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UNIVERSAL DESIGN IN THE TECHNOLOGY EDUCATION CURRICULUM: EXPERIENCES FROM NORWAY

Frode Eika SANDNES and Evelyn EIKA
Department of Computer Science, Faculty of Technology, Art and Design, Oslo and Akershus University College of Applied Sciences, Oslo Norway

ABSTRACT
In recent decades the engineering and technology education curriculum has changed from being purely technical oriented towards being more socially aware. In addition, to adequately master technologies and subsequent technical problem solving, engineers need to be alert to potential social impacts of their work and reflect upon their decisions accordingly. Most engineering studies have included elements of ethics for some time. During the last decade, environmental issues including renewable technology have gained an increasing emphasis. A growing trend is that legislation in various countries requires that the presence of universal design, being it the physically-built environment or the virtual environment, be accessible to as a large segment of the population as possible. These new expectations demand engineers to be aware of the problems and the impact of their work as well as being trained to design with universal accessibility in mind. This paper briefly reviews the phenomenon of universal design, the recent trends in standards and legislation, and how these changes are affecting the engineering profession. Experiences with the inclusion of universal design in engineering education curriculum at several higher education institutions in Norway are provided.

Keywords: Universal design, Design for all, Engineering education curriculum, Social responsibility.

1 INTRODUCTION
The core of engineering education is the learning of mathematics, physics, and technological subjects. However, most engineering study programs also include non-engineering subjects essential for the candidates to practice as engineers. Some examples include economics, project management, and languages. Many engineering subjects also include subjects along the ethical dimension that train students to reflect over the impact of their work and ethical dilemmas. Engineering students need to be aware of how engineers may affect the environment and the society. Both ethics and green subjects are common.

A new trend emerging in engineering education around the world is the issue of universal design [1]. In short, universal design entails that engineering solutions should be accessible to all, or at least, as many individuals as possible. In the built environment, universal design means that individuals should be able to determine where they are, determine how to get somewhere else in the environment, and physically get there. In the digital domain, universal design means that computer solutions should be accessible by all so that all individuals have access to the functionality provided. This is especially important if the society expects all people to use a solution. If we expect all citizens to use a service, the service must also be accessible to all. A common example is the introduction of e-election that can be a threat to democracy if voters are effectively prevented from voting. Issues that cause barriers typically include blindness [2], low vision [3, 4] and contrast [5], motor issues, and cognitive issues such as memory [6], dyslexia [7, 8], and reading abilities [9, 10, 11].

UN Convention on the Rights of Persons with Disabilities [12] defines universal design as follows: ‘‘Universal design means the design of products, environments, programmes and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. Universal design shall not exclude assistive devices for particular groups of persons with disabilities where this is needed.’’

The Centre for Universal Design at North Carolina State University defined the following widely accepted principles [13]: equitable use, flexibility in use, simple and intuitive, perceptible information, tolerance for error, low physical effort, and size and space for approach and use. These general principles apply to both the physical world as well as the virtual world. For the virtual world, the W3C WCAG2.0 guidelines are commonly cited as best-practice [14] for designing web-pages that are accessible to all. The guidelines have four parts, addressing issues related to the human sensory system (computer output), human motor action (computer input), human cognition (understanding), and technical flexibility and interoperability.

Universal design has made its way into the legislation in many countries, and according to paragraph 14 of the Norwegian anti-discrimination law [15], it states the following: ''Information and communication technology (ICT) is defined as technology and systems that are used to express, create, transform, exchange, store, distribute, and publish information, or that in other ways makes information applicable. New ICT-systems must be universally designed. This demand is applicable twelve months after standards or guidelines are available. All ICT-systems must be universally designed from January 1st, 2012. Exceptions can be given by the governing body if there are reasonable reasons. The law applies to ICT solutions that support the ordinary functions of organizations and that are the main solution that targets or is made available to the general public.''

In other words, universal design is not an option, but a legal requirement. Engineers responsible for designing such systems therefore need to have sufficient knowledge, skills, and general competences to ensure universal design.

2 CORE KNOWLEDGE, SKILLS AND GENERAL COMPETENCES

Engineering students, and computer science students specifically, usually design systems with themselves as reference, that is, they design systems that they themselves like. This is problematic since young individuals are commonly at a physical peak of their lives. These students are often more computer literate than the population in general and are therefore also more tolerant of badly designed systems. The foremost learning objective is therefore to make the students realize that they must design for the least common denominator. Next, they need to learn that systems and ideas need to be tested on various target groups and hence they need to acquire basic usability testing skills.

Further, the students require basic understanding of human physiology, including the sensory system, motor system, and cognition as well the consequences of reduced functioning. The fact that human physiology deteriorates with age implies these issues will be relevant for all at some time in the future. Often the students will claim that disability is a narrow specialized subject; a core goal is thus to change and widen the students' perspectives on the issue of disability. For example, if designing an online store that discriminates certain groups because of poor design, the owners of the store will likely lose potential business. By making the store more accessible, the owners will get access to a larger market. In other words, accessible design is both ethically correct and also is a sound practice from a business perspective.

Connected with this is the goal of making students appreciate diversity, that is, to design inclusive systems that embrace diversity, inclusive of neutrality to gender, age, sexual orientation, functioning, political standpoint, cultural origin [16, 17, 18], religion, etc. The goal is to design for self-service and individual freedom that gives citizens in various situations the dignity to manage on their own [2]. A broad perspective on who the users are is thus essential. Diverse student teamwork is one way of learning about teamwork in practice. The personas methodology is another way in which students can explore diversity.

Our aim is to develop a positive attitude among the students where the design constraints become inspiring design challenges with a competition to achieve the best solution. Computer students are often fascinated by achieving near impossible things, being it novel and effective algorithms, making hardware do things it was not meant to, etc. The objective is to tap into these interests.

3 CURRICULAR MODELS

Four models in which universal design was incorporated into the curriculum in Norway were identified, namely: thematic intro seminars or summer schools, integrated model, module based, and specialization. These four models are discussed in the following sections.

3.1 Thematic intro seminar

Bergen University College has experimented with thematic intro seminars for several years. Their scheme has involved first year students from the built environment, computer science, and health sciences. Typically, the seminar is run midway through their first semester from one to three days. The intro seminar comprised general introductory and theoretic lectures from various experts in the field, followed by practical exercises. During one year, the students were organized into multidisciplinary groups consisting of engineering and health science students. Together, they had to simulate various disabilities and then use the public transport system to get from one part of Bergen to another. Initially, the seminar ran for three days, but has subsequently been cut to two and then one day, respectively.

Oslo and Akershus University College has offered an international summer school in universal design and ICT for four years [19]. This initiative can be classified as a thematic intro seminar, but is also partially a module as our summer school is running for longer than the initiative at Bergen University College, viz., three weeks intensive. The purpose of the summer school is to prepare international students for the master program by giving the students the necessary prerequisites needed as curriculum content varies widely across higher education institutions and disciplines.

Generally, the thematic intro seminar is relatively simple to realize as long as one can set aside time in the students' semester schedule. Another benefit is the mixing of students from widely different fields early in their studies.

One problem with the scheme is that the students may fall off and disappear if participation is not compulsory or if there is required or assessed coursework associated with the model. Another issue is that the learning effect may be limited if the content is not reinforced later on in their studies. A one-day or three-day seminar may not be sufficient to imprint good design practices in the students. A final challenge with the model is that it typically involves a small group of dedicated individuals. There is a chance that the other members take a minimal interest in the initiative and the probability that the students will meet the topic later on in the various modules is small.

3.2 Integrated model

In the integrated model, universal design is taught as an integral part of the entire curriculum, where relevant issues in universal design are introduced when relevant in the various courses. There can be special lectures with a special subject. For instance, universal design can be taught in software engineering where students are exposed to a method for software development that embraces diversity. Obviously, human-computer interaction courses can easily be filled with content related to accessible user interfaces [20]. Another example is economy, where the students can be aware of the legislation governing purchasing and tenders.

This is probably the best way to include universal design into the curriculum since all the students are exposed to the subject of universal design. Moreover, the various aspects of universal design are placed in relevant contexts in the various modules, which helps promote learning. Next, the integrated approach is likely to enhance learning as the students encounter universal design at several stages of their study.

The authors are unaware of any bachelor programs that fully employ the integrated model. Oslo and Akershus University College of Applied Sciences has partially landed on the integrated model because many faculty members are actively involved in universal design research and dedicated to universal design principles. There are therefore traces of universal design in several of the courses on offer for the computer science students.

Unfortunately, it is hard to realize the integrated model for the same reason as it is hard to integrate ethics and environmental issues in the curriculum. The model is dependent on the faculty being familiar with universal design and also interested in universal design to some extent.

3.3 Module based

The module-based approach is probably the most common in Norway because it is the easiest to realize. In this model, the topic of universal design is introduced in either a compulsory or optional course. This allows the students to get some in-depth knowledge on the topic. It requires only one, or very few, faculty members to have universal design competences. This model is employed at Oslo and Akershus University College of Applied Sciences and at the Norwegian University of Science and Technology, Gjøvik campus.

At Oslo and Akershus University College of Applied Sciences, there is a 10 ECTS course in universal design for the computer science students [21], which runs in the third year of the bachelor programs. The Norwegian University of Science and Technology, Gjøvik campus, offers a more general 15 ECTS distance learning course on universal design that focuses on the built environment [22].
A challenge with the model approach is that bachelor programs, especially in engineering, often have too many constraints and little flexibility for courses that are a bit off the beaten track of the core engineering courses [23]. At Oslo and Akershus University College of Applied Sciences, the universal design course is only optional for the computer engineering students, while compulsory for the non-engineering computer students. Some students decide to opt for different modules and end up not taking this course. Consequently, they will have gaps in their knowledge.

3.4 Specialization

The last model described herein is universal design specializations. Oslo and Akershus University College of Applied Sciences developed an international master program in universal design and ICT [24]. It is a 120 ECTS master program, that is, two years of full time study. The course comprises six 10 ECTS courses on various related topics including introduction to universal design, ICT barriers, academic writing, research methods, advanced interaction design, globalization, intelligent user interfaces, and a 60 ECTS individual project which runs over the last three semester with a build-up from 10, 20, 30 ECTS for the respective semesters to ensure that the students develop feasible and relevant projects.
One benefit of running a specialization in universal design is that students do get an in-depth knowledge on the topic. Also, the applicants will hopefully be more motivated to study the topic and have ambitions to secure a career as a universal design and accessibility expert. The drawback of this approach is that only the students who decide to study this specialization acquire this knowledge.
As indicated above, the bachelor students get some insight into universal design through the various bachelor modules, potentially also serving as a recruitment platform into the master specialization program.
Signals from the Ministry of Education and Research indicate that master programs are to become less specialized and more general. It remains to see if master provisions are instructed to widen the scope of the program.

4 EXPERIENCES

The Institute of information technology, Oslo and Akershus University College of Applied Sciences, has deployed a strategic investment in universal design. One of the obvious and immediate benefits experienced is improved gender balance. At the master specialization in universal design, it is close to equal gender balance, while the bachelor programs in engineering are male dominated. Our non-engineering computer bachelor programs have a higher ratio of females than the engineering disciplines. One explanation for the improved gender balance achieved with universal design is that the goal is to help individuals specifically and mankind in general. This is a noble goal. On the other hand, plain engineering is often driven by a sole interest in the technology.
Another effect of the strategic investment in universal design is more multidisciplinary staff and students. Universal design is itself a multidisciplinary field that tangents many subject areas from sociology, health science, and engineering. Experts from all these areas increasingly have to work together in the future in order to solve the challenges of the ageing population.
However, could the increased multidisciplinary tendencies be a problem? Is technology education facing a social science creep? There is undeniably a dichotomy between the technological versus the human perspectives. In addition, there is an increasing number of faculty members with backgrounds from social science and other non-technological fields. Although the phenomenon surrounding universal design is interesting in their own right, they should not draw attention from the core issues of technology as society have a need for newly graduated engineers with a technological inclination capable for difficult technical problem solving.
Another experience is that faculty members drawn towards universal design often have a personal stake either being disabled themselves or with disability in their own family. The question is whether this is an advantage or disadvantage. On one side, these individuals have first-hand experience and knowledge. However, the phenomena associated with universal design are wide and personal experience is not likely to suffice. A further issue is that of neutrality and balance. Will a person with a

certain personal standpoint be able to handle the subject matter neutrally? In addition, the over-focus on one type of disability may draw attention away from the wider perspectives of diversity such as gender, sexual orientation, cultural origin, etc.

Although universal design has been around for several decades, it is challenging to find faculty members with updated knowledge. Finally, the most challenging aspect experienced is that it is hard to recruit students for the master specialization.

5 CONCLUSIONS

This paper addressed the universal design competences of engineering students in Norway. Four models of incorporating universal design into the curriculum were discussed, namely, thematic intro seminar, integrated model, module based, and specialization. Based on our experience so far, it seems that an integrated approach is probably the one that will help all the engineering students to acquire some knowledge of universal design. Moreover, the integrated model allows the students to see the universal design in context. The fact that they encounter universal design several stages in different contexts is likely to reinforce learning. A challenge with this approach though is that a majority of the faculty members would need some competences and interest in universal design.

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