Sevo, Ruta. (2012) Recommended Reading: Disabilities and Diversity in Science and Engineering. In B. Bogue & E. Cady (Eds.). *Apply Research to Practice (ARP) Resources*. Retrieved <Month Day, Year> from http://www.engr.psu.edu/AWE/ARPResources.aspx

Literature Review: Disabilities and Diversity in Science and Engineering

By Ruta Sevo, STEM Consultant

Introduction

Today, more students with disabilities are in the educational pipeline than ever before, as a result of special education, legally mandated services, and structural accommodations (McGuire & Scott, 2006). As many as 11% of undergraduate students in science and engineering fields have one or more disabilities (National Science Foundation (NSF), Committee on Equal Opportunities in Science and Engineering [CEOSE], 2009). About 1% of people holding doctorates in science and engineering report having disabilities (CEOSE, 2009). If the United States is to have effective and productive learning environments in higher education, updating the nation's understanding of disability and its implications and updating educational practices are critical.

Why Inclusion Is Important

The United States is a leader in accommodation, rehabilitation, and assistive technologies. New products support independent living, community integration, learning and work. The idea of universal design—that all products and all environments are usable to the greatest extent possible by people of all ages and abilities—is an unmet goal. Society is just beginning to acknowledge a wider range of abilities, and many people are not, but could be, accommodated. Society is learning more about how discrimination poses a barrier to accommodation. The design of assistive technologies is better with the input, insight, and leadership of the people for whom it is being created.

For quality of life, developing assistive technologies and making consumer products, telecommunications, and transportation accessible is important and beneficial to the majority, especially as everyone ages; however, the economic weight of assistive technologies is not clear. Because of fragmentation and small markets, the field is sometimes called "orphan technology" (Seelman, 2001). Commercial revenue and funding are problems. Although products can benefit a broad range of consumers, a high level of mass-market sales is unlikely.

Values also influence where people invest. Sympathy for disabled veterans, for example, has driven trends in engineering. After World War II, investment emphasized the rehabilitation of disabled veterans. Medical rehabilitation and rehabilitation engineering flourished, especially in the development of prosthetics (artificial body parts) and orthotics (supports for weakened limbs). Later research studied wheelchairs, hearing aids, and Braille printers.

The participation of and leadership by disabled people will provide the most effective solutions to problems of impairment. "Research accountable to, and preferably done by, disabled people offers the best insights into disability" (Shakespeare, 2010, p. 268). Cultural sensitivity in the development of assistive technologies is required. The trend in modern technology development is to value the input and feedback from the consumer of a product. Finding people who understand both the disability and the technical design process is challenging. From the 1960s on, the disability rights movement questioned decision making about treatments, devices, and services without the participation of the consumer—people with disabilities.

Advocates point to the need for developing assistive technology with cultural sensitivity and participation in making decisions about what devices are needed, how they are designed, and how they are tested.

Researchers with disabilities should be included in the cycles of discovery, innovation, and technology development generally. Disabilities should not be a barrier to professional success. Many examples of "hidden" disabilities exist among famous contributors in history and contemporary leaders (see below). Educational environments are better when diverse students learn together (American Educational Research Association, Association of American Colleges and Universities, & American Association for Higher Education, 2003). Inclusion of students with disabilities in science and engineering is a national goal (CEOSE, 2009). The rate of participation could be higher.

Demographics

The NSF collects data on students with disabilities in science and engineering (NSF Division of Science Resources Statistics [SRS], 2006). The data are incomplete because they come from students who are asked to report their own disabilities, and some students do not report their disabilities (CEOSE, 209, p. 9), although the extent of underreporting is unknown. About 11% of undergraduate students in science and engineering fields have one or more disabilities, and that percentage is parallel with the number of persons with disabilities of ages 15 through 24 in the general population. Among all people ages 15 through 24, more than one half (of the 11%) have learning disabilities (CEOSE, 2009, p. 30).

National statistics on the science and engineering workforce show that about 7% of graduate students in science and engineering were persons with disabilities in 2004, the latest year available (CEOSE, 2009, p. 9). Women made up about 57% of that group, and the majority of students were White (CEOSE, 2009, p. 9). Only 1% of people holding doctorates in science and engineering reported having disabilities (CEOSE, 2009, p. 30). As table 1 illustrates, the number of STEM doctorates awarded annually to persons with disabilities is low (about 1.7% in CEOSEm 2005), and the absolute number declined between 1998 and 2005 (CEOSE, 2006, p. 9).

Table 1. Percent of STEM Doctoral Degrees Awarded by Gender, Race, and Disability, 1998–2005

Group	**1998**	**2005**
Male	60.7%	55.4%
Female	39.3%	44.6%
Total	100.0	100.0
Number	18,271	16,024
White	76.7	76.6
African American	3.5	4.4
Hispanic	4.1	5.0
American Indian/Alaska Native	0.5	0.4
Asian/Pacific Islander	11.8	10.2
Unknown Race/Ethnicity	3.3	3.4
Total	100.0	100.0
Disabled Persons	**1.5**	**1.7**

The number of faculty with disabilities in science and engineering fields is low overall (about 19,700 of 249,700 faculty or 7.9% in 2008; NSF, SRS, 2011, Table 9-28). As table 2 illustrates, the number of persons with disabilities in lower ranks is increasing slightly (CEOSE, 2009, p. 12).

Table 2. Change in Disabled Full-Time STEM Faculty Positions at Four-Year Colleges And Universities, 1997 and 2006

Group	All STEM Faculty	Professor	Associate Professor	Assistant Professor
Disabled: 1997	10,300	6,300	2,900	1,100
2006	10,300	5,800	2,400	2,100
% change	+0%	-8%	-17%	**+91%**

In 2008, students with disabilities received 1% to 3% of the doctorates in most science and engineering fields except biological sciences, where they were received 13% (NSF, SRS, 2011, Table 7-6). Among those students, 0.06% had a visual impairment, 0.14% had a hearing impairment, 0.39% had a learning disability, 0.25% had a physical or orthopedic disability, and 0.03% had a speech disability (NSF, SRS, 2011, Table 7-5).

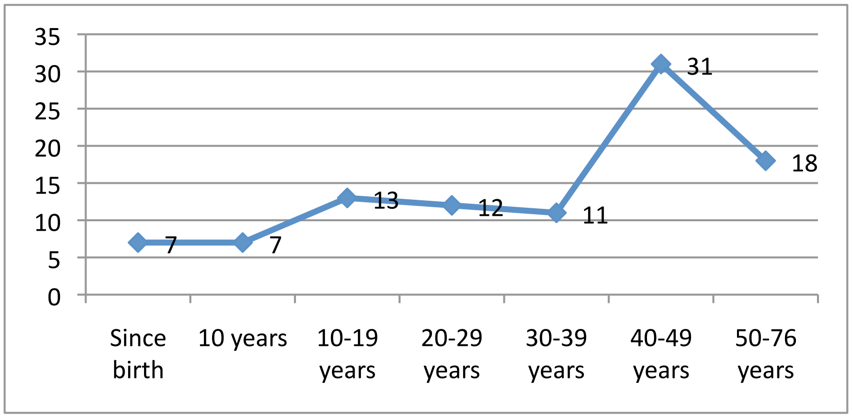
The number of scientists and engineers with disabilities in the workforce increases with age. As of 2006, 2.4% were younger than 35, and 11.1%, were between the ages of 55 and 64. Across all ages, those with disabilities made up 6.5% of the science and engineering workforce (NSF, SRS, 2006, Table H-8). In the general population not specifically in science and engineering fields in 2009, 10.1% of adults between the ages of 18 and 64 were disabled (Rehabilitation Research and Training Center on Disability Statistics and Demographics, 2010). Within this group, the types of disabilities are as follows:

- 5.2% have an ambulatory disability (serious difficulty walking or climbing stairs)
- 4.2 have a cognitive disability
- 3.5 have difficulty with “independent living” (running errands)
- 2.1 have a hearing disability
- 1.8 have a “self-care” disability (difficulty dressing or bathing)
- 1.7 have a vision disability

Only 35.3% of disabled adults of working age are employed, compared with 74.3% of the U.S. working-age population without disabilities. Of those who are “employed full time,” the rate is 20.4% for adults with disabilities compared with 50.8% of adults in the general population.

Fewer than 15% of disabilities are present from birth. The other 85% are acquired due to accidents (such as car, sports, gunshot) or illnesses (such as strokes, arthritis, asthma; Miller & Sammons, 1999). As figure 1 illustrates, most scientists and engineers who were employed in science and engineering occupations as of 2006 acquired their disability in adulthood (NSF, SRS, 2011, Table 9-10). Many students and professionals in the workforce are likely to know someone with a disability, especially a disability acquired in adulthood.

Figure 1. Scientists and Engineers with Disabilities Employed in Science and Engineering Occupations by Age of Onset of Disability, 2006 (Percent of Those in Each Age Group)

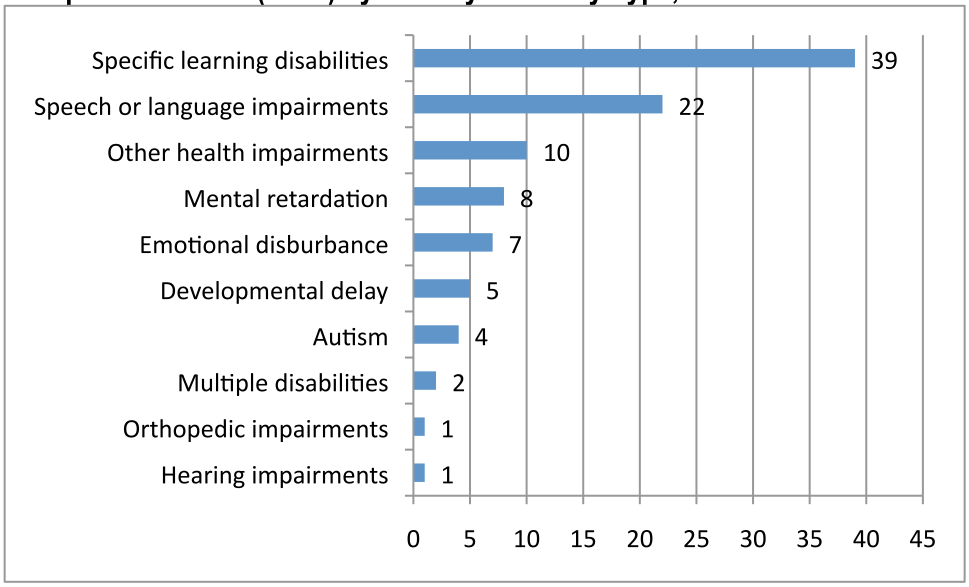


Trends in Special Education

The Individuals with Disabilities Act (IDEA) of 2004 requires U.S. public schools to offer free and appropriate education to children with disabilities, and its regulations guide the provision of special education services. (http://idea.ed.gov). Special-education-teacher teams assess each student and prepare an annual individualized education plan, which spells out what services and assistance the child needs. The target school setting is as close as possible to the setting provided to children without disabilities. Because the program is federally funded, government support helps carry out programs consistent with the regulations. Accommodations and modifications that are suggested for students in every category under IDEA are also well documented for the benefit of teachers by special projects (usually funded by the government), such as Project Ideal, a project of the Texas Council for Developmental Disabilities(http://www.projectidealonline.org/overview.php).

About 13% of students enrolled in public schools in 2007–08 received special education services (Aud et al., 2010). Of those, 39% received services because of learning disabilities and 22% because of speech or language impairments. Most students (80%) spent their school day in general classes. Figure 2 shows the distribution of students served under IDEA by disability type.

Figure 2. Percentage of 3 to 21-year-olds Served under the Individuals with Disabilities Education Improvement Act (IDEA) by Primary Disability Type, School Year 2007–2008



U.S. Department of Education, Office of Special Education Programs (http://idea.ed.gov/)

A number of issues arose in the early history of special education (Lazerson, 1983). The public discourse included disagreement about who belongs in special education. Special education was linked to studies of retardation and intelligence testing, and it has been associated with racism and cultural bias against immigrants. Intelligence tests, which were criticized for racial and cultural bias, were used extensively to assign students to special education. There was also the motivation of protecting “normal” students, and regular classroom teachers, from the disruptions of both “naughty” and “stupid” children. Legislation mandating the provision of special education placed a new burden on public schools, and the public resented the costs. The interest in providing child welfare, that is, providing health and social services, was integrated with educational services. According to Lazerson (1983, p. 47),

> These were the contexts of the emerging revolution in special education: an extraordinary expansion in the size and cost of special education; parents demanding access to and adequacy in special education; the spillover of the civil rights movement determined to prevent segregation, stigmatization, and de facto second-class citizenship through improper classification; and special educators and related professions willing to join parental lobbies on behalf of handicapped children.

Much evidence showed, eventually, that the investment in special education paid off in reducing other social burdens, such as the need for reformatories and prisons. Ironically, special education also came to be seen as an entitlement and a desirable benefit (Lazerson, 1983):

A New Climate and Environment for Disability

The revolution in special education is part of significant recent changes in the treatment of people with disabilities in the United States. During a few decades starting in the early 1970s, a great transformation occurred:

Before

- Residence in institutions isolated from the community
- Patronization by caretakers (the "helping industry")
- Many physical barriers to mobility in public places
- No accommodation for deafness or blindness in public areas
- Limited employment options
- Exclusion from public presence
- No persons with disabilities teaching or running institutions for disabled people
- Small advocacy organizations for a few subgroups (blind, deaf, some diseases)
-

After

- National advocacy organizations; self-advocacy; strong parent groups
- Removal of physical barriers in public places (by law)
- Public transportation designed for assistance
- Ban on employment discrimination (by law)
- Signage and interfaces for hard-of-hearing and visually impaired people
- Entrance into professional positions in general
- Increasing number of jobs as teachers and administrators serving disabled people
- Boom in assistive technologies research and products
- Rise of independent living centers and support networks
- Biographical and anthropological testimonials about life with a disability
- Rise of the field of disability studies
- Rise of special education in schools and integrated into mainstream
- National identity for persons with disabilities as a group and as a movement

The Disability Rights Movement gained momentum as a protest against the slow implementation of the Vocational Rehabilitation Act in 1973, which was a milestone in U.S. public policy. It banned discrimination, encouraged affirmative action in hiring, and mandated "reasonable accommodation" and accessibility to public places, public transport, and public communication systems. Federal regulations, essential to implementation, were finally signed in 1977.

Other laws in the same decade boosted the transformation in conditions and opportunities (Scotch, 2001). The Supplemental Security Income program began in 1972 and covered people with disabilities who had no work history (for example, those with severe psychiatric and addiction disorders). The Education for All Handicapped Children Act of 1974 (later strengthened by the Individuals with Disabilities Education Act of 2004) led to federal support and regulation of special education. Finally, the Americans with Disabilities Act of 1990 banned discrimination in employment, public accommodations, commercial facilities, transportation, and telecommunications. The phrase "reasonable accommodation" became part of the public discourse.

Advocacy by specific, single-disability groups began to coalesce into cross-disability coalitions during this time (Braddock & Parish, 2001), and the infrastructure for information, advocacy, social and medical support, employment, and research is now well established. Organizations include the National Organization on Disability (http://www.nod.org), ADAPT (http://www.adapt.org), the American Association of People with Disabilities (http://www.aapd.org), the Center for an Accessible Society (http://www.accessiblesociety.org), and the Disability Rights and Education Defense Fund (http://www.dredf.org) . The Center for an Accessible Society specializes in assistive technologies and the Society for Disability Studies specializes in research.

The Rate of Change in Higher Education: Case Study (University of Illinois)

Universities introduced programs to support students with disabilities in response to disabled World War II veterans seeking college degrees. One of the earliest programs, founded in 1948, provides a case study in shattering barriers (Brown, 2008). Several conditions set the stage and marked a shift in social values. The first national cross-disability political organization was formed in 1940. A paralyzed-veterans group formed just after World War II, as did a President's Committee on the Employment of the Handicapped. Significant incentives helped veterans reenter society and the workforce. The G.I. Bill was passed in 1944, enabling veterans to attend college with full financial support and obtain low-interest home loans.

Tim Nugent created the University of Illinois Disability Resources and Educational Services program starting with eight wheelchair users and five semiambulatory students (all veterans). According to Brown (2008, p. 165):

> From 1948 to 1960, [Nugent] shepherded a program that succeeded in shattering longstanding, pervasive institutional, physical, economic, psychological, and other barriers that marginalized and ostracized people with disabilities. . . . He battled prevalent negative social attitudes, university bureaucracy, and an inaccessible environment. He cajoled, badgered, and encouraged many students who were unprepared for postsecondary success. As a result, the Illinois program became an oasis . . . [for] . . . those considered to have the most severe impairments, including people with spinal cord injuries, post-polio disabilities, and genetic conditions such as muscular dystrophy and cerebral palsy.

By 1964 the program had graduated 307 students and served about 1,000 students. It became a model for other universities, demonstrating success for students and providing a roadmap for the range of services needed. Support programs after the Rehabilitation Act of 1973 offer early diagnostic evaluation, remediation, coordination with faculty and tutors, and advising.

Changing Practices (Universal Design for Instruction)

Disability services in higher education evolved and expanded in the 1980s and 1990s, following enactment of the Education for All Handicapped Children Act of 1975 and the Americans with Disabilities Act of 1990 (McGuire & Scott, 2006). The demographics of college students also changed as more students with disabilities entered college. Pressure to accommodate college students increased accordingly.

The instructional environment of the K–12 system, which is regulated under the Education for All Handicapped Children Act of 1974 and its successor, IDEA, is quite different from the environment in higher education (McGuire & Scott, 2006). Teachers in the K–12 system must be certified and continually maintain their professional skills as educators. Some teachers specialize in the education of children with disabilities, with certification for the specialty. K–12 students are assured access to schooling by law, and the curriculum is standardized at the state level. By contrast, students with disabilities are not assured a higher education.

In McGuire and Scott's analysis (2006) colleges are not obligated to provide a special curriculum and services. They are obligated by law to provide "reasonable accommodation" that applies in any public environment. Standardization of any curriculum on a state or national level is unlikely. Faculty are not expected to be experts in pedagogy but rather to focus research and scholarship in an academic field. The reward system rates lower the importance of teaching and ways to improve it.

McGuire and Scott introduced universal design for instruction (UDI) in 1998 following focus groups with college faculty and incorporating research on approaches to college instruction. The American Association for Higher Education applied pressure to institutions to improve access (McGuire & Scott, 2006). Traditional means of meeting the needs of students with disabilities include allowing extra time on tests and providing note takers, allowing a sign language interpreter, and including captioning on videos. These services are well intended and helpful but do not compare with the potential effectiveness of a more systematic approach. UDI was developed as a comprehensive framework and a set of principles to guide new ways to teach (Scott, McGuire & Embry, 2002).

UDI's foundation is universal design, which originated in the field of architecture. Universal design identifies features of products and environments that anticipate a variety of needs, ages, abilities, and disabilities. Many of those features benefit everyone (for example, curb cuts on sidewalks make navigation easier for people with strollers, luggage, loading carts, and bicycles, as well as wheelchairs). Like universal design, UDI starts with principles and then integrates them into the design of courses and interactions in the classroom (Scott, McGuire, & Shaw, 2003):

1. ***Equitable use***: Design instruction for students with diverse abilities. For example, provide class notes and make them accessible regardless of hearing ability, English proficiency, learning or attention disorders, or note-taking skills.

2. ***Flexibility in use:*** Design instruction to accommodate a wide range of abilities. Provide choice in methods. For example, transfer information through lectures with visuals, group activities, stories, or web-based discussions.

3. ***Simple and intuitive***: Simplify instructions and expectations and eliminate complexity. For example, explain the basis for grading, provide a syllabus, and guide students through homework assignments.

4. ***Perceptible information***: Anticipate different sensory abilities. For example, select materials that have digital versions as an alternative to paper copy, so students can access them using tools such as screen readers and text enlargers.

5. ***Tolerance for error***: Anticipate different paces of learning and different foundations in prerequisite skills. For example, allow for breaking up a large assignment into smaller pieces for incremental feedback, and provide online practice exercises that supplement classroom instruction.

6. ***Low physical effort***: Unless physical effort is integral to the course, minimize it. For example, allow the use of computers by those who have difficulty with handwriting.

7. ***Size and space for approach and use***: Organize the physical setting so that body size, mobility, movement, and reach are not limitations. For example, use a circular seating arrangement so that students can see the instructor.

8. ***A community of learners***: Promote interaction among students and between students and faculty. For example, foster study groups, e-mail lists, and chat rooms. Make personal connections with students, encouraging them and acknowledging excellent performance.

9. ***Instructional climate*:** Make the learning experience welcoming and inclusive. Have high expectations for all students. For example, affirm the need for peer respect and an expectation of tolerance. Encourage students to discuss special needs with the instructor. Highlight role models for contributions to the field. Recognize students' creative approaches.

A number of centers and websites serve faculty, especially junior faculty and graduate teaching assistants, as they seek to assimilate and incorporate UDI principles:

- The University of Connecticut's Center on Postsecondary Education and Disability offers information about the UDI principles and is collecting descriptions of instructional products and methods put into practice (http://www.facultyware.uconn.edu).
- The Association on Higher Education and Disability (AHEAD) offers standards for disability services programs (http://www.ahead.org).
- CAST provides curriculum examples for teachers at all levels, as well as technical assistance, online and in-person courses, and resource materials(http://www.cast.org).
- The University of Washington's DO-IT project houses The Faculty Room, a concentration of materials for faculty and administrators, including videos showing accommodation strategies, sample PowerPoint that educate others about accessibility, videos showing students with particular disabilities explain how they use assistive tools, an online course for faculty on the topic, an explanation of legal issues, frequently asked questions, and case studies (http://www.washington.edu/doit/Faculty/).

Comprehensive Campus-based Services

Significant financial support for the recruitment and support of students with disabilities in science and engineering fields comes from the NSF Research in Disabilities Education program, which funds regional alliances that integrate a comprehensive range of services (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5482&org=HRD&from=home).

One example is the Midwestern Alliance in Science, Technology, Engineering & Mathematics (MidwEST), a consortium of educators, scientists and disabled-student service providers from the University of Wisconsin-Madison, the University of Illinois at Urbana-Champaign, and the University of Northern Iowa (http://stemmidwest.org). Its key foci include the following:

- Identify students with disabilities in middle and high school and in undergraduate and graduate levels who demonstrate academic excellence and potential for success in science, technology, engineering, and mathematics (STEM), and nurture student interests in STEM with stimulating learning activities and supportive academic success programs.
- Offer professional development activities to faculty and student-disability service providers so modifications can be made to curriculum, lab experiences, and internships.

MidwEST provides assistive technologies for students, such as remote captioning, equation translation with Braille code, individualized strategy instruction for students with learning disabilities, and services management for students with severe physical disabilities Programs also include student stipends and a wide range of technical assistance (for example, webinars on special topics) to faculty and administrators. This alliance expects to affect 406,000 students with disabilities, 1,692 school districts, 3,374 public and private middle and high schools, and 221 institutions of higher education in Wisconsin, Illinois, and Iowa.

Other alliances are based at the University of Washington, the University of New Mexico, the University of Southern Maine, the University of Hawaii, CUNY Hunter College, and institutions in Alabama.

Research on Methods to Broaden Access to Science and Engineering Courses

The population called "students with disabilities" encompasses great demographic variation on the basis of type of disability alone. Compounded by the social dynamics of gender and race/ethnicity, a student's experience can be hard to generalize and address categorically. Research on the experience of students with disabilities is challenged by the difficulty of finding adequate-sized research samples and defining and finding control groups. Scarcity of research funding further limits the amount of quality research conducted. Few generalized survey and assessment tools exist, and their evolution requires a wide base of experience and special investment in cross-project evaluation methods.

Still, large alliances, smaller special education programs, and pedagogy and curriculum experiments are contributing to the experience and knowledge of possible interventions and whether they have positive results. Lessons learned are cumulating, and the sophistication of assessment methods is growing as more programs are tested.

In addition to alliances (providing comprehensive, campus-based services) and experimental, short-term "intervention" programs, such as internships or summer camps, NSF funds exploration in pedagogical strategies and curriculum that promise greater access and effectiveness for students with disabilities:

- A study comparing two math-teaching methods in Elementary Algebra I will be conducted with 32 classes and 128 students with disabilities in community colleges (NSF, 2010a).
- A "signing avatar" is being developed for deaf or hard-of-hearing students in high school to sign words commonly used in life sciences and physical sciences courses. It will be an interactive 3-D dictionary of about 750 terms that can be called up on demand (NSF, 2011).
- An intelligent mathematics tutor (software), applying UDI principles, will be modified for students with learning disabilities. The project targets approximately 200 undergraduates, with and without learning disabilities, across four classrooms in experimental and control conditions (NSF, 2009a).
- Research will address how students who are blind or visually impaired learn spatial thinking. It will adapt curricula to use tactile and audio interaction and evaluate whether the training enhances spatial thinking. The project is housed in a Spatial and Map Cognition Laboratory (NSF, 2009b).
- A team will incorporate audio and tactile tools for making simulated experiments in virtual biology laboratories accessible to blind and low-vision students. Students will be able to access information on a computer screen and interact with simulations (NSF, 2010b).

One project focuses on teachers and faculty, specifically teaching science and engineering courses. SciTrain, at the Center for Assistive Technology and Environmental Access (CATEA) at the Georgia Institute of Technology, conducts research on methods to train high school math and science teachers to be more effective instructors for students with disabilities. (http://catea.gatech.edu/scitrain). It provides online training modules that teachers can use for students with disabilities, specifically in courses in science, computer science, and mathematics.

In parallel, SciTrain U provides tools for postsecondary educators to implement UDI in college classrooms (http://www.catea.gatech.edu/scitrainU/login.php) . It offers tutorials designed to answer many of the questions raised by instructors who have never taught a student with a disability. It also offers a course called "Improved Teaching for Large Lecture Classes" that is not specific to science and engineering content.

Research on Methods Targeting Minority and Female Students with Disabilities

A number of experimental programs explore how to encourage and support disabled girls and minority students who are pursuing science and technology careers. WAMC Northeast Public Radio captured profiles of several outstanding examples (http://www.womeninscience.org):

- The U.S. Space and Rocket Center in Huntsville, AL, hosts a weeklong Space Camp for Interested Visually Impaired Students to help middle and high school girls who are blind or who have low vision learn about space technologies (http://www.tsbvi.edu/space). The students experience simulated space missions using equipment that is adapted with Braille and large print and computer programs that convert text to speech.
- The Entry Point program initiated by Association for the Advancement of Science in 1996 provides internships in science for undergraduate and graduate female students with disabilities (http://ehrweb.aaas.org/entrypoint). IBM, NASA, Google, Lockheed Martin, Merck, Shell, and other companies provide internships in which students are mentored and given experience in the workforce. The ten-week paid internships host about 125 students each summer. Ninety percent of participants pursue study and careers in the sciences.
- The Rochester Institute of Technology's National Technical Institute for the Deaf in Rochester, NY, runs TechGirlz, a weeklong summer camp for middle school girls who are deaf or hard of hearing. The camp features hands-on learning(http://www.rit.edu/ntid/techgirlz).
- MIND Alliance summer institutes serve high school and college students from New York, New Jersey, and Louisiana. Hunter College, City University of New York and Southern University in Baton Rouge, Louisiana provide field trips, hands-on activities, tutoring, mentoring, internships, and career assessment and counseling(http://www.mystem.org).

A comprehensive and long-established program called DO-IT at the University of Washington has a component called AccessSTEM, in which two community colleges and all high schools in the Seattle area are coached in making science and technology courses more welcoming and accessible (http://www.washington.edu/doit/Stem). Students are offered mentoring, peer support, and internships. Educators and employers are given information and technical assistance regarding accessibility.

Barriers to Progress: Chilly Climate for Students with Disabilities

The first U.S. college program for students with disabilities opened at the University of Illinois in 1948. In general, however, faculty are just now encountering larger numbers of students that that started entering public school after IDEA in 1975 and benefited from special education in larger numbers. Higher education institutions have been willing to make physical accommodations for students with disabilities; however, social acceptance by faculty sometimes lags (Beilke & Yssel, 1999).

In the 1990s, researchers interviewed ten students with disabilities at a large midwestern university known for its support services. The group included male and female students between the ages of 19 and 47 with both visible (for example, spina bifida and cerebral palsy) and invisible (for example, learning) disabilities. The students described a number of negative experiences: faculty who were impatient with the distraction of a wheelchair and uncontrolled physical movement, discouragement from enrolling, reluctance to change the way things were taught, skepticism that the student was disabled, and denial of extra time with tests and assignments (although federal guidelines require these accommodations for students with learning disabilities).

Learning disabilities in particular are a relatively new subject of study and are not well understood. They are invisible. Resulting student behaviors are easily confused with lower intelligence, procrastination, poor study habits, and disorganization. Faculty sometimes feel that academic integrity is compromised. Ever more incoming freshmen are labeled learning disabled. The rationale for labeling is not well understood, generally, and may not seem scientific to academics (Beilke & Yssel, 1999).

Like the reaction to affirmative action, the reaction to increasing numbers and types of students with disabilities challenges the value system and culture of higher education. Fiercely competitive faculty may find it hard to act welcoming, tolerant, and accommodating (Beilke & Yssel, 1999).

Early attempts to change the status of women and minorities focused on improving the abilities of individuals to compete in a dominant White and male workplace (Schriner, 2001). This approach was characterized as the “deficit model” in interventions: fix the individual by training her or him to look and act like the dominant group. Similarly, in the evolution of disability-rights consciousness, there was an initial focus on correcting impairments in individuals and making them “fit” the constraints of a typical education or work environment. As people now realize, that the environment is unnecessarily difficult, embeds bias, and needs to be improved.

Experience with Student Success

Students with learning disabilities who receive comprehensive support (for example, counseling, tutoring, allowance for time) are able to develop strategies to compensate for difficulties due to their disability (Adelman & Vogel, 1990). Some of the difficulties students with disabilities experience include difficulty with (1) processing information (understanding spoken or writing material), (2) retention (remembering content), (3) completing tasks in the amount of time allotted, and (4) perception (reversing numbers or letters). Compensating for these difficulties includes spending extra time to do work, asking for assistance and clarification, and monitoring work for errors.

Studies of employment of persons with learning disabilities showed mixed results with obtaining and maintaining jobs and success (Adelman & Vogel, 1990). Some of the variables that explain the mixed results are socioeconomic status, differences in intellectual ability, differences in family support, and educational intervention (Adelman & Vogel, 1990). It is important to note that the severity and type of difficulty varies under the label of “learning disability,” as does a student’s history in educational and social support (Adelman & Vogel, 1990).

A key variable is whether the adult has learned to understand his or her own areas of strength and chosen employment and a career that leverage strengths and avoid weaknesses (Adelman & Vogel, 1990). For example, students who are good at visual-perceptual and quantitative information might enter engineering, accounting, and finance. Those with reading disorders will avoid positions that emphasize reading and writing reports. Students with some types of learning disabilities go into law and engineering, for example, but may have to work harder than others and learn where to pay extra attention. Self-awareness and adoption of special strategies can compensate for the learning disability and help the student choose career paths and jobs that maximize her or his success (Adelman & Vogel, 1990).

Role Models

The value of role models in attracting underrepresented students to STEM fields and careers is recognized, whether those students are women, minorities, or students with disabilities (*Report from the Workshop on Excellence . . .,* 2009). Nearly 20,000 faculty with disabilities worked in science and engineering fields in 2008 (NSF, SRS, 2011, Table 9-28). Some well-known scientists and inventors allegedly had disabilities that were hidden or undiagnosed. Examples include the following (from Disabled World [2006], unless otherwise noted):

- Physicist Stephen Hawking has had Lou Gehrig's disease for 26 years (Wendell, 2010).
- Robert Murphy, a professor of anthropology at Columbia University, became paralyzed at age 52 (Murphy, 1995).
- Dr. Jacob Bolotin was the first congenitally blind man to receive a medical license (at the turn of the 20th century).
- Bernard Morin, a French mathematician, has been blind since age 6.
- Albert Einstein suffered from dyslexia and possibly Asperger's, a developmental disorder.
- Alexander Graham Bell, who had dyslexia, invented the telephone because his mother started becoming deaf when he was 12.
- Alfred Nobel, a Swedish chemist, engineer, innovator, and armaments manufacturer and the inventor of dynamite, was subject to migraines and epileptic seizures from infancy.
- Charles Darwin possibly had obsessive-compulsive disorder and stuttered. His illnesses became incapacitating around age 28.

At the Workshop on Excellence Empowered by a Diverse Academic Workforce in 2009, a number of presenters shared their personal stories (*Report from the Workshop on Excellence . . .*, 2009):

- Bill McCarthy, a professor of civil engineering at New Mexico State University, was injured in a car accident 43 years ago and uses a wheelchair.
- David Wohlers, a professor of chemistry at Truman State University, lost sight in one eye at age 4 and the other at age 8. He uses a device called a Perkins Brailler to convert English text to Braille.
- Ian Shipsey, a professor of physics at Purdue University, lost his hearing in 1989 as a side effect of cancer treatment. Twelve years after he became deaf, he got a cochlear implant.
- Victor Day, a director of the Small Molecule X-ray Crystallography and Protein Structure Laboratories at the University of Kansas, was diagnosed with rapid cycling bipolar disorder more than 15 years ago. Medication has controlled his symptoms.

A group of scientists and engineers gathered at a meeting in 2009 to highlight how professionals with disabilities have solved the problems of navigating their work environments and succeeded as professional scientists, engineers, technologists, and mathematicians (American Association for the Advancement of Science, 2010). Fifty individuals with paraplegia, neurodegenerative diseases, hearing loss, and blindness, as well as invisible disabilities, such as attention deficit hyperactivity disorder, Asperger's syndrome, and poor health, attended and described how they found a way to build satisfying, high-impact careers. Some of their challenges included difficulties with the logistics of travel and old buildings with inaccessible bathrooms. Trends like the increased use of e-mail were a boon to those whose hearing had diminished.

Changing Attitudes, Understanding, and Tolerance

Can we reeducate ourselves and reduce or eliminate the psychological depth of stigmas associated with impairments? Some believe that the social integration of stigmatized groups—greater exposure to differences in a wide range of normal social activities—reduces the onus of the stigma. As Coleman (2006) points out, each individual can choose to ignore social norms regarding stigma.

Early childhood socialization can reduce a child's association of negatives with particular differences in others (Bronson & Merryman, 2009). Educational television shows such as *Sesame Street* can intentionally build cultural awareness and tolerance (Guernsey, 2009). A recent movie about animal scientist Temple Grandin, who is autistic, educated the public. Grandin published a best-selling book on autism titled *The Way I See It: A Personal Look at Autism and Asperger's*, and maintains a website (http://www.templegrandin.com).

Miller and Sammons (1999) developed a method for exploring the kinds of feelings people have in response to disabilities. The researchers offer exercises that lead people to reflect on unconscious and often negative dynamics and make their feelings and thoughts both conscious and positive. Miller and Sammons suggest many activities to draw out personal emotions and assumptions behind typical everyday reactions to difference:

- Difference in ***appearance***—illness, anger, depression, missing body parts, disfigurement
- Difference in ***movement***—use of wheelchairs, assistance dogs, canes, walkers
- Difference in ***communication***—stuttering, slurring, tics, lip-reading and signing, using a device to speak
- Difference in ***social behavior***—lack of eye contact, standing too close or too far away, extremely fearful about arbitrary objects, inappropriately friendly
- Difference in ***learning***—inability to understand signs or instructions, manage money, operate common appliances

Project Implicit at Harvard University recognized that people are either unwilling to report their negative attitudes and beliefs or unable to report them because those attitudes and beliefs are unconscious (https://implicit.harvard.edu). Project Implicit staff designed an online test to uncover unconscious thinking and feeling. The test prompts for associations between words. It measures not so much the patterns of associations that the subject makes but rather the time (in milliseconds) it takes to respond to a sequence of rapid prompts. Longer times suggest a difficulty making an association automatically. Among the Implicit Association suite of experiments is a test on associations between "disabled" and "abled."

A method for educating with the goal of reducing prejudice based on identity and increasing tolerance has emerged in undergraduate education in the last 15 years (Zuniga, Nagdo, Chesler, & Cytron-Walker, 2007; Zuniga, 1998). The approach called intergroup dialogue was developed at the University of Michigan and exported to many other universities. Themes around social justice may focus on particular conflicts between sociocultural identity groups, for example gender, race and ethnicity, sexual orientation, White racial identity, religion, people with disabilities, and people without disabilities. Characteristics of the course include small (12 to 16 people) face-to-face groups, members from two or more identity groups, trained facilitators, self-reflective and open conversation about differences, a weekly meeting for least two hours for six to 12 weeks, and basic reading outside of class. The process includes sharing perspectives from each identity-group member, discussing the readings, reflecting on socialization, exploring controversial issues, reflecting on taking action, and building alliances and a sense of community.

Areas for Future Research

The field of disability studies emerged in the late 20th century. A special issue of *Social Science and Medicine* marked the beginning of anthropological research on disability (Whyte & Ingstad, 1995). The Society for Disability Studies was founded in 1982 and started publishing *The Disability Studies Quarterly* in 1986(http://www.disstudies.org/about/history). The journal arose from a newsletter called *The Disability Newsletter* and was issued as a stapled photocopy until 1996. Roots of the field are interdisciplinary: social science, humanities, and rehabilitation sciences (Albrecht, Seelman & Bury, 2001). Organizations such as Rehabilitation International, the Society for Disability Studies, the British Council of Disabled People, and the U.S. National Institute on Disability and Rehabilitation Research emerged. Academic disability studies programs now offer degrees. The field has strong theoretical, applied, and social policy origins.

Research specializing in educational access in science and engineering fields is even more scarce and recent. The database of awards of the NSF Research in Disabilities Education program shows 182 grants since 1992, of which only a fraction are strictly educational or social science research yielding academic peer-reviewed publications (as opposed to alliances or centers providing comprehensive services, educational demonstration programs, or conferences and workshops (http://www.nsf.gov/awardsearch). It would be useful to have a catalog or database categorizing and summarizing research projects, websites, and resulting academic publications in a uniform way.

The matrix of possibilities for research on educational access in science and engineering fields is quite large. Here are the gross parameters defining the scope of study:

- ***Disability type***: visual impairment, hearing impairment, cognitive or learning disability, ambulatory difficulty, and speech impairment
- ***Educational level***: elementary, middle school, high school, community college, undergraduate, graduate
- ***Gender***
- ***Race/ethnicity***
- ***Socioeconomic status***
- ***Field and content areas*** within science, mathematics, engineering, and technology (such as bioscience, geosciences, physics, spatial skills, computer skills)
- ***Application of assistive technology tools***, such as Braille printers, text readers, captioning
- ***Application of principles of UDI***
- ***Social supports,*** such as mentoring, tutoring, advice, and management of student services (for individuals or the group)

Any emerging field of research needs a frequent review of findings and identification of new research questions. Synthetic overviews can consolidate the knowledge base and suggest new directions. One reason for this is that academic publication is scattered among established journals in which the focus is not limited to the emerging field, including *Disability Studies Quarterly*, *Journal of Intellectual Disability Research*, *Journal of Educational Psychology*, *Journal of Learning Disabilities*, *Journal of Developmental Psychology*, *Journal of Child Psychology and Psychiatry, Journal of Rehabilitation*, *Remedial and Special Education*, *Journal of Special Education*, *Journal of Counseling and Development*, *Anthropology and Education Quarterly*, and the whole gamut of journals specializing in education or STEM education.

A knowledge database of 147 articles on disability and accommodations in science and mathematics is available now in the SciTrain database (http://www.catea.gatech.edu/scitrain/kb/index.php). A new annotated bibliography is pending and will be posted in 2011.The bibliography should provide a good overview of what has been tried and explored as well as findings. With such a resource, someone could write a critical review and identify trends and promising directions.

Recommendations/Future Needs

1. More research on the effectiveness of particular assistive technologies
2. More research on the effectiveness of particular UDI applications
3. A database, catalog, or summary of research projects focused on science and engineering education and access for students with disabilities, by detailed classification
4. Synthetic reviews of findings to date and identification of new research questions
5. Wide dissemination of research bibliographies that have been compiled, for example, the SciTrain annotated bibliography
6. Wide dissemination and “translation” of promising practices

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