Including Universal Design in Engineering Courses to Attract Diverse Students

Dr. Brianna Blaser, University of Washington

Brianna Blaser is a counselor/coordinator at the DO-IT Center at the University of Washington where she works with the AccessEngineering program. She earned a bachelors degree in math and psychology at Carnegie Mellon University and a PhD in women studies at the University of Washington. She has a background in broadening participation and career development in science and engineering fields. Before joining DO-IT, she was the project director for the AAAS (American Association for the Advancement of Science) Science Careers Outreach Program.

Dr. Katherine M Steele, University of Washington

Dr. Steele is an assistant professor in mechanical engineering at the University of Washington. She received her BS in engineering from the Colorado School of Mines and MS and PhD in mechanical engineering from Stanford University. She is the head of the Ability Lab, dedicated to designing new tools and techniques to improve human ability through engineering, and also a leader of AccessEngineering to enable individuals with disabilities to pursue careers in engineering. Dr. Steele previously worked in multiple hospitals as an engineer, including The Children's Hospital of Colorado, Lucille Packard Children's Hospital, and the Rehabilitation Institute of Chicago.

Dr. Sheryl Elaine Burgstahler, University of Washigton

Dr. Sheryl Burgstahler founded and directs the DO-IT (Disabilities, Opportunities, Internetworking, and Technology) Center and the Access Technology Center. These two centers promote (1) the use of mainstream and assistive technology and other interventions to support the success of students with disabilities in postsecondary education and careers and (2) the development of facilities, computer labs, academic and administrative software, websites, multimedia, and distance learning programs that are welcoming and accessible to individuals with disabilities. The ATC focuses efforts at the UW; the DO-IT Center reaches national and international audiences with the support of federal, state, corporate, foundation, and private funds. Dr. Burgstahler is an affiliate professor in the College of Education at the University of Washington in Seattle. Her teaching and research focus on the successful transition of students with disabilities to college and careers and on the application of universal design to technology, learning activities, physical spaces, and student services. Her current projects include the Alliance for Students with Disabilities in Science, Technology, Engineering, and Mathematics (AccessSTEM), the Alliance for Access to Computing Careers (AccessComputing), the RDE Collaborative Dissemination project, and the Center for Universal Design in Education.

Dr. Burgstahler has published articles and delivered presentations at national and international conferences that focus on universal design of distance learning, websites and multimedia, computer labs, instruction, student services, and other applications in education; and the management of electronic communities, work-based learning activities and transition programs for youth with disabilities. She is the author or co-author of eight books on using the Internet with pre-college students and directing e-mentoring and transition programs and lead editor of the book Universal Design in Higher Education: From Principles to Practice. Dr. Burgstahler has degrees in mathematics, education, and administration of higher education. She has taught precollege and postsecondary mathematics, computer programming, assistive and accessible technology, and preservice/inservice courses for teachers on mathematics instruction and technology applications.

Dr. Burgstahler and her projects have received many awards, including the Professional Recognition Award for the Association for Higher Education and Disability, the National Information Infrastructure Award in Education, the President's Award for Mentoring, the Golden Apple Award in Education, and the Harry J. Murphy Catalyst Award.

Including Universal Design in Engineering Courses to Attract Diverse Students

Abstract
Research has shown that members of some groups, including women and people with disabilities, are particularly interested in how their fields of study, such as engineering, can improve the world around them. Teaching students about universal design (UD) and how it benefits individuals with disabilities has the potential to attract these students to engineering and encourage them to create products and environments that are accessible to and usable by individuals with a broad range of characteristics. In this paper, we present findings from an online discussion and site visits to engineering labs with students with disabilities. Based on these findings, we identify opportunities for including disability and UD topics in engineering curricula. Capstone or cornerstone engineering design classes are a natural fit for incorporating these concepts, but other engineering course can be enhanced with disability and UD content as well. We also present suggestions for applying UD to instruction in order to ensure that engineering courses are accessible to the widest audience possible. This investigation provides a foundation for using UD to broaden participation in engineering and training engineers who can design products and environments that address the diverse needs of society.

Introduction
Many factors influence a student's choice to pursue a career in engineering.[1, 2] Research has suggested that some underrepresented groups are attracted to engineering as a means for improving the world around them. For example, Grandy[3] documented a stronger preference among women in engineering and science for future employment that could benefit society; Margolis and Fisher[4] found women to be specifically interested in using computers to do something useful for society; and students with disabilities have demonstrated an interest in using design in order to improve the experiences of individuals with disabilities.[3] Furthermore, students that decide to leave science and engineering fields after completing their undergraduate degrees are more likely to report having the desire to make a contribution to society than students who pursue further education in science and engineering.[5, 6] Including information about the societal impacts of engineering in engineering education may help to retain these students. Grandy noted that minority role models and advisors had a strong influence on some underrepresented students' choice of college major by making them more aware of their ability to serve society and effect social change through their chosen field of study.[7] Across science, technology, engineering, and mathematics (STEM) fields, women and other underrepresented groups have shown a preference for interdisciplinary and team-based environments that have the potential to improve life for themselves and others.[8, 9, 10, 11] Clearly, topics related to improving their surroundings can motivate and inspire students who may not otherwise consider pursuing careers in STEM. Thus, curricular developments that highlight the societal impacts of engineering may support the recruitment, retention, and long term success of women, people with disabilities, and other underrepresented groups in engineering.

Universal design (UD) provides a potential framework for integrating disability, accessibility, and usability topics across the engineering curriculum. Universally designed products are designed to be usable by the largest audience possible. Teaching future engineers to apply UD principles in product design challenges them to consider how their current and future endeavors can help others and thereby improve the world around them, which will ultimately result in future products and environments that are more broadly accessible. Prior research has demonstrated that students who have been explicitly taught about UD are more likely to consider criteria that increase usability in their design process than students who have not learned about UD.[12] Capstone or cornerstone engineering design classes are a natural fit for incorporating UD concepts into the engineering curriculum. However, UD can also be a valuable addition to other core engineering courses, such as evaluating the stability of devices in a dynamics class for individuals of different statures or creating design modifications for diverse users in courses on computer-aided design (CAD).

It is also important that engineering courses themselves are universally designed in order to ensure that they are welcoming and accessible to the widest audience possible, including women, students with disabilities, and underrepresented minorities. By providing an example of UD in action in the classroom, engineering faculty can make their courses accessible to a wide audience while they inspire students to do the same within their own engineering careers.

In spite of its potential to enhance engineering courses, UD or related topics are not often integrated into the engineering curricula.[12, 13] Our work aims to increase diversity in engineering through the inclusion of UD and disability topics in the curriculum. A long-term goal is to determine whether incorporating UD into engineering curriculum attracts and retains students with more diverse characteristics into the engineering field. These potential students include those with disabilities, women, and other underrepresented groups that have demonstrated an interest in and preference for improving the world around them.

In this paper, we present findings from a preliminary online discussion and site visits to engineering labs with students with disabilities. Based on these findings, we identify opportunities for including disability and UD topics in engineering curricula as well as ways in which engineering courses can be made more universally accessible.

Universal design

UD is defined by the Center for Universal Design as "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design."[14] Universally designed products and environments are usable by audiences that are diverse with respect to race, gender, ability, national origin, age, and other characteristics.[15] Universal design applies seven basic design principles to ensure that a product or environment meets these criteria. Examples of the application of each principle are provided in Chart 1.

A classic example of UD is a curb cut, which allows individuals with a wide range of mobility characteristics to better access sidewalks. Individuals using wheelchairs, pushing strollers, or pulling rolling suitcases all benefit from curb cuts. Likewise, the universal design of videos, which includes captioning, creates videos that more usable to individuals with hearing impairments, non-native speakers of English, and viewers who are in noisy or noiseless environments. A universally designed website is accessible to visitors who use screen readers and those who use mouse alternatives, and it includes images of individuals who are diverse with respect to gender, race, ability, and other characteristics.

Chart 1. Universal Design Principles (Adapted from *Universal design: Process, principles, and applications*.[16])	
Principle	**Example**
Equitable use	A website that is designed to be accessible to everyone, including people who are blind and use screen readers.
Flexibility in use	A museum that allows visitors to choose to read or listen to the description of the contents of a display.
Simple and intuitive	Lab equipment with clear and intuitive control buttons that can be used regardless of a user's experience, knowledge, language skills, or concentration level.
Perceptible information	Captioned television programming shown in a noisy sports bar.
Tolerance for error	Software applications that provide guidance when the user makes an inappropriate selection.
Low physical effort	Doors that open automatically for people utilizing a wheelchair, pushing a stroller, or carrying an armful of books.
Size and space for approach and use	A flexible work area that can be used by employees who are left- or right-handed and have a variety of other physical characteristics.

Although applying principles of UD may contribute to the creation of better products, it is not typically taught in engineering or design curricula.[17] UD overlaps with many of the foundational principles of design and analysis in engineering. For example, in capstone design courses, engineering students are often asked to develop detailed specifications to guide their design and to consider the viewpoint of multiple stakeholders. The incorporation of UD challenges these students to consider stakeholders with diverse characteristics, including disabilities. This does not mean designing products that can be utilized by every potential user, which can often lead to overly complex products; instead, UD focuses on making design decisions that are cognizant of diverse users and their abilities and perspectives. For example, in addition to an audio alert, many newer kitchen ovens flash the lights inside the oven on and off when the oven has preheated. This simple design feature is not only useful for individuals with hearing impairments, but can be useful for catching the eye of a busy cook in a noisy kitchen. When teaching about the application of safety standards, a topic that has been effectively integrated into engineering curriculum, an instructor can introduce UD by requiring that students take into account the requirements of diverse users as they address safety issues. Content related to disability can be included in a course that does not specifically address UD. For example, an assignment to design a prosthetic arm may focus on designing a product for a specific individual and not consider UD features in general.

Perspectives of STEM students with disabilities

To gain a greater understanding of current topics of disability and UD in engineering education and the impact on students from underrepresented groups, we sought the perspectives of STEM students with disabilities. In an existing online mentoring community of STEM students with disabilities and recent graduates, we asked participants if topics related to disability or accessibility were covered in their STEM courses. We were interested in the extent to which these topics, which address societal impacts of engineering, were typically a part of STEM curriculum.

The online community engaged in the discussion consists of almost five hundred individuals from across the United States. Participants include community college, undergraduate, and graduate students who have disabilities as well as recent graduates and professionals who serve as mentors. The group is diverse with respect to field of study, gender, race, ethnicity, age, and type of disability.

A message was sent to the list asking students what they had learned related to disability or accessibility in their classes. The message also asked students how they felt about having disability addressed in their courses and how they thought instructors could incorporate these topics into the curriculum. Twenty students engaged in a conversation on the topic over the course of thirty email messages. Given the limited number of participants and the qualitative nature of the conversation, we have chosen to analyze their comments qualitatively rather than quantitatively.

Most students reported not learning about disability in any of their engineering or other STEM courses. Student comments included

- "I never hear a word about disability in any of my classes. Class content never says a word about disability, which I view as [an aspect of] diversity."
- "I learned nothing at all [about disability]."
- "I have a feeling there will be a common general consensus across the board for many of us that disability rights, accessibility, awareness, or even knowledge of disabilities are not being taught or discussed in our STEM related fields. I am a senior in software engineering who is blind. To date, not one professor has had any knowledge of my disability nor how to interact with a student with my disability."

When topics related to disability or accessibility were introduced in class, they typically focused upon a specific individual or a specific application, such as in biology:

- "The only time I ever heard it mentioned was when the [Disability Resources for Students] director came to speak at a course on teaching biology, which I attended on invitation. Certainly genetic diseases are discussed in some biology courses, but never the aspects of disability around them; they're more like teaching examples without human context."
- "In the class material itself, we typically don't discuss the diverse backgrounds and experiences of the scientists who built the field (with regard to disability or otherwise). The one exception was when we discussed the persecution of Alan Turing by the British government."

The few students who had learned about disability were largely students pursuing careers related to accessibility, typically in graduate school. Some of these students found information integrated into the curriculum, others educated themselves on the topic:

- "It has been sort of a mixed bag, since my advisor, my lab, and a number of professors on my campus actually do disability and assistive technology related research. When I was in my HCI (human computer interaction) graduate class, my professor let me teach the entire class period about assistive technology. . . . We also have a class, called web accessibility, which happens to be taught in the industrial design program. It is only taught once a year and enrolls about 20 students."
- "I learned nothing about disability or accessibility in the STEM classes I took. I was always the one to bring it up. I had some final projects in grad school where it was important to me to create accessible materials and faculty members and/or team members thought I was being ridiculous. While working on the project I was disappointed that there wasn't more support from those involved because the project was centered around accessibility. I think faculty members could have been more supportive of accessibility-related issues and could have used these situations as learning experiences for the whole class."
- "We have a class dedicated to assistive technologies. . . . This satisfies a number of School of Engineering requirements, which serves as an incentive for people to take this class. Another class offered called "Social Perspectives on Disability." [There is also a] class on assistive technologies and the considerations that designers should take to ensure that their apps and websites are accessible to people with disabilities. We also have an online program that provides guidelines for web developers working on university websites."

Many students reported that they would be interested in learning about disability-related topics in their coursework and some had ideas for how such content could be integrated into the curriculum:

- "I would be interested in seeing information on accessibility in a course. In fact, I believe there are multiple places where that could be applied. In a programming course that teaches Java or HTML, there could be a unit on how to write accessible software applications and web pages. This could include students with visual, hearing, or physical disabilities."
- "I would be interested in seeing units on designing accessible products. I might seek out a course like this if I ever have an open elective to fill."

Others noted that including disability-related topics was important for preparing the next generation of professionals:

- "Engineering is all about innovation and making structural change on a variety of levels, I think it is imperative students entering the field have this background."
- "I think accessibility should be integrated into the curriculum, to build better technologies and conscientious students."
- "Adding AT (assistive technology) to the school's curriculum would be an excellent way of assuring future educators/students are knowledgeable and well trained in the discipline. My knowledge has come mostly from sources outside of any curriculum."

- “I think the reason for many accessibility-related issues in today's technologies is because it isn't being taught. If it isn't taught, folks go on to create things without this awareness, resulting in inaccessible technologies.”
- “If it is not taught at the design level, then they never learn it.”
- “It really should be a part of all STEM courses because that is where it will reach the greatest number of students and have the most impact. Not every student takes every course in a curriculum so if it were a stand-alone course only those who take the specific course will be exposed to the content. Unless the course was required, I don't think it would reach as many folks because there are so many classes to choose from and, to be honest, most will not find disability issues interesting enough to take a whole class on it."

Overall, participants in this discussion reported little content on disability and accessibility in their STEM courses, but were enthusiastic about including these topics in STEM curriculum. One student, however, highlighted the need for sensitivity in covering this content and the importance of understanding that there are many different responses to having a disability, that a person’s response to his or her disability should be respected, and that one person with a disability cannot be the spokesperson for an entire group. This student reported that her instructor in a biotechnology course focused on the need to “cure” disability in order to make people “normal.” She wrote,

- “I felt like I was forced into a position where I was the spokesperson of disability. Many times I had to bring up the fact that not everyone wants to be cured. As an amputee, I spent countless class periods explaining why I didn't want prosthetic limbs, even if they were bionic. Overall, being the only one with a (visible) disability in that class was overly awkward, and I feel like the topic wasn't covered well. In a case like this, I think I would have rather had the topic of disability avoided altogether.”

UD offers one framework to address topics related to disability and accessibility and the societal impact of engineering.

Incorporating universal design in engineering curricula

As our participants noted, there are few examples of accessibility and disability being included in the engineering curricula. What are the best places to start introducing disability or UD into an already packed engineering curriculum? Capstone or cornerstone engineering design classes are a natural fit for incorporating UD concepts into the engineering curriculum, challenging students to design for individuals of all abilities and backgrounds. Many engineering programs offer specialty capstone design courses focused on assistive technology that provide a natural point for introducing UD principles. For example:

- Recent senior design projects from the Colorado School of Mines under the mentorship of Joel Bach have worked with local adaptive sports centers to design better mountain bikes for individuals with spinal cord injuries (CSM FourCross).
- The University of North Florida’s Adaptive Toy Project (http://www.unfadaptivetoyproject.com/) challenges students to create broadly accessible toys that encourage learning.
- In the Devices for the Persons with Disabilities course offered through the Biomedical Engineering Department at Duke University, students design assistive technology for an individual with a disability and learn about UD concepts. Applying UD when designing

AT for a specific person can make it easier to adopt and utilize the technology more broadly.[18]

Likewise, UD can be integrated into first year engineering design courses, for which instructors often design a course project aligned with their own research interests. At the University of Dayton, Kimberly Bigelow has had students apply UD principles to redesign an engineering laboratory as part of a first year engineering design course project; in these projects, students often work directly with individuals with disabilities.[12]

When a topic has been iteratively introduced and applied by the students it is more likely to become a central part of their engineering process. Principles of UD can be productively incorporated throughout the engineering curriculum to provide opportunities for exploration, professional development, and practice. Instructors and mentors can challenge students to always consider potential product users with diverse characteristics such as individuals with impaired vision, individuals who are exhausted at the end of the day, individuals who can only use one hand, and so on. Considering diverse abilities can serve as seeds for brainstorming sessions that push students to consider more inclusive design options while instilling the fundamentals of UD.

UD can be incorporated into the curriculum of many core engineering courses, as demonstrated by the examples that follow:

- In fundamental statics or dynamics classes, students can be introduced to UD by evaluating loads and motions for different individuals or modes of transportation (*e.g.,* will this support the load of a power wheelchair?).
- In computer aided design courses, students can be challenged to create models that can be used by individuals with visual impairments. Computer-aided design and 3D-printing have become common tools in many engineering classrooms. One of the most popular repositories of digital designs, Thingaverse.com, already offers a broad array of models that can be used as teaching aids for individuals with vision impairments, as well as other assistive technology. These freely-available designs can serve as a starting point for discussions about UD.
- In programming classes, students can learn about how to make websites and apps that are broadly accessible and create final projects that can be used by diverse users. Students can be challenged to redesign one of their lab activities or other assignments to be accessible to students with disabilities. The Web Design and Development Curriculum developed by the DO-IT (Disabilities, Opportunities, Internetworking, and Technology) Center at the University of Washington integrates accessibility and universal design into its lessons.[19] The curriculum has been adopted and applied in university settings.

Applying UD principles to instruction

Besides including UD topics in the curriculum, UD strategies can be applied to instruction to ensure that engineering courses are welcoming and accessible to a wide audience that includes women, students with disabilities, racial/ethnic minorities, and other underrepresented groups. Faculty can apply UD to the class climate, their interactions with students and interactions among students, classrooms and products, delivery methods used, information resources and technology, feedback, assessments, and accommodations.[20] Chart 2 provides examples of how UD can be applied to these aspects of instruction.

Chart 2. Universal Design of Instruction (Adapted from *Universal design of instruction: Definitions, principles, guidelines, and examples*).[21]	
Category	**Example**
Class climate	Include a statement on the syllabus inviting students to discuss accommodations or other concerns they may have.
Interactions	Assign group work that requires students to support one another and that values students' diverse skill sets.
Classrooms and products	Develop safety procedures for all students including those who have vision, hearing, or mobility impairments.
Delivery methods	Use multiple modes to deliver content.
Information resources and technology	Allow adequate time for students to arrange for alternate formats of books and ensure that the course website is accessible.
Feedback	Provide opportunities for students to receive feedback before a final project is due.
Assessment	Assess group performance as well as individual contributions.
Accommodation	Be familiar with campus procedures for arranging a variety of accommodations.

UD can serve to increase the participation of not only students with disabilities, but also other underrepresented groups in the engineering classroom. For example, including culturally-relevant materials in engineering courses can enhance the engagement and performance of underrepresented groups. Culturally Situated Design Tools (http://csdt.rpi.edu) explores ways that math and computing principles are displayed in African, African American, Native American, and Latino designs. Likewise, eliminating masculine-associated language from promotional materials and decorating rooms in a gender-neutral manner can help increase the participation of females.[11, 22]

Engineering programs typically include a rich set of hands-on laboratories that support classroom-based curriculum. These hands-on laboratories can create particular challenges in making a curriculum that is broadly accessible, especially for individuals with disabilities. However, simple UD strategies can often make these labs accessible to a broader audience. We conducted site visits of a machine shop and four engineering labs at a large research university. Based on these site visits and resources developed for making science labs more accessible,[23] we created suggestions for applying UD to engineering labs.

One of the simplest approaches in team-based labs is for instructors to help students learn to support one another's participation by identifying tasks that each individual can successfully perform in order to contribute to the team. Further, the trend toward more computer-based lab activities can result in greater accessibility. For example, machine shops now routinely use 3D-printing and other computer-aided manufacturing and machining processes (CAM), which may allow individuals with limited dexterity or strength to actively design and build.

Specific characteristics of universally designed engineering laboratories and machine shops include the availability of:

- Adjustable height lab tables or work benches
- Equipment and controls that can be reached from a seated position
- Clear, large-print, or Braille labels
- Adequate lighting or additional light sources
- Clear lines of sight between instructional and laboratory areas
- Wide aisles throughout the space that are kept clear of obstructions
- Clear safety procedures for students with mobility, vision, and hearing impairments

Environmental and curricular changes with UD in mind may increase the likelihood that students with disabilities and students from other underrepresented groups pursue and persist in engineering. By providing examples of UD in action in classrooms and labs, engineering faculty can make their courses accessible to a wide audience and inspire students to do the same in their own engineering careers.

Conclusion and future work

Including disability and UD topics in the engineering curriculum is important for multiple reasons. These topics appeal to underrepresented groups, including women and individuals with disabilities. They can also help train the next generation of professional engineers to develop and design products that are accessible to the largest audience possible. Applying UD to instruction can also contribute to the retention of students from underrepresented groups in engineering programs.

We are part of *AccessEngineering*, a National Science Foundation funded project designed to increase the participation of people with disabilities in education and careers in engineering and improve engineering fields with their perspectives and expertise. We are working with engineering faculty nationwide to (1) better serve a diverse student body that includes students with disabilities in engineering courses and programs, and (2) integrate relevant disability-related and universal design content into engineering courses.

Starting in 2015, we will host a workshop each year with engineering faculty from across the country to discuss their approaches to achieving these goals. We will be drafting resources based on these conversations and disseminating them widely through our networks of engineering faculty members, the disability community, and professional organizations. Students with disabilities play a critical role in this work. We work closely with a team of students who share their experiences, respond to issues presented by staff and faculty leaders, and provide feedback on resources. Although the students we talked with were eager to see more information about disability and accessibility in their courses, it’s imperative that the information is presented in a sensitive way. Including students as we develop best practices will help to ensure that information does not alienate students with disabilities or other underrepresented groups in engineering.

Efforts to develop resources and disseminate them will continue for the duration of the grant. We will also continue to examine ways that UD principles can increase the recruitment and retention of underrepresented groups in engineering through surveys, interviews, and deployment of curricular material in engineering courses. Although the inspiration for this work was to increase the representation of students with disabilities in engineering fields, we believe integrating information about UD and accessibility into the engineering curriculum can increase the representation of other underrepresented groups, including women and minorities, who are interested in improving the world around them. Our goal is to provide best practices and easy-to-use tools to support a diverse group of engineers who are better prepared as professionals to design products that are accessible and usable to a broad range of individuals.

---

[1] Lent, R. W., Sheu, H., Singley, D., Schmidt, J. A., Schmidt, L. C., & Gloster, C. S. (2008). Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students. *Journal of Vocational Behavior, 73*(2), 328 – 335. http://dx.doi.org/10.1016/j.jvb.2008.07.005

[2] Porter, S. R., & Umbach, P.D. (2006). College major choice: An analysis of person-environment fit. *Research in Higher Education, 47*(4). 429 – 449. http://dx.doi.org/10.1007/s11162-005-9002-3

[3] Grandy, J. (1994) *Gender and ethnic differences among science and engineering majors: Experiences, achievements, and expectations* (GRE Board Research Report No. 92-03R). Princeton, NJ: Educational Testing Service.

[4] Margolis, J. & Fisher, A. (2002). *Unlocking the Clubhouse: Women in Computing*. Cambridge, MA: MIT Press. Princeton, NJ: Educational Testing Service.

[5] Grandy, J. (1992). Graduate enrollment decisions of undergraduate science and engineering majors: A survey of GRE test takers (GRE Board Professional Report No. 85-01). Princeton, NJ: Educational Testing Service.

[6] Grandy, J. (1998). *Science and engineering graduates: Career advancement and career change* (GRE Board Report No. 91-14). Princeton, NJ: Educational Testing Service.

[7] Grandy, J. (1998). Persistence in science of high-ability minority students: Results of a longitudinal study. *The Journal of Higher Education, 69*(6), pp. 589 – 620.

[8] Ambrose, S., Lazarus, B., & Nair, I. (1998). No universal constants: Journeys of women in engineering and computer science. *Journal of Engineering Education, 87*(4), 363 – 368.

[9] Diekman, A.B., et al. (2010) Seeking congruity between goals and roles a new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science, 21(*8), 1051 – 1057.

[10] Rhoten, D., & Pfirman, S. (2007). Women in interdisciplinary science: Exploring preferences and consequences. *Research policy, 36*(1), 56 – 75.

[11] National Center for Women and Information Technology. (n.d.). *Top 10 ways to increase girls' participation in computing competitions*. Retrieved from http://www.ncwit.org/resources/top-10-ways-increase-girls-participation-computing-competitions/top-10-ways-increase-girls

[12] Bigelow, K.E. (2012). Designing for success: Developing engineers who consider universal design principles. *Journal of Postsecondary Education and Disability*, *25*(3), 212 – 231.

[13] Erlandson, R., Enderle, J., & Winters, J. (2006). Educating engineers in universal design and accessible design. In J.M. Winters & M.F. Story (Eds.). *Medical instrumentation: Accessibility & usability considerations*. CRC Press.

[14] Connell, B. R., et al. (1997). *The Principles of Universal Design*. Retrieved from http://www.ncsu.edu/ncsu/design/cud/about_ud/udprinciplestext.htm

[15] Burgstahler, S.B. (2008). Universal design in higher education. In *Universal design in higher education: From principles to practice* (pp. 3 – 20). Boston: Harvard Education Press.

[16] Burgstahler, S.B. (2015). *Universal design: Process, principles, and applications*. Retrieved from http://www.uw.edu/doit/universal-design-process-principles-and-applications

[17] Ostroff, E. Limont, M., & Hunter, D.G. (2002). *Building a world fit for people: Designers with disabilities at work*. Retrieved from http://www.humancentereddesign.org/adp/profiles/index.php

[18] Enderle, J.D. (Ed.) (2011). *National Science Foundation 2011 Engineering Senior Design Projects to Aid Persons with Disabilities*. Retrieved from http://nsf-pad.bme.uconn.edu/2011/NATIONAL%20SCIENCE%20FOUNDATION,%202011,online.pdf
[19] DO-IT. (2015). *Web design & development I*. Retrieved from http://www.uw.edu/accesscomputing/webd2/
[20] Burgstahler, S.B. (2008). Universal design of instruction: From principles to practice. In *Universal design in higher education: From principles to practice* (pp. 23 – 44). Boston: Harvard Education Press.
[21] Burgstahler, S.B. (2012). *Universal design of instruction: Definitions, principles, guidelines, and examples*. Retrieved from http://www.uw.edu/doit/universal-design-instruction-udi-definition-principles-guidelines-and-examples
[22] National Center for Women and Information Technology. (n.d.). *Top 10 ways to engage underrepresented students in computing*. Retrieved from http://www.ncwit.org/resources/top-10-ways-engage-underrepresented-students-computing/top-10-ways-engage-underrepresented
[23] DO-IT. (2014). *Checklist for making science labs accessible to students with disabilities*. Retrieved from http://www.uw.edu/doit/checklist-making-science-labs-accessible-students-disabilities

Acknowledgement
This material is based on work supported by the National Science Foundation under Grant #EEC-1444961. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.