Teaching Universal Design – How and Why

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Abstract: Universal design is a product design philosophy that strives to give freedom to all; the freedom of mobility, the freedom to work, to enjoy entertainment, and to use ones' physical and mental abilities without encountering unnecessary barriers. Software design in higher education should focus not only on technology, but on people, psychology, learning theories, attitudes, empathy, and demography. Students must learn to understand that people differ widely in physical and cognitive ability, and computer literacy. This paper describes a third year bachelor course in Universal design at Oslo University College (OUC) in 2008.The course was student-driven. Student assistants gave assignments and acted as supervisors under the guidance of a professor. Experts were hired as guest lecturers. Project groups of 2-4 students defined design problems, and created solutions using prototyping techniques with active user participation. Testing was performed with personas and real users. Test persons were fellow students, and users from organizations for the deaf, blind and Parkinson's disease (PD). There were many interesting and innovative project results. One of the projects evolved into a larger research project.

1. Introduction

Universal design is not primarily a technological challenge, but an approach to understanding how people use information systems, and to design products and services that are user friendly, accessible and aesthetically pleasing. However, there is still little knowledge on Universal design in the software industry. There is therefore an increasing demand to incorporate Universal design into the computer science curriculum.

Although many software systems can be accessed with screen readers, they come with huge, illegible user manuals. Programs behave in inexplicable ways, causing frustration and time-loss. Company policy in industry, health care and education leads to the purchase of computer systems that employees end up hating, and sabotaging if possible. Buildings may be accessible for wheel-chair users, but contain innumerous switches labeled ‘This is a light switch’, or ‘This is a door switch’. Door opening schemes are confusing. We are surrounded by serious design failures.

One third of the population has difficulties reading an ordinary text, to such an extent that they have trouble mastering daily life, for instance reading public information (OECD). Illiteracy and language problems are common. Autism, Down’s syndrome, dementia, dyslexia or learning difficulties lead to cognitive problems. Traumatic brain injury is a major cause of disability worldwide, especially in children and young adults (Parikh). People are growing older. Statistics show that up to 25% of the population has some kind of disability, permanently or temporarily. A course in universal design should touch on all these aspects.

As one cannot provide a quarter of the population with assistive technology or special solutions, it is necessary to start planning for inclusive technology. How to create a workplace for users with diverse needs must also be part of a course in universal design. Since there are hardly any jobs in modern society that do not involve the use of computers, it is vital to move away from a workplace dominated by a desktop computer and inefficient, hard-to-use software. The costs of repetitive strain injuries are high. There will be an increasing demand for flexible tools and workplaces, mobile solutions, and accessible, user-friendly software. The proof of good software design is when a program or a device is ‘invisible’, when the user does not realize that he or she is using a computer (Norman).

2. Background

Universal design is defined as the concept of designing all products to be aesthetic and usable to the greatest extent possible by everyone, regardless of their age, ability, or status in life. Universal design of ICT should be regarded as an ideology, rather than a set of guidelines and principles for designing accessible web-pages and usable technology for the disabled. NTNU and the University College of Gjøvik have courses in Universal design, but these concentrate on the built environment and transport. The course at OUC is the first in its kind in Norway where Universal design of ICT is included in the computer science curriculum. Focus is placed on changing attitudes. Unless corrected, students will design systems that primarily satisfy their own ideas, instead of the real needs of diverse users.

The initial course in universal design at OUC is described in (Ribu). Here, focus was mainly on developing accessible web pages. The second course described in this paper was broader in its approach, defining ‘ICT’ as all digital products and services like ticket machines, digital transport systems, ATMs, mobile phones, Internet banks, software and web-pages.

The motivation was the Norwegian Discrimination and Accessibility Act from 2009, and the observation that people experience enormous frustrations with computer systems. Due to lack of knowledge and the belief that designing for all means added costs, the attitude towards universal design in industry is one of skepticism and resistance. Users still have to put up with badly designed software with invisible menus, cryptic naming schemes and inconsistent labeling, ticket machines that are hard to use, web-pages with mysterious navigation and user manuals with horrendous language and grammar. This will hopefully change when designers with a different attitude enter the field of software development.

Students of computer science are so familiar with technological devices that they often fail to recognize the problems ordinary users are faced with. The goals of this course were to enhance the students' reflection, independent thought, social awareness, empathy and respect for diverse users. As there is no suitable text book on Universal design, resources were found on the Internet (Stephanidis) (Hendrix), in addition to selected texts from the Google version of 'The Inmates are Running the Asylum' by Alan Cooper, a warrior for the inclusion of interaction design in software development (Cooper). Other resources were the guidelines of the Delta centre, WCAG 1.0 and 2.0, and the Web Accessibility Toolbar, WAT.

3. Pedagogical Techniques

Universal design is in its nature a question of democracy and ethics. Two basic tools in the pedagogical strategy are the principles of Universal design, and the IEEE code of ethics. These guidelines, along with WCAG, are rather general, but can serve as an inspiration for reflection and discussions in class.

3.1 Language and terminology

Students of computer science are often not very good writers. They tend to adopt the complicated and confusing style of texts and user manuals found on the Internet, with contents difficult to understand because of inconsistent language and unfamiliar terminology. Stress must therefore be placed on accurate language and a consistent style of expression. A requirement for the project report was unambiguous language with straightforward sentences, in order to encourage an awareness of how to convey a meaning in a clear and concise form.

The use of terminology must be discussed. The term 'intuitive' is misleading, and should be avoided. All too often, students and developers claim that the user interface is 'intuitive', without defining if or how this can be measured, thus implying that human 'intuition' or emotion suffices, and that training is not necessary. A better term is ’familiar’. Users gradually become familiar with the workings of a computer program and recognize navigation schemes and features. This learning is later transferred to other programs. Finding examples of unfamiliar and inconsistent program behaviour is a good exercise. Google mail provides an illustration of the problem. A pause in writing an e-mail leads to the prompt: ‘Draft has been modified. Abandon changes?’ Other programs ask if the user wants to save changes. Also, the words ‘modify’ and ‘abandon’ are unusual. Familiarity is lacking. As a result work can be lost.

Misunderstandings may be caused by the ambiguous word ‘design’. From a software developer’s perspective, design means ‘program design’ or code, and maybe UML class diagrams. Graphical user interface design is regarded as a ‘layer’ on top of the program. However, interaction design is not so much the graphic design of an interface, as the understanding and implementation of the workings of the communication between user and software. The word ‘interaction’ itself is difficult. People use computers, they do not see themselves as are not engaged in interaction. Expert terminology should therefore be used with caution, and avoided when communicating with users.

3.2 Exercises

Learning to understand different cultures and other peoples’ needs takes time and demands reflection and imagination, so the course started off with a few exercises to clarify some important points.

The first task was to define the class as a group, and reflect on whether it was heterogeneous or homogenous. The 60 students constituted a small and not very representative selection of the population in Norway, being for the most part white, middle-class young men between the ages of 20 and 25.

The second exercise was to find examples of computer illiteracy amongst friends and family. Statistics were presented showing that about one third of the population is print-disabled, meaning either dyslexic or having serious trouble reading an ordinary written text. Several examples of this kind lead to a discussion which revealed that many students knew one or more people with a chronic illness or disability. Some of the students were themselves dyslexic. In this manner it was established that statistically it is just as normal to for instance have poor eyesight as being a student of computer science at Oslo University College.

Surfing the web with only a keyboard and taking a lift blindfolded were enlightening exercises. A popular task was to find really bad examples of web-design. Webpagesthatsuck.com provides hilarious examples.

Here lies the clue to success: Understanding how to make things work well is satisfactory. Design is fun!

3.3 Course organization

The course consisted of lectures, exercises and project work. Focus was on user centered design; prototyping with user participation. The students conducted interviews, made observations, and recruited testers amongst fellow students and from organizations for the disabled. Testing was conducted in friendly and secure environments. Instructions were given on professional behaviour. Data gathering and storing was performed according to the Personal Data Act.

Seven of the top students were involved actively as assistants. Students benefit from collaborating with and receiving instruction from their peers (Biggs). The assistants formulated the project task and supervised the project groups, in addition to their own project work.

Resource lectures were given on the following topics by various experts:

- Introduction to universal design, digital divides, usability and accessibility.
- Accessible web pages.
- Universal design for the visually impaired. Eye diseases and human sight.
- Universal design of ICT based on experience from diverse user surveys.
- Universal design and assistive technology. A demonstration of technologies.
- User-centered design. Interviews and observation techniques.
- Text size on the web.
- How do the blind surf the Internet? A demonstration of tools and techniques.
- Principles of accessibility, with special focus on users with cognitive difficulties. Testing accessibility with personas.

4. The project task

The project was divided into three parts: Definition of the problem or problem domain, development of prototypes, and testing and evaluating the solution. The assignment text was:

4.1 Part 1. The Problem

'Identify an existing problem related to a digital product. Describe the problem with regard to Universal design principles. The problem can be related to a certain product, a type of product or problem domain. Examples: Not enough contrast on information screens, or the difficulties people with disabilities have using ATMs or ticket machines. Refer to lectures on these topics.

4.2 Part 2. The Solution

Find a solution to the defined problem based on course theory. Use prototyping techniques and iterative development.

4.3 Part 3. Method and results

Test the prototypes, evaluate and analyze the results. Repeat the process until you are satisfied with the product. User testing should be conducted with personas and real users. Define a representative selection of users. Let users with disabilities test your prototype if possible. Summarize, reflect on the development process and write a conclusion.

Hint: The focus is on observation and evaluation. Write a clear and concise report. Use simple, straightforward sentences.'

Duration of the project was 2 months, with an estimated three weeks work on each part.

4.4 Project solutions

The task was to either improve an existing design or create a new design. The students defined the following problems:

1. Norwegian State Railway - NSB – Ticket vending machine (4 project groups chose this project).
2. Accessible form and colour: Painting software for people with motor disorders
3. iFinger – an alternative to the computer mouse
4. A payment terminal for everybody
5. A mobile phone for the elderly
6. Universal Design Wizard for Windows XP
7. Emergency phone for the deaf
8. Transport information system for the visually impaired
9. Internet bank solution for all
10. ATM for everybody
11. Universal Internet forms – based on guidelines specified in the ELMER-project (elmer.no)
12. Daily shopping for everybody
13. Talking lift for the blind

4.5 Examples of project solutions

An outline of three of the most innovative projects are presented here: 'NSB –

Ticket vending machine', 'Accessible Form and Colour', and 'iFinger'. The text selections are taken from the project reports and have been shortened and modified to show different aspects of the project work: Problem description, prototyping work and testing.

4.5.1 Project 1: Ticket Vending Machine: The Norwegian State Railways, NSB.

'The Problem: Many diseases affect human sight, for instance Macula degeneration, Diabetis retinopati, Retinis pigmentosa, Cataract and Glaucoma. These diseases cause the visual field to grow smaller. NSB's ticket machine spreads information all over the screen, and visually impaired users may not realize that there is more information on the screen, and that they must shift focus to see it.

Parkinson's disease (PD) affects the nervous system. Symptoms are rigidity, tremors, hypocinesis (reduced motion), postural instability (balance problems), and gradually reduced cognitive abilities. Tremor makes it difficult to hit the right button, and the screens are complex, presenting many choices. Complexity leads to stress, which again increases the problems of tremor and rigidity.

The solution: The task is to uncover the challenges visually impaired people and users with PD have trying to buy tickets. The goal is to design a prototype for a new NSB ticket machine, accessible to as many users as possible.

Method: Prototyping and iterative development with Power Point, based on the results of a questionnaire. User interviews were performed at Oslo Central Station. Testing and developing the prototype on the grounds of feed-back. Test persons are visually impaired and people with PD.

Result: The prototype was made with larger buttons and less overall complexity. A problem with the existing machine is its sensibility. PD users experience too much double clicking. Sticky keys will improve usability. The screen saver is modified, a big button with an arrow invites to pressing the screen. On the next screen, the user chooses the type of ticket to buy. All tasks are collected in one column, in order to improve the solution for users with a small field of vision. This is an improvement for all users. The 'return ticket' button is gone, and the need to group buttons has thus been eliminated. Ticket categories are reduced to three: 'Ticket', 'Periodical ticket' and 'Pre-ordered ticket'.

4.5.2 Project 2: Accessible Form and Colour

Problem: Everybody has a desire to communicate with other people. It is often beneficial to express an idea with a simple illustration. This may be difficult or impossible for the physically disabled.

Solution: The motivation was to enable people with a low grade of motor capacity to express themselves with the aid of a digital painting tool. Existing tools enable the production of text, but graphic tools like Photoshop, Painter and Power Point are used with a mouse or pen, have too many menus and levels, mouse and keyboard functions that cannot be used without hands, and small buttons and icons for clicking. We will design a simple user interface for a painting tool with a broad range of users in mind, but with the main focus on people with physical disabilities, maybe lacking the use of limbs.

Method: Iterative development of a low fidelity prototype. Test persons have little experience with computers, and ideally experience from 'foot- and mouth painting'. The prototype is designed as simple screen shots presented either on paper or on a computer screen. Testing will be performed with head mouse and eye tracker. Users must have basic understanding of and experience with drawing.

Result: A Prototype covering basic features like mixing colours, drawing lines, colour fill and undo action. Testing of early prototypes will be performed using personas paralyzed from the neck down. The persona does not need to have former experience with digital programs. Real users will test the later prototypes.

The solution is inspired by drawing programs for children, where there are fewer menus and the ability to co-ordinate movement does not play an overall important part. Four principles of layout are considered: the principles of importance of features, frequency of use, function and sequence of use.

Buttons are big and round, because round forms are easier to perceive than square. They are three-dimensional, which makes them protrude and create affordance, since buttons are pushed. When the user focuses or clicks on a button, text appears to explain the tool. With eye-tracking it is easy to lose focus on the text, therefore the text field clings to the button. Icons are metaphors for traditional tools like a paint brush, similar to icons found in other programs, and therefore familiar.

Feed-back from testers proves that the low fidelity prototype gives a good illustration of how the user interface of a paint program for the physically disabled can be designed.

4.5.3 Project 3: iFinger

Problem: The problems users with Parkinson's disease have related to the use of ICT. PD affects people in different ways, and it is therefore difficult to make the same technology work for all. One of the main problems for this user group is tremor and rigidity. We have therefore focused on creating an alternative to the computer mouse.

A questionnaire will not help to uncover the problems for this user group, so it is necessary to recruit users to test the prototypes. The testers will be observed and filmed in order to observe movements, and define which movements are the easier to perform. The tests will consist of making simple drawings like straight lines and circles using both a normal mouse, and the prototype. The results will then be compared.

Method: Further development of the existing prototype ‘iGlåv’ – a visual navigation tool in the form of a glove with infrared diode that registers ‘clicks’, used with a low budget touch screen scheme where the Nintendo Wii control is connected to a computer containing the software Wiimote Smoothboard. The computer screen is projected onto a wall or table, and the user can click on the screen directly. Testing is done with personas, and with real users.

Results: One of the first ideas was to use a single finger instead of the glove. This makes it easier to use the prototype with different fingers, or with the other hand. It is also much easier to put on than a glove, an important consideration, since people with PD have motor system disorders. The prototype was named ‘iFinger’.

Prototype 1: Low fidelity’ iFinger ‘made of cardboard with small battery and a button for clicking. The button gives good affordance. Testing with personas.

Prototype 2: Low fidelity ‘iFinger’ without the button. The goal is to find the ideal position for the diode. Observations of how personas testers press different areas of the iFinger.

Prototype 3: High fidelity prototype: An ‘iFinger’ made of a soft material with a battery fastened to it, with the electronic components on the outside of the prototype, and a better diode. Testing was done with real users. After the tests, there was an open discussion about the prototype and the tests. The results showed a marked better control of the iFinger prototype than a mouse.

5. Evaluation

The main object of the practical part of the course was learning by doing, using prototyping and continuous user testing and feed-back. There was no final written exam, the project reports, presentations and demonstrations of prototypes were evaluated and graded. Grades were given from A to C.

It is fairly easy for an experienced instructor on a course of this size to detect if students are doing the required work. Project groups or individual students could, if considered necessary, be examined orally in order to establish the final grades.

6. Conclusion

The main goals of the course were to change attitudes and enhance understanding of the demands of diverse users. The methods were resource lectures, practical exercises, prototyping and user testing with personas and real users: fellow students and people with disabilities. The projects showed great variety and technological imagination. Designing prototypes in cardboard, paper and on screen was perceived as good fun. Satisfaction was great when the prototypes and solutions worked well. User feed-back gave inspiration to new ideas.

After completing the course, the students were equipped with some theory, a few techniques and quite a bit of experience, and reported a deeper understanding of the complexity of accessible design for all. They were aware that creating universally designed systems is more than constructing web pages according to WCAG, it is a complex strategy of creating accessible, user friendly systems with meaningful content applying a variety of techniques.

Interestingly, the 'iFinger' project evolved into a larger project named PIPPI - Projected Interactive PC-controlling Pilot solution- through the co-operation with the company MediaLT, and received funding from the Norwegian Research Council. The pointing device of the pilot solution was developed further by students of Product design at Akershus University College, who created a 'diode-finger' prototype for the touch screen. The Akershus University College student collaboration is ongoing, with the aim of developing a market-ready PIPPI solution. Future collaboration with the department of Product Design will grow as the two university colleges now are in a process of merging into one.

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