (Chen & Usher, 2013). In the current study, participants were already successful in STEM. They identified largely positive physiological/ affective states in association with their STEM participation. There were notable exceptions in which participants reported anger and frustration, loneliness and isolation and feelings of insecurity. Interestingly, situations resulting in anger and frustration often led participants to mastery experiences as they pursued avenues to improve their situations.

Access to sources of self-efficacy may impact how individuals weigh sources of self-efficacy. Studies of women in STEM (Hackett, 1985; Hacket & Betz, 1989; Lent et al., 1991; Muira, 1987) suggest that women have less access to STEM mastery experiences and consequently, less access to information important to the development of their self-efficacy beliefs. Stevens et al. (2004) conducted a study of math self-efficacy of Hispanic and white high school students. Findings led authors to conclude that Hispanic students relied more heavily on their mastery experiences of school-based math achievement to inform their self-efficacy beliefs because they did not have access to role models in math or positive social persuasions to help them develop their math self-efficacy beliefs (Stevens et al., 2004).

Participants in the current study gave detailed reports of social persuasions from many sources and they were largely positive in nature. Participants did not, however, report on mastery experiences with paralleled abundance or detail. Vicarious experiences in the form of role models were even less well represented. Participants not only reported limited role models, some individuals in the study noted that role models of people with disabilities in STEM were lacking and that this was a problem. As a consequence, limitations on access to mastery experiences and role modeling could be leaving individuals with disabilities in STEM to rely heavily upon social persuasions for the development of their self-efficacy beliefs.

Research on people with disabilities in STEM.

This study contributes to a small but growing body of literature examining the experiences of people with disabilities in STEM. Barriers and supports associated with the STEM participation of people with disabilities have been identified in the research and some were evidenced in the current study.

Barriers were identified in several studies. Studies of formal STEM learning experiences for students with disabilities have found that science educators in K-12 and college lack appropriate training and knowledge to adequately support their students with disabilities (Abner and Lahm, 2002; Alston and Hampton, 2000; Stefanich et al., 1996). It has also been identified that educators hold low expectations for their students with disabilities and harbor unsubstantiated concerns about lab safety (Stefanich et al., 1996). Stefanich et al. (1996) found that students with disabilities, likely mainstreamed for science, should expect to have no discipline-specific accommodations to support their STEM learning. Most participants in the current study attended public school and many expressed that they, too, had little support for STEM-specific course accommodations. However, most participants did not report bleak pictures of public education. The participants in this study who shared their experiences with mainstream science and math teachers reported that these professionals were encouraging, supportive and interested in fostering student success. While participants in the current study did find that disability specialists were lacking in STEM training, they reported that these specialists worked hard and creatively to develop workable solutions that supported participants' STEM experiences.

Stefanich et al. (1996) found that college science educators expressed beliefs that it was not their responsibility to deal with accommodations/modifications for students with disabilities. Seymour and Hunter (1998) reported on skepticism harbored by STEM college faculty about STEM participation by students with disabilities. Some participants in the current study reported these issues also. However, members of the STEM communities that participants encountered in formal and informal learning contexts throughout their college years were largely welcoming and supportive. The focus of participants' reports was on faculty who worked to support effective accommodations and those professors and STEM professionals who took time to encourage participants. These faculty and professionals helped to shape students' understandings of what could be possible for them in STEM.

Participants frequently referenced the additional time that they needed to spend in order to complete coursework and STEM tasks. Seymour and Hunter (1998) referred to the STEM students with disabilities as time disadvantaged. This was the consequence of the extra time demands associated with all aspects of their STEM participation, including time sinks associated with medical treatments. Participants in the current study did not report the ongoing medical conditions requiring treatment that were relevant for participants in the Seymour and Hunter (1998) study. Participants in this study generally portrayed the extra time they spent to complete STEM tasks or practices as simply another aspect of their STEM participation. However casually it was mentioned, additional time requirements were a factor that participants had to cope with in their STEM learning and career work.

There were challenges associated with accessibility mentioned both in the literature and in the current study. The participant in the study with orthopedic disabilities echoed issues with physical barriers such as repetitive and tiring dexterity-intensive laboratory practices identified by Burgstahler (2005) and Seymour and Hunter (1998). The increasing reliance on computer-based resources can be problematic for STEM students with disabilities when resources are not accessible to students or not compatible with their assistive technologies (Hitchcock and Stahl, 2003). The issue of incompatibility between learning/career resources and assistive technologies was frequently reported in the current study. Finally, Seymour and Hunter (1998) identified challenges of availability and timing associated with relying on Braille and audio-recorded resources. When these resources are being prepared by disability services, they may not be ready for students to use if professors choose to skip ahead chapters or have not selected the textbook for the semester with sufficient advanced notice (Seymour and Hunter, 1998). This was a problem identified in the current study by some participants. It limited their ability to keep up in class and was a point of frustration for the faculty, the student and the disability services professional involved.

Research studies also revealed findings associated with supports for students with disabilities in STEM. The importance of social supports was identified in multiple investigations. Burgstahler et al. (2011) identified the importance of parents in supporting students with disabilities in STEM. Participants in the current study, with some exception, reported tremendous support, encouragement and high expectations from their parents throughout their STEM experiences. Stevens et al. (1996) and Jenson et al. (2011) shared findings about the extremely influential role that secondary and college-level STEM instructors played in the STEM success of their participants. Participants in the current study communicated the importance of the different kinds of support they received from teachers and faculty in their STEM success. Participants in the current study were encouraged, challenged, guided and supported by STEM teachers and faculty. Seymour and Hunter (1998) reported that a disability-based center on campus was valued by participants as a place to connect with friends and other peers with disabilities. It was also reported to be an important place to access academic support (Seymour & Hunter, 1998). Few professionals and upper level students in the current study identified campus-based disability centers as important resources but they did consistently identify the importance of peers and friends in STEM. Participants reported that they made and fostered these connections in their college STEM departments and labs and during STEM programs, internships and fellowships. Some of the STEM programs were specifically for people with disabilities and they were also highly valued.

Findings from the current study reveal that participants had exceptionally positive experiences with STEM educators and professionals compared to the experiences of others with disabilities in STEM learning contexts. However, there are two challenges with other people that were reported in the literature and were also identified in this study. Alston and Hampton (2000) reported that parents and teachers of students with disabilities identified a problematic lack of access to science and engineering role models with disabilities. Alston and Hampton (2000) also reported that these parents and teachers found that career guidance counselors were counseling students with disabilities to reconsider their interest in STEM pathways for other options. Participants in the current study identified the lack of role models with disabilities as a problem as well. Given the unique and important function that role models with disabilities play in the lives of successful STEM professionals with disabilities, the issue of access to role models for STEM students with disabilities is particularly problematic. Some participants in this study also reported that they had either been personally counseled or knew of others with disabilities that had been counseled by educators and counselors to reconsider their choice of STEM because of their disabilities. Reports were similar, expressing that these educators and counselors believed that they were doing the right thing, trying to help people with disabilities to be more realistic about their capabilities.

Research on assistive technologies.

The research about assistive technologies does not focus on learning gains. Instead, the emphases of early investigations in the 1970s was on providing details of lab resource modifications to make them accessible to students with disabilities and determining if students could use the modified materials (Baughman & Zollman, 1977; Franks, 1970; Franks & Butterfield, 1977; Franks & Murr, 1978; Weems, 1977). Later studies in the 2000s, focused on higher levels of technology. Their emphases were on determining if students could use the high tech AT devices designed by authors, assessments of compatibility between the new AT and other daily technologies and identifying if students were enjoying themselves and feeling motivated to learn (Bouk, Flanagan, Joshi, Sheikh & Schleppenback, 2011; Duerstock, 2006; French, McBee, Harmon & Swaboda, 2003; Mansoor, Ahmed, Samarapungavan, Cirillo, Schwarte, Robinson & Duerstock, 2010; Sanchez & Aguagyo, 2008; Sanchez & Elias, 2009; Sanchez & Flores, 2002; Supalo, 2010). The current study indicates that participants' experiences with disability specialists and educational AT was entirely focused on how well the AT supported participants' learning. The STEM professionals and students in this study did not discuss taking any specialized assessments pre/post assessments to measure learning gains in affiliation with AT use. But they did report that disability specialists and educators tried out many AT options with participants and checked in with them frequently about how their academic progress was being impacted by the AT and accommodations. Participants in the current study took rigorous STEM courses throughout their STEM academic preparation and they were eager to succeed in them. They had to be successful in order to remain in their courses and to continue in upper level tracks.

The AT in both the research literature and in the participant reports of the current study are disability-specific. Overall, studies of STEM AT for students with visual disabilities were the most common. The focus of these studies was on ways to increase information access and access to interactions with STEM content for students who were blind or had low vision (B/LV). These studies of AT for B/LV students in STEM ranged from classroom-based low tech solutions for modifying existing lab resources (Baughman & Zollman, 1977; Franks, 1970; Weems, 1977) to studies of tactile resources involving embossing and 3-D models (Franks, 1970; Franks & Murr, 1978; Fraser & Maguvhe, 2008). There were also high tech studies of digitalized learning resources including digitized lab equipment, games and computer-based platforms. The focus of these studies was on supporting students' interactions with STEM content, rendering visual lab and mathematical data audible and providing audible feedback for students in STEM learning gaming environments (Bouk et al., 2011; Isaccson et al, 2010; Mansoor et al., 2010; Sanchez & Agauyo, 2008; Sanchez & Elias, 2009; Sanchez & Flores, 2002; Supalo, 2010; Supalo, Wohlers & Humphrey, 2012). B/LV participants in the current study reported that information access was the biggest challenge they faced and that it was ongoing. Human/screen readers, large print, screen magnification and monoculars provided participants access to STEM content alongside Braille. Braille was, by far, the most consistently identified AT mentioned by B/LV participants. AT associated with

Braille included Braille writers and readers, printed Braille and Braille math languages like Nemeth Braille. Participants identified the need for a full-page refreshable Braille display with refreshable tactile graphics. Participants commonly described positive interactive learning experiences with tactile graphics (raised line diagrams and graphing with Braille labeling), 3-D models and accessible calculators. It is unclear whether or not participants in the current study had access to the kinds of educational gaming and computer-based AT discussed in the high tech studies of the 2000s. It is clear, however, that participants in the study sought access to the mainstream curriculum, not educational AT gaming resources that were separate from their coursework. Though participants reported on their engagement in informal learning and self-teaching outside the classroom, in their formal learning participants consistently sought AT that facilitated their access to the classroom lab and learning resources used by their sighted peers and teachers.

Only two studies were found on AT for students with hearing disabilities. The focus of one was on increasing social interactions between hearing students and teachers and students with hearing impairments through texting technologies (Pagano & Quinsland, 2007). The other was focused on accessing information, addressing the critical issue of the lack of STEM conceptual and vocabulary knowledge of interpreters for students with hearing disabilities and presenting a digitized interpreting avatar solution (Andrei et al., 2013). The single participant in the current study with a hearing disability reported the ongoing challenges he faced with inadequately prepared interpreters. He emphasized the detrimental impact on individuals with hearing disabilities in STEM at all levels ranging from learning to career work because of their inability to adequately interpret STEM terminology and conceptual information. He did not report any use of digitized resources to improve this issue, however.

In the STEM AT literature about students with orthopedic impairments, the focus was on supporting student access to microscope use (Duerstock, 2006; Mansoor et al., 2010). The issue of access to lab work was reported by the single participant in the study with orthopedic disabilities. However, her disabilities had increased over time so during her earlier years as a learner, she did not require the accommodations she needed at the time of the study. This participant focused much of her discussion AT on the challenges she had finding out about STEM-specific AT and having opportunities to pilot these technologies before making large financial investments they could require.

Conclusion.

There were many circumstances in which the STEM professionals and upper level students in the current study had experiences that were more positive, supportive and more focused on learning than those identified in research about students with disabilities in STEM. It does not seem feasible that any single experience, positive or negative, could have made the difference between STEM participation or not for these participants. The differences between their experiences and those of students from other studies were perhaps not significant individually. However, these experiences were compounded over years and contributed to the STEM choice and participation of talented, interesting and successful participants in this study.

Recommendations

Findings from the current study suggest practices and recommendations for (1) public K-12 STEM educators, (2) developers and implementers of K-12 out-of-school STEM programs and initiatives, (3) STEM college faculty and (4) assistive technology developers interested in broadening STEM participation to include people with disabilities.

A. For public K-12 STEM educators:

- Successful STEM professionals with disabilities attended public schools in mainstream environments. Public school K-12 STEM teachers should expect to have students with disabilities in their classes. STEM educators do not need to have knowledge of all accommodations at their fingertips. Instead, practicing a willingness to explore options for accommodations/ assistive technologies that best support students' learning and holding high expectations for students with disabilities will foster a welcoming and supportive STEM learning environment.
- Upper level STEM courses, such as honors and advanced placement, are important for building students' content knowledge and skills prior to their matriculation into college programs. STEM professionals with disabilities identified their experiences in these courses as valuable to their STEM preparation. Schools and teachers should expect to have students with disabilities in these rigorous upper level STEM courses offered through the school and to meet students' accommodations to support their success.
- People with disabilities have been successful in all levels of STEM careers. K-12 STEM teacher encouragement is important to the construction of student and parent beliefs that STEM careers are feasible and realistic options to pursue.

- STEM role models with disabilities are valuable for students with disabilities. They are also important to students' parents and to those offering students career guidance because they model what is possible for students with disabilities. Guidance counselors are reported to counsel students with disabilities away from considering careers in STEM and parents do not necessarily know how their children's capabilities compare to those required for STEM careers. K-12 STEM teachers should share examples, available online, of people with disabilities in STEM careers. Professional STEM organizations and disability-based organizations often have networks of mentors for students with disabilities interested in STEM.
- Disability specialists in public school settings rarely have STEM-specific training and often have heavy student caseloads. STEM educators need to work with disability specialists and students to clearly communicate course objectives and goals, to work toward finding appropriate assistive technology solutions that best support student learning.
- It is critical that STEM students with sensory disabilities have access to resources with technically appropriate language and concepts. Teachers should be cautious about relying on screen readers to provide access to computer-based content for students with visual disabilities. Screen readers cannot fully access all web-based content or educational software. Screen readers often provide limited to no information presented in images on computers. Braille and Nemeth Braille formats are important for students who are blind and fluent in Braille because they provide students with the

most accurate representations of written text and mathematics. For students with hearing impairments, it is important that captioning is reviewed for accuracy and that interpreters are fluent in technical STEM language.

B. For developers and implementers of out-of-school K-12 STEM programs or initiatives

- Out-of-school STEM learning experiences can provide hands-on opportunities with STEM practices and tasks for students with disabilities. When advertising for out-of-school STEM learning experiences (camps, after school programs, etc…), specify that the program is open to students with disabilities and that accommodations will be made. The program must be in the position to make accommodations. It is important to engage with the student / family to understand what students' needs will be in the context of the program. Creative solutions to meet students' needs may be negotiated with parents, students and disability specialists at the students' schools. Consider consulting with disabilities specialists about implementing accommodations and be sure to prepare in advance. Be sure to assess the resources to be used in the program for issues of accessibility.
- STEM mentors and role models, especially those with disabilities, have important roles in showing students with disabilities what is possible and offering guidance for how to negotiate STEM pathways. Programs should connect students with disabilities to STEM role models and/or mentors. Consider connecting with major organizations like the National Federation of the Blind and AAAS that have networks of STEM professionals with

disabilities. Organizations often have listservs that can help students with disabilities connect with other STEM community members with disabilities.

- Parents can hold students back from considering STEM careers because they do not understand their child's capabilities. Share information with parents about people with disabilities who are successful in STEM careers. Create a climate of open dialogue so parents feel that they can approach program facilitators with questions about STEM careers for their children.
- Be explicit with all members of the team of facilitators for out-of-school STEM learning experiences that a goal of the program is to include students with disabilities. Expectations for meeting program objectives should be high and also the same for all students in the program. Social interactions between facilitators and students with disabilities will be impactful for students. Social messages from facilitators should be encouraging. They should also reflect high expectations and a commitment to providing accommodations.

C. For STEM College Faculty

- People with disabilities hold the highest academic degrees in STEM and work successfully in all levels and branches of STEM fields. They must explore and try out creative solutions to enable them to engage fully with STEM resources and tasks. STEM instructors and research faculty should not discourage students with disabilities from STEM opportunities and pathways.
- Internships, fellowships, research experiences, STEM summer programs and field experiences provide students with disabilities hands-on STEM

experiences that are important to their success in STEM. These opportunities also allow students with disabilities to explore how they can logistically engage with STEM tasks and practices. Programs like these enable students with disabilities to build key social relationships with other people in STEM. STEM college advisors and professors should encourage STEM majors with disabilities (and those considering STEM majors) to consider applying for and attend STEM internships, research programs, fellowships, STEM summer programs and field experiences.

- Accommodations and assistive technologies are critical to the participation of individuals with disabilities in STEM. The implementation of accommodations is not the sole responsibility of disability services. Both students with disabilities and faculty members must be engaged in the process. Faculty should expect to have students with disabilities in their classes and to work with them to foster clear communications about establishing and implementing accommodations.

D. For Assistive Technology Developers

- Assistive technologies are only assistive when they can reliably and reasonably facilitate access to resources that people with disabilities want and/or need. AT developers must engage with people with disabilities, including students and professionals, as well as disability specialists and STEM teachers. These people will help AT developers to understand both the realities of learning contexts and the needs of students with disabilities to be successful in STEM.

- Successful STEM professionals used AT to support their access to the curricula and resources used in their mainstream STEM classes. AT development for students with disabilities should focus on increasing their access to the existing school curricula. Efforts should not focus on the development of learning resources that are separate from the curricula used in mainstream STEM learning settings.
- The Americans with Disabilities Act has design standards that maximize the accessibility of computer-based resources. Increased use of these standards in the development of computer-based STEM learning resources would greatly improve access for students with disabilities. Assistive technology developers should consider ways to foster widespread implementation of these design strategies for new computer-based STEM resources and redesign of existing resources. Examples and guidelines are available here: http://www.ada.gov/pcatoolkit/chap5toolkit.htm
- Tactile graphics, embossed models, 3-D models with Braille labels and large print were useful tools that supported the STEM learning of successful STEM professionals with visual disabilities. The development of technologies would enable these proven resources to be affordably generated and maintained in standard mainstream learning settings.
- Interpreting services for students with hearing disabilities are known to be inadequate for successfully communicating challenging technical vocabulary and concepts associated with STEM learning. The development of

technologies that target this issue would enhance access to STEM learning for students with hearing disabilities.

- The development of a full-page refreshable Braille display with refreshable tactile graphics would be a critically important and useful resource for STEM learners and professionals alike.

Limitations

The potential flaws in the study design are associated with an imperfect researcher creating imperfect instruments. Participants were gathered via snowball method, which has inherent limitations. Using this method for sampling I relied upon professional and social networks, connections between people based on contextualized experiences and relationships. Consequently, my sample was heavily biased toward people with visual disabilities based on the people I first engaged to begin the process of sampling. It was also biased toward people in assistive technology and computer science careers.

In interviews, we can only gather from participants what they share. The participants in this study were generous with their stories, ideas and recollections. This willingness to share provided its own challenges. I had some interviews that lasted 2.5 hours and the average interview was over an hour and a quarter. Participants had wonderful stories and information but much of it did not fall within the scope of the study. As I progressed through the interviews, my ability to keep participants on track with the interview question topics improved. Some participants also felt compelled to take the lead and rather than answering the questions I was asking, they told the stories they wanted to tell. This is a consequence of the nature of interviewing and of qualitative research. An additional challenge was the difficulty associated with scheduling time with busy professionals. I missed opportunities to include more people in this study because we simply could not find times that would work for the interview. For people who did participate, there was some rescheduling, interruptions mid-interview and one participant who did not answer when I called him. However, he quickly got back to me and we found another time. One participant had to leave before finishing the interview, so he finished it through emailed responses. Of course, without question, I was grateful to my participants for their willingness to share their time, ideas and experiences with me.

I conducted the bulk of the analysis alone however, my advisor reviewed all content in this dissertation. I also engaged three other researchers in discussions about emerging themes and interpretations of data. They were not, however, formally included in the analysis and we did not discuss all aspects of my interpretations. This means that the data have been interpreted without additional perspectives, which limits the reliability of this research. Additionally, I did not conduct member checks with participants following the interviews to validate my understandings and interpretations of what they shared in the interviews. During the interviews, when I was not clear about things participants said, I rephrased what I understood and asked participants about the accuracy of my understanding. The lack of member checks following the interviews impacts the validity of my findings.

Finally, the small sample size limits the generalizability of these findings. This issue of the small sample is exacerbated in the cases of only one participant with a hearing disability and one with an orthopedic disability. Disabilities can be present in people across ethnicities, sexes and from all socioeconomic conditions. Grouping people who are different in so many ways simply because they have disabilities may ultimately prove to be insufficient to yield truly meaningful results. This yet remains to be determined.

Future Work

There are many directions to follow after the current study. Three directions are of particular interest to me. I did not detect differences in the information provided in the responses of men and women or of people from different ethnic groups. With only four female participants and few of non-white ethnicities, the demographics of my sample constrained the potential for finding meaningful differences. The viability of investigating STEM participation for people with disabilities as a group aggregated by disability is questionable. There is little to suggest that people with specific disabilities are more like each other than they are like other people of the same sex or ethnicity. One line of investigation would be to explore the intersectionality of disability, sex and ethnicity in STEM choice and participation. I could explore this by engaging people with and without disabilities from the same ethnicity and sex groups for comparison. The community of STEM professionals with disabilities is not large, however, and might impact my ability to find enough people for this line of investigation.

While role models were not mentioned by all participants in the current study, they were significant to those who identified role models. Even those who did not identify personal experiences with role models indicated that, though scarce, they are valuable. I found the differences in the nature of role modeling between STEM professionals with and without disabilities to be an interesting potential for future study. Findings from the current study suggest that STEM role models with and without disabilities play different parts in modeling STEM participation for people with disabilities. Furthering this avenue of investigation would be of particular interest to me because in my experience, outreach initiatives in STEM education often incorporate connecting students with role models from academia, industry and government. It would be practical to understand how to best serve students' role modeling needs.

A third research direction stems from suggestions I received from several participants in the current study. Participants thought it would be interesting for me to talk with their parents, teachers, mentors, research facilitators to understand their experiences and views as they supported and encouraged my participants. This would be an exciting research trajectory that could yield results potentially useful for parents, teachers and college STEM faculty about the logistics and perspectives associated with effectively encouraging and supporting people with disabilities in STEM.

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APPENDIX A

AMERICAN DISABILITY LEGISLATION

Americans with Disabilities Act (1990):	
28 Code of Federal Regulations pt 3656 (1991): 36.104 *Department of Justice Regulations codifying the ADA into Fed Regs 35544*	**(1)The phrase *physical or mental impairment* means –** (i)Any physiological disorder or condition, cosmetic disfigurement, or anatomical loss affecting one or more of the following body systems: neurological; musculoskeletal; special sense organs; respiratory, including speech organs; cardiovascular; reproductive; digestive; genitourinary; hemic and lymphatic skin; and endocrine; (ii)Any mental or psychological disorder such as mental retardation, organic brain syndrome, emotional or mental illness, and specific learning disabilities; (iii) The phrase physical or mental impairment includes, but is not limited to, such a contagious and noncontagious diseases and conditions as orthopedic, visual, speech, and hearing impairments, cerebral palsy, epilepsy, muscular dystrophy, multiple sclerosis, cancer, heart disease, diabetes, mental retardation, emotional illness, specific learning disabilities, HIV disease (whether symptomatic or asymptomatic), tuberculosis, drug addiction, and alcoholism (iv) The phrase *physical or mental impairment* does not include homosexuality or bisexuality (2) The phrase *major life activities* means functions such as caring for one's self, performing manual tasks, walking, seeing, hearing, speaking, breathing, learning and working. **2) Major life activities** (A) In General. –major life activities include but are not limited to, caring for oneself, performing manual tasks, seeing, hearing, eating, sleeping, walking, standing, lifting, bending, speaking, breathing, learning, reading, concentrating, thinking, communicating, work (B) Major bodily functions Major life activity also includes the operation of a major bodily function, including but not limited to functions of the immune system, normal cell growth, digestive, bowel, bladder, neurological, brain, respiratory, circulatory, endocrine, and reproductive functions (4) Rules of construction regarding the definition of disability (A) The definition of disability in this chapter shall be construed in favor of broad coverage of individuals under this chapter, to the maximum extent permitted by the terms of this chapter (B) The term "substantially limits" shall be interpreted consistently with the findings and purposes of the ADA Amendments Act (2008) (C) An impairment that substantially limits one major life activity need not limit other major life activities in order to be considered a disability (D) An impairment that is episodic/in remission is a disability if it would substantially limit a major life activity when active **(** (E) –a. the determination of whether an impairment substantially limits a major life activity shall be made without regard to the ameliorative effects of mitigating measures such as

A *continued*. A physical or mental impairment that substantially limits one or more of the major life activities of an individual *continued*

Americans with Disabilities Amendments Act (2008)	b. medication, medical supplies, equipment, or appliances, low-vision devices (which do not include ordinary eyeglasses or contact lenses), prosthetics including limbs and devices, hearing aids and cochlear implants or other implantable hearing devices, mobility devices, or oxygen therapy equipment and supplies; (II) use of assistive technology; (III) reasonable accommodations or auxiliary aids or services; or (IV) learned behavioral or adaptive neurological modifications. (ii) The ameliorative effects of the mitigating measures of ordinary eyeglasses or contact lenses shall be considered in determining whether an impairment substantially limits a major life activity. (iii) As used in this subparagraph (I) the term "ordinary eyeglasses or contact lenses" means lenses that are intended to fully correct visual acuity or eliminate refractive error; and (II) the term "low-vision devices" means devices that magnify, enhance, or otherwise augment a visual image. Sec. 12103. Additional definitions - As used in this chapter (1) Auxiliary aids and services. The term "auxiliary aids and services" includes (A) qualified interpreters or other effective methods of making aurally delivered materials available to individuals with hearing impairments; (B) qualified readers, taped texts, or other effective methods of making visually delivered materials available to individuals with visual impairments; (C) acquisition or modification of equipment or devices; and (D) other similar services and actions.

B. A record of such impairment

B. A record of such impairment **American with Disabilities Act (1990)** (B) *A record of such an impairment*	
28 Code of Federal Regulations pt 3656 (1991): 36.104 *Department of Justice Regulations codifying the ADA into Fed Regs 35544*	(3) The phrase *has a record of such an impairment* means has a history of, or has been misclassified as having, a mental or physical impairment that substantially limits one or more major life activities

C. Being regarded as having such an impairment

American with Disabilities Act (1990) C) *Being regarded as having such an impairment*	
28 Code of Federal Regulations pt 3656 (1991): 36.104 *Department of Justice Regulations codifying the ADA into Fed Regs 35544*	(4) The phrase *is regarded as having an impairment* means— (i) Has a physical or mental impairment that does not substantially limit major life activities but that is treated by a private entity as constituting such a limitation (ii) Has a physical or mental impairment that substantially limits major life activities only as a result of the attitudes of others towards such impairment; or (iii) Has none of the impairments defined in paragraph (1) of this definition but is treated by a private entity as having such an impairment
Americans with Disabilities Amendments Act (2008)	**(3) Regarded as having such an impairment** (A) An individual meets the requirement of "being regarded as having such an impairment" if the individual establishes that he or she has been subjected to an action prohibited under this chapter because of an actual or perceived physical or mental impairment whether or not the impairment limits or is perceived to limit a major life activity (B) Does not apply to impairments that are transitory and minor. A transitory impairment is an impairment with an actual or expected duration of 6 months or less

APPENDIX B

STUDY RECRUITMENT LETTER

Dear Dr./Ms./Mr. _______________

My name is Heather Pacheco and I am a doctoral candidate at Arizona State University in the Science Education PhD program. My advisor and Principal Investigator is Dr. Dale Baker. _________________________ (recommender) recommended you to us, thinking that you might be interested in participating in the study described below and provided us with your contact information.

We are conducting a study involving science, technology, engineering and mathematics (STEM) professionals with sensory and/or orthopedic disabilities. We are gathering data about experiences participants identify as integral to their choice and participation in their STEM careers as well as participants' perspectives about the role(s) assistive technologies have played in these choices. Our goal is to establish a fundamental knowledge base about these experiences and the role(s) assistive technologies have played in participants' choice and participation in their STEM careers.

We are recruiting STEM professionals with sensory and/or orthopedic disabilities to participate in
(1) a brief participant selection survey
(2) an interview that will be conducted by phone, web-based video or in person.

The survey will take 10 – 15 minutes to complete and the interview will take approximately 30 minutes to one hour. The interview will be recorded and transcribed analysis. If you identify that you are using assistive technologies that you have adapted to your specific purposes, we will request a photo of the technology if it is convenient and if you are willing to provide a picture. Any photos contributions should be of technology and not include users. Photos will not be published; they will be analyzed for trends across users. This is not required for your participation in the study. Your participation in this study is completely voluntary. Following the interview, you will be contacted for a brief "member check" so that you have the opportunity to confirm and/ or correct and understandings that the researchers has identified from your interview data.

If you have questions concerning the research study, please call me at (617) 417-4850. There are no known risks from taking part in this study. Although there may be no direct benefits to you, the possible benefits of your participation in the research may be for current and future students with sensory and/or orthopedic disabilities with the potential to enter STEM fields.

All information obtained in this study is strictly confidential. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you. In order to maintain confidentiality of participant records, names on the initial survey will be converted into codes, which will then be used throughout the study. The name-code key will be stored on a secure server. Audio recordings will be transcribed and the digital copies of both the recordings and the transcripts will be stored on a secure server. Following the study, recordings, notes and digital transcripts will be deleted and paper transcripts and notes will be shredded.

Participation in this study is completely voluntary. It is okay for you to say no. Even if you say yes now, you are free to say no later, and withdraw from the study at any time. If you choose to say no after the interview has begun, audio recordings will not be converted to transcripts and will instead be deleted immediately.

Any questions you have concerning the research study or your participation in the study, before or after your consent, will be answered by Heather Pacheco, Farmer Hall, Arizona State University, (617) 417-4850, hapachec@asu.edu or Dr. Dale Baker, Farmer Hall Arizona State University, (480)965-6067, dale.baker@asu.edu.

If you have questions about your rights as a subject / participant in this research, or if you feel you have been placed at risk, you can contact the Chair of Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

If you are interested and willing to participate in this study, please reply to this email. Replying to the email will be considered your consent to participate.

We greatly appreciate your time,

Thank you,

Dr. Dale Baker and Heather Pacheco
Dale R. Baker
Professor of Science Education
Fellow of the American Association for the Advancement of Science
Fellow of the American Educational Research Association
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Tempe, AZ 85281
617-417-4850

APPENDIX C

EMAIL WITH LINK TO PARTICIPANT SELECTION SURVEY (PSS)

Hello,

Thank you for agreeing to participate in the Arizona State University-based study of STEM career choice and participation of STEM professionals with sensory and orthopedic disabilities with Heather Pacheco and Dr. Dale Baker. We are delighted to have you!

Please complete and submit the brief 10-item questionnaire below.

Remember, your participation is voluntary. You may choose not to participate or to withdraw your consent and discontinue participation at any time without penalty or loss of benefit. Any questions you have concerning the research study or your participation in the study, before or after your consent, will be answered by Heather Pacheco, Farmer Hall, Arizona State University, (617) 417-4850, hapachec@asu.edu or Dr. Dale Baker, Farmer Hall Arizona State University, (480)965-6067, dale.baker@asu.edu.

Here is the link for the survey: https://www.surveymonkey.com/s.aspx

Thank you!

Best
Heather Pacheco and Dr. Dale Baker

If you have chosen not to participate, please select the REMOVE link below:
https://www.surveymonkey.com/optout.aspx

APPENDIX D

PARTICIPANT SELECTION SURVEY (PSS)

Participant Selection Survey

1. Please provide your first and last name.

2. Please indicate the phone number or email address that is best for correspondence about the study.

3. What is your current field and occupation? (i.e. Field: biomedical engineering, geology; Occupation: research scientist, graduate student, engineer)

4. Please check the most appropriate box(es) that best characterizes your current occupation.
- Science
- Technology
- Engineering
- Mathematics

5. Please identify your academic degree(s) and year of completion. (i.e. B.S. Geological Oceanography (1985); M.S. Chemistry (2004) etc.)

6. Please identify your gender.
- Female
- Male
- Other

7. How would you describe your ethnicity?

8. What was your approximate age when your disability was first identified?

9. Do you use any assistive technology in you daily work life?
Assistive technology device (Tech Act, 1988) refers to any item, piece of equipment or product system, whether acquired commercially off the shelf, modified or customized, that is used to increase, maintain or improve functional capabilities of individuals with disabilities (Yes/No)

10. In your own words, please briefly describe your disability (~ 100 words)
In your own words, please briefly describe your disability (~ 100 words)

APPENDIX E

INTERVIEW PROTOCOL

Interview Protocol Summer 2013

Critical factors and role(s) of assistive technology associated with the STEM choice, participation and persistence of STEM professionals with sensory and orthopedic disabilities

BE SURE TO CHANGE THE LANGUAGE FOR EACH PERSON
(i.e. not "STEM field" but "technology")

Pre-interview script:
Thank you so much for agreeing to participate in this study. This interview will take between 30 minutes and one hour. The interview will be recorded. Please let me know if you would like to be to not record the interview and instead take notes.

If, at any point during the interview, you would change your mind about your participation, please let me know. Your participation is voluntary and you can change your mind at any point. If there are questions that you do not feel comfortable answering, please feel free to let me know and I will move on to the next questions.

At the end of the interview, I will ask you if you know of any other STEM professionals with sensory or orthopedic disabilities who you can recommend for the study.

Do you have any questions at this point?

Let's begin. There are 28 questions broken into three sections: Background information, influences on your choice and participation in your field and questions about the assistive technologies you use today. Please let me know if you need a break at any point. Ready?

Background Information
1. What is your age?

1. Where were you living during the initial onset of your disability (geography)?

2. What kind of K-12 School Type(s) did you attend?
    a. Regular public school,
    b. Private school,
    c. Independent school,
    d. Specialized school

3. What was your age at high school graduation?

4. What was the size of your graduating high school class?

5. Did you take Advanced Placement or honors courses in high school? If so, in Math and/or science? (Added Feb 2014)

6. At what institution did you complete your STEM undergraduate degree?

7. How many undergraduate institutions, including community colleges, did you attend for this undergraduate degree?

8. How many total years did it take to complete your undergraduate degree?

9. Family history
    a. Were you raised by one or two parents? Or by guardians?
    b. What is your father's / Guardian 1's highest education?
    c. What is your father's / Guardian 1's profession?
    d. Does your father/ Guardian 1 have a disability? If so, what is it?
    e. What is your mother's / Guardian 2's highest education?
    f. What is your mother's / Guardian 2's profession?
    g. Does your mother / Guardian 2 have a disability? If so, what is it?

10. Please describe your current occupation / graduate program.
    Just to refresh my memory, could you briefly describe your disability?

Self-efficacy Questions

1. What experiences contributed to your decision to pursue your occupation?

2. How were you influenced by others?

3. What did people (family / teachers / peers / culture) say to you as you were pursuing your STEM (i.e. geology, mathematics) field? What sorts of sociocultural messages did you get?

4. How would you describe your feelings and beliefs about [your STEM field] (i.e. geology, mathematics) as you were pursuing it?

5. Tell me one memorable story that would really help me understand how you came to do what you do?

6. Why do you think that so few people with sensory / orthopedic disabilities pursue STEM-related (i.e. geology, mathematics) careers? What could be or should be done to alter that?

7. Considering your academic and career history, if you could have done anything differently, what would that be?

Assistive Technology (AT) Questions

1. Did you use (AT) before undergraduate college?

2. What specific assistive technologies did you use that supported your learning in science and math at any point?

3. How would you describe the role(s) AT played in your participation in (your STEM field) (i.e. geology, mathematics)?

4. Were there technologies that proved unsupportive for (your STEM field)? That provided obstacles or were counterproductive?

5. Now that you are in your career, what career-specific assistive technologies are you using?

6. Were there any barriers to accessing some technologies that would have been helpful?

7. Thinking back to your experiences as child in school, what kinds of AT would you like to see invented that would have facilitated your learning connected to (your STEM field)?

8. What AT exists today that you wish you had access to currently to support your work in your (your STEM field) career?

9. What kinds of AT can you envision in the future that would make a difference for a person with the same disability as they were preparing and pursuing their (your STEM field) education and career goals?

10. Weigh the relative importance of your own motivation, the social supports that you have experienced and the assistive technologies you have used in your successful choice and participation in (your STEM field)

Post-Interview Script

Thank you so much for taking the time to answer our questions! This study is exciting and we're delighted that you chose to participate.

I have one last question for you. This study uses what's called a "snowball" method to gather participants. The way this works is I ask people I know if they know anyone who would be a potential participant and I contact them and invite them to the study. Do you know of anyone who is a STEM professional with sensory or orthopedic disabilities who might be interested in participating in this study too?

Do you have any questions right now? Please don't hesitate to let me know if you have questions following the interview.

Thank you again so much!!