

Accessible Design Issues and Principles in the Undergraduate Engineering Curriculum

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Introduction

Ethical concerns and market potentials provide compelling reasons for the inclusion of accessible design issues and principles in undergraduate engineering programs. Federal laws, rules and regulations mandating accessibility to products, services, jobs and public places for people with disabilities, however, are the most pressing reasons for including accessible design material in undergraduate engineering programs. These laws, rules, and regulations impact all engineering design disciplines and cover the design spectrum from the assembly and manufacturing of products to consumer use of products and services.

Undergraduate engineering programs typically do not include material on accessible design. There are conflicting pressures on engineering curricula that affect the acceptance of these proposed additions to undergraduate programs. There is pressure to reduce the number of credit hours required for the Bachelor of Science in Engineering degree while concurrently there is pressure to include more new material. The competition among new material for inclusion into the undergraduate curriculum is intense, hence the question; "Why include material on accessible design?" If one concludes that it is important to include material on accessible design the question then becomes; "How can this be done?"

This paper addresses these two questions. First, a case will be made as to the importance of including accessible design issues and principles in the undergraduate engineering curriculum. Second, strategies will be presented as to how accessible design curriculum and educational material can be naturally included into existing course offerings.

Accessible Design

Accessible design means to design processes, products, and services so that as many people with as broad a spectrum of abilities as possible can access and use the processes, products, or services. Accessibility has economic and social dimensions in addition to human factors considerations. The cost of products and services determines their accessibility. The more expensive a product or service the fewer people who will have access. Societal values are made explicit by a nation's laws. These laws are important because they provide a legal matrix that supports all other efforts.

Accessible design seeks to ensure physical accessibility through the use of sound human factors principles. In addition to physical accessibility, the design must facilitate cognitive accessibility--that is, reduce memory requirements, computational demands, possibly eliminate reading requirements, or in short, to keep things as simple as possible. Accessible design needs to reduce the variability associated with processes, jobs, and device performance. Jobs, processes or device operations that are not predictable, consistent or reliable lead to errors, frustrations, and accidents. Accessible design must build in error-proofing and error-handling capabilities and designers must take into account the many possible causes of human error and design for error prevention, protection and recovery.

Ethics, Markets and Laws

The application of accessible/universal design principles provides a concrete and demonstrable ethical statement by business and industry. An example of industry's commitment is the June 3, 1998, SBC (Southwestern Bell Communication) policy on universal design (accessible design): "SBC's commitment to universal design principles is a tangible demonstration of the value SBC places on the worth and dignity of all individuals, including people with disabilities. SBC is committed to universal design."¹ This statement is only one example of the ethical and compassionate efforts being shown in the business community for individuals with disabilities.

A market study performed by the Electronic Industry Foundation states that "NCHS and the Census agree that roughly 15 percent of the total population have some type of functional limitation. More than one-third of the total cannot perform major life activities like working, going to school, playing or caring for themselves."² It is further agreed that this is an underestimate because people with disabilities do not tend to classify themselves as disabled or functionally limited. A Pacific Bell study estimates that there are about 10 million people with disabilities in California alone.³ More significantly, their research shows that "many people with disabilities are avid purchasers and users of products that help them communicate more effectively."³ It is an emerging realization that individuals with disabilities represent a potentially huge market for a large variety of products and services.

These studies did not include the aging "baby boomer" population, another dominating factor in the marketplace for goods and services. The "baby boomers" have influenced markets all through their maturation process. In terms of demanding more accessible products, services, and jobs, markets are just beginning to feel the impact of this group.

Hence there is a growing awareness that individuals with disabilities and the aging population represent significant market potentials for more accessible products and services. More and more businesses are recognizing the potential dollar value of what were once considered "niche markets." While the changing perceptions may have started as a rationalization and a coming-to-terms with the legal mandates, marketing to this particular consumer group is now recognized as smart, ethical business. This is a powerful combination.

While ethical and marketing concerns are part of the motivation for the inclusion of accessible design principles and issues in the undergraduate engineering curriculum the most pragmatic

pressure comes from recent legislation that has mandated that the principles of accessible design be incorporated into a wide variety of facilities, products, and services. Such legislation includes the Americans with Disabilities Act (ADA) ^{4,5}, the Telecommunications Act of 1996, ⁶ and Section 508 of the Rehabilitation Act ⁷. As federal agencies provide clarification regarding the enforcement of this legislation, it is imperative that engineers, business owners, information/telecommunication system designers, web authors, and others be cognizant of the legal and social concerns that surround the issue of accessible design—an issue that will have significant impact on the products, facilities, and services that such professionals provide.

The ADA mandates job accessibility by prohibiting discrimination in all employment practices. ⁴ The ADA also mandates that Americans of all capabilities have access to buildings and government programs and services. ⁵ Services include information sources. In the past, the need for accessible information was met with Braille texts, large print, captioning, and other types of aides. With the introduction of the World Wide Web and other telecommunications-related information sources, however, many businesses and communities are falling short of meeting their ADA obligations for accessibility. ⁸

Supportive of the ADA in regard to information accessibility is the 1992 revision and reinstatement of the Rehabilitation Act, which ensures that “individuals with disabilities [be able to] produce information and data, and have access to information and data, comparable to the information and data, and access, respectively, of individuals who are not individuals with disabilities.”⁹ More recently Section 255 of the Telecommunications Act reinforces this right to information access with its focus on telephony. Section 255 stipulates that a manufacturer of telecommunications equipment or customer premises equipment “shall ensure that the equipment is designed, developed, and fabricated to be accessible to and usable by individuals with disabilities, if readily achievable.” Telecommunications services shall also be accessible to and usable by individuals with disabilities, if readily achievable. ⁹ The law goes on to state that if rendering the equipment or service accessible is not readily achievable, “a manufacturer or provider shall ensure that the equipment or service is compatible with existing peripheral devices or specialized customer premises equipment commonly used by individuals with disabilities to achieve access, if readily achievable”. ⁹

The Workforce Investment Act of 1998 contains amendments to the Rehabilitation Act of 1973. The changes to Section 508 in the 1998 amendments specify accessibility requirements for Federal departments and agencies that use electronic and information technology. The evolving standards for this current round of legislation define Electronic and Information Technology (E&IT) as electronic technology that is used in carrying out information activities, involving any form of information. ⁷

It is understood from Section 508 that Electronic and Information Technology addresses a broader spectrum than Information Technology alone, and includes the full breadth of the information environment of the future. The intent of Section 508 is to ensure that government employees and the public have access to the government’s information environment as it evolves. As specified, information activities include, but are not limited to, “the creation, translation, duplication, serving, acquisition, manipulation, storage, management, movement, control, display, switching, interchange, transmission, or reception of data or information.” ⁷

Furthermore, the evolving regulations would require that the documentation (instructions, service, etc.) associated with E&IT also be accessible and useable. ⁷ Lastly, the E&IT should not interfere with the assistive technology used daily by people with disabilities. ⁷

Current knowledge level

An informal survey by the Association of Access Engineering Specialists concludes that the current workforce does not possess the knowledge and skills required to seriously address the legal and market needs for accessible design. ¹⁰ This lack of knowledge is also found at the university level.

Most college and university faculty, and thus students, are not aware of the evolving laws and regulations dealing with accessible design for individuals with disabilities. This hypothesis is supported by a review of online course offerings. As part of the needs assessment for an NSF curriculum development grant, about thirty university web sites were reviewed. With the exception of Industrial Engineering, human factors, and rehabilitation engineering courses, issues of accessible design for individuals with disabilities were not mentioned. In a review of the on-line listings of the introductory level engineering texts of McGraw-Hill, Prentice-Hall and John Wiley, only one of 26 books mentions disability and accessible design issues. Two of the books mention human factors and the need to design for usability, but fail to mention disability-related issues. This is a small sample, but based on discussions with editors from Prentice-Hall and John Wiley, this lack of material on accessible design is apparently representative of the textbook market.

While these information-gathering activities were modest, a clear and consistent pattern emerged. Most practicing and student engineers are not aware of the legal, ethical, and market issues that surround accessible design. This represents a serious knowledge gap with potentially serious consequences for institutions that cannot or will not apply accessible design principles.

Strategies for inclusion

As part of an NSF grant on the development of prototype curriculum material for accessible design (AD) the Enabling Technologies Laboratory (ETL) at Wayne State University (WSU) developed integration strategies as well as educational material (DUE 9972403). Table 1 summarizes some of the strategies.

I want to focus on the last two categories, engineering and non-engineering, in that I believe these to be the most problematic with respect to the integration of AD material. Experience has shown that while instructors are not opposed to the inclusion of AD material, they do not have the time to research and develop examples, case studies and special homework assignments. If materials were readily available, however, most instructors would try to include the AD material if it supported or complemented the existing course content.

Engineering Classes

While every engineering class is not a design class, every engineering class typically contains design components. The inclusion of design components presents an opportunity to introduce accessible design principles and issues. This can be achieved using hierarchically-structured curriculum modules that contain material targeted for a specific class yet contains accessible design principles or issues.

Table 1. Strategies for inclusion of AD material into various class categories.

Category of class	Example	Strategy
Dedicated	Rehabilitation Engineering Human Factors Telecommunications and E&IT	Dedicated content covering accessibility and AD principles.
Design	Capstone Design	AD issues raised and considered as part of the design specifications. AD principles applied as appropriate.
Engineering	Any engineering class with a design component	Integrate AD issues and principles via lecture examples, case studies, homework problems, or special assignments.
Non-Engineering	Technical writing Economics History, Political Science	Integrate AD issues and principles via lecture examples, case studies, homework problems, or special assignments.

For example, a course on electromagnetic field theory or fundamentals of communications can discuss the interference between most cellular phones and hearing aids. The details of this interference and examples of designs to correct the problem can be presented in varying degrees of technical detail depending on the technical level of the class. The problem with this approach is that while faculty would be willing to incorporate such material, they are generally not aware of such examples, nor do they have time to explore and develop such examples.

The following prototype materials were developed under the NSF grant: two basic awareness-raising modules that introduce accessible design principles, laws mandating accessibility, population demographics supporting markets, and ethical imperatives; two demonstration modules developed as student projects; and fifteen experiment modules. All the modules contain educational material that can be used in courses from freshman level to senior design level.

The basic awareness modules provide instructor background information on the relevant laws, the demographics of disability, and accessible design principles. The accessible design principles are presented as a complement to good design strategies as presented in Donald Norman's book *The Design of Everyday Things*.¹¹ These modules were designed for use in a basic introduction to engineering class. The homework exercises focus on products and services common to all students regardless of discipline.

Class demonstrations are a powerful way to engage students and provide examples of concepts and issues. One of the demonstrations dealt with web site accessibility. Two similar web sites were studied and compared with respect to accessibility. First, both sites were viewed. Next, both were run through the Bobby Web Evaluation System.¹² One passed the Level 1 accessibility criteria and the other did not pass. Both systems were then viewed through Lynx, a program that allows users running cursor-addressable, character-cell display devices (e.g., vt100 terminals, vt100 emulators running on PCs or Macs) access to web sites¹³, and Opera, a browser that supports a variety of built-in accessibility features.^{14 15} Lastly, the systems were “viewed” using the online demonstration version of the IBM screen reading system, which provides synthesized voice output.¹⁶

This collection of view experiences drives home some of the basic notions of accessible web design, yet there is sufficient depth provided by the Bobby analysis results, that advanced programming classes could go into considerable detail on design studies. Note also that each module allows one to simply experience the phenomenon and, once experienced, explore the phenomenon in varying degrees of detail depending on the level and focus of the class.

Fifteen experiment modules were developed to explore different facets of human performance. All of the experiments derive from an established theoretical concept. The modules present the area of concern, the theoretical concept, practical examples of the concept, one or more experiments along with data collection and analysis requirements consistent with the student’s academic level, a discussion of the relationship between the concept and accessible design, exercises suitable for homework or class assignments, resource and reference material, and evaluation rubrics for the exercises and Module.

As such, each experiment module is a self-contained unit ready for inclusion into an appropriate class. The prototype modules allowed a hierarchical utilization of the material starting with a purely phenomenological or introductory exposition of the concepts (suitable for freshmen or introductory level courses), to material that covered increasingly more complex and technologically advanced topics (suitable for sophomore, junior and senior, even graduate-level courses).

One example is the Fitts’ Law Module. Fitts’ law basically says that the bigger and nearer the target, the easier it is to hit. One mathematical expression of this law expresses movement time (MT) as follows: $MT=K_1 + K_2 \text{Log}(2D/A)$, where D is the movement distance, A the target area, with two parameters K_1 , K_2 representing various characteristics of the person, method, and task.¹⁷ In addition to the basic concept and theoretical overview, the Module provides a variety of examples.

Examples of Fitts’ Law can be found in push-button TV and VCR remote controllers¹⁸, and cell phone control button size and placement. Other examples include placing groceries into a shopping bag, inserting an ATM card into the receiving slot, or pulling your car into the garage.

The examples are followed by a number of experiments or demonstrations. One experiment is a pencil and paper task of moving a pencil back and forth between two squares on a piece of paper

for a specified amount of time. At least two situations are presented: 1) two relatively large squares (~3") about four inches apart, and 2) two relatively small squares (~1/2") about 10" apart. The exercise is timed. The task is to move the pencil from square to square as fast and as accurately as possible within the allotted time. One can then count the number of "hits" (landing inside the square) or "misses" and transitions. Knowing the number of transitions between squares and the allotted time one can estimate an average movement time. Students can then display the data in a variety of ways.

The Module contains a discussion on the relationship between Fitts' Law and its implications for the accessible design of products and processes. This information provides the link to accessible design principles. References and background material are provided as well as suggested homework and class exercises. Evaluation rubrics are provided for the homework/exercises expressing educational objectives and assessment procedures.

This Module was field-tested with a variety of students ranging from students majoring in special education with no engineering background, to industrial engineering graduate students. The students majoring in special education experienced the phenomenon, conducted simple data collection and analysis exercises and came to appreciate the importance of the concept. The industrial engineering (IE) students delved much more deeply into the concept, and the assumptions and range of validity of the expressed mathematical models. The IE students conducted more sophisticated experiments based on information contained in the more advanced references provided in the Module.

The Proof-of-Concept's (PC) results to-date demonstrate the viability of developing hierarchical, modular curriculum materials on accessible design principles and issues that can be naturally integrated into a variety of existing courses. The PC results demonstrate that both students and faculty gained knowledge about accessible design and that the integrated material concurrently supported the main educational thrust of the host courses. The PC results demonstrate that the material was very well received by both students and faculty.

Non-Engineering Classes

As noted before, issues related to accessibility for individuals with disabilities span economics, history, political science, anthropology, sociology and a host of liberal arts disciplines. Currently the ETL is working with the technical writing group of the English Department at WSU to develop research and writing assignments that combine technical elements and also incorporate accessibility issues.

Successful integration into these non-engineering areas requires collaboration. Our non-engineering colleagues need to be provided curriculum and background material and support in developing new topic areas within their existing classes. Early collaboration might involve joint grading of research and writing assignments until collaborating non-engineering faculty become comfortable with the new material. ETL experience at WSU has been that non-engineering colleagues understand the need for inclusion of accessible design material, but lack the time to develop such new cross-disciplinary material.

Conclusions

There are very important reasons why undergraduate engineering programs need to include material on accessible design issues and principles. These reasons follow from ethical and market considerations, legal mandates and the associated standards and regulations. The most fundamental reason, however, is that accessible design principles are, in general, good design principles.

The utilization of accessible design principles results in products and services that are accessible to people representing a broad spectrum of abilities. For example, power steering and power brakes render SUVs more accessible to a wider segment of the population. The utilization of accessible design principles encourages new and unintended uses of the products and services. Closed captioning, for example, was originally designed for individuals with a hearing disability, but is now commonly used in health clubs, restaurants and other places where either the noise level is too loud to hear or the TV sound would cause a disturbance. Closed captioning is also used to help people learn a new language. Similarly, the microprocessor stabilizing systems found on new binoculars and cameras expand the utility of these devices. They help stabilize images for all users, whether a fatigued bird watcher or a person with a neuro-muscular tremor.

The inclusion of accessible design principles and issues into the undergraduate engineering curriculum can be accomplished in a variety of ways that complement and leverage the existing curriculum material while also addressing ABET requirements with respect to the inclusion of ethical and social issues ¹⁹. The rate and degree of inclusion can be significantly accelerated with the creation and dissemination of suitable curriculum material. As more people become aware of the issues, needs and benefits, the potential for the creation and sharing of new curriculum material increases.

The Enabling Technologies Laboratory has created a web site for the sharing and dissemination of accessible design curriculum material. ETL's web site is <http://ece.eng.wayne.edu/etl>.

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