

Techniques to Assist in Developing Accessibility Engineers

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ABSTRACT

This paper describes techniques used in a recent computer science course designed to develop accessibility engineers. It provides sufficient detail for other instructors to replicate the highly successful experience that resulted. It also discusses a number of results of the course that act as indicators of its success.

Categories and Subject Descriptors

D.2.1 [Software Engineering]: Requirements/Specifications - *methodologies.*

D.2.2 [Software Engineering]: Design Tools and Techniques – *user interfaces.*

H.1.2 [Models and Principles]: User/Machine Systems – *human factors, human information processing.*

H.5.2 [Information Interfaces and Presentation]: User Interfaces – *auditory, ergonomics, evaluation/methodology, haptic i/o, input devices and strategies, interaction styles, natural language, screen design, standardization, style guides, training, help and documentation, user-centered design, voice i/o.*

K.3.2 [Computers and Education]: Computer and Information Science Education – *computer science education, curriculum.*

K.4.2 [Computers and Society]: Social Issues – *assistive technologies for persons with disabilities.*

General Terms

Design, Human Factors

Keywords

Accessibility, assistive technology, universal access, universal access reference model, usability, user-system model.

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1. INTRODUCTION

It is nice to have an awareness of accessibility needs and solutions, but it is far more important to put this into action. That is the basis of a new course at the University of Saskatchewan. CMPT 480/840 *Accessible Computing* focuses on producing Accessibility Engineers. It helps students from diverse backgrounds (with a wide range of motivations – but with at least a reasonable background in computing science) to discover their own approach to integrating accessibility concerns within the development of mainstream computing applications and systems.

While the course presents students with a comprehensive survey of user needs and accessibility issues, it recognizes the importance of developing an “engineering” approach to the application of accessibility principles and technologies to particular development activities for actual products and systems.

This engineering approach incorporates consideration of the importance of using methodologies and methods to ensure that user requirements are met. A methodology is a high level structure of individual methods that guides development throughout the life cycle of a product or system (from the initial identification of a need for a new or improved product or system, through its development and use, to its final replacement or retirement). Methods specify the means of combining and applying research and experience to one or more life cycle activities.

This course situates accessibility engineering within the family of engineering practices already developed within information technology.

- **Systems Engineering** deals with general methodologies and methods for use in the development of all types of information technology systems [18].
- **Software Engineering** deals with general methodologies and methods for use in the development of all types of software systems [17].
- **Usability Engineering** deals with specific methodologies and methods for use in the development of user interfaces to all types of systems [12, 13, 14]. Since users generally interact with a combination of hardware and software, it needs to deal with both systems and software engineering.
- **Accessibility Engineering** deals with specific methodologies and methods for use in the development of all types of accessible systems. ISO 9241-20 [10] and ISO 9241-171 [11]

define accessibility as “usability of a product, service, environment or facility by people with the widest range of capabilities”. This ties the emerging field of accessibility engineering to usability engineering, and through it to software and systems engineering.

2. THE PARTICIPANTS

The January 2007 version of CMPT 480/840 involved one instructor, one teaching assistant, and nine students.

The instructor is a professor of computer science and the head of the Usability Engineering Research Lab (USERLab) at the University of Saskatchewan. He is the co-developer of the Universal Access Reference Model [4], the editor of ISO/IEC TR 19866 *Guidelines for the design of icons and symbols accessible to all users, including the elderly and persons with disabilities* [21] and the co-editor of ISO 9241-20 *Accessibility guidelines for information/communication technology (ICT) equipment and services* [10] and of ISO/IEC 24756 *Information technology – Framework for specifying a common access profile (CAP) of needs and capabilities of users, systems, and their environments* [19].

The teaching assistant is a graduate student in computer science and a member of USERLab, who took a previous version of the course three years before. His participation in that previous version of the class led to the development of the Universal Access Reference Model [4]. The teaching assistant is the editor of ISO/IEC 24756 [19], which is based on his master’s thesis research. He is also hard of hearing. In addition to leading the lab exercises (the Accessibility Demonstration Experiences), he participated in the class sessions along with the other students.

The course was made available in January 2007 as a special topics course to both senior undergraduate and graduate students. (It has since been approved as a regular offering of the Computer Science Department for undergraduate and graduate students.) The prerequisites have remained relatively open, focusing on an advanced standing in computer science rather than on particular courses.

In January 2007, four graduate students and five undergraduate students took the course. Reasons for taking the course varied considerably between students. One student was blind and one student had a brother with cerebral palsy. Four students recently came from countries where English was not their first language (i.e. from China and from Finland). While the majority of students were interested in human-computer interaction or usability engineering, one undergraduate student chose it because she had a lack of proficiency in technical English and one undergraduate student chose the course as an alternative to taking an advanced algorithms class.

3. THE TREATMENT

3.1 The Methodology

The course starts from the perspective that we all have many disabilities. By accepting disabilities as normal to the human condition, we make the provision of accessible systems equally normal. Thus, it is recognized from the start that accessible design is good design, and that it should be the norm rather than the exception. The course also makes use of the Universal Access Reference Model to recognize that identifying and removing

barriers to communications is more important than assigning the blame for these barriers [4].

The course topics follow an engineering life cycle approach, building knowledge and understanding systematically. They follow a simplified life cycle approach from problem identification, through analysis, to design and construction. Rather than relegating evaluation and testing to a single stage late in the life cycle, the course includes evaluation throughout the life cycle.

The course takes an active learner-centered involvement approach in the class sessions, the lab exercises, and the project. By focusing more on student activities than on traditional lectures, it should be easier for other instructors to reproduce successfully.

The emphasis of class sessions is on students critiquing and discussing a variety of research papers and international standards. Student critiques go beyond recognizing existing knowledge, requiring them to identify important challenges (problems with what the papers suggest) and opportunities (omissions that the papers failed to include). Prior to the first class of the week, students are expected to read the main paper for the week and to submit a critique containing five challenges and/or opportunities. The instructor then uses the best critique items as the basis for the week’s discussions. The use of critiques is discussed further in the following section. Additional papers are provided to reinforce topics to be discussed for the week.

The lab component provides students with a range of first hand experiences via the set of USERLab Accessibility Demonstration Experiences (ADEs). Each ADE introduces an accessibility issue (set of barriers to the abilities of individuals to access various forms of information technology) or option (strategies and technologies for meeting the needs of users with specific partial or full disabilities, combinations of disabilities, or barriers resulting from the user’s environment). Each ADE is intentionally kept short enough to leave students wanting to know more. Most ADEs also provided suggestions for further readings and research that students could use to satisfy their desire to know more and/or to help create the basis of a class project. These ADEs are further discussed later in this paper.

The projects expect students to research and apply some aspect of Accessibility Engineering at a level more advanced than that covered by the main portion of this class. The requirements and methods of class projects are discussed later in this paper.

3.2 Critiques and Their Discussions

Critiques are very important for the class, since they form the basis of most course discussions. Each critique deals with the primary reading for that week. Critiques are not book reports or summaries of a paper. Creating good critiques requires students to thoroughly understand the paper being critiqued, to identify the important concepts in the paper, and, most importantly, to go beyond what it contains.

Critiques involve identifying and discussing at least five major challenges and/or opportunities (critique items) arising from the paper.

- **Challenges** identify portions of a paper where significant improvements (e.g. further discussion and/or consideration of an alternate viewpoint) should be made.
- **Opportunities** identify omissions from a paper where significant additions (e.g. of topics not discussed but that

should be included in a discussion of this area) should be made.

Each critique item is formatted to:

- **Identify** the challenge or opportunity. It is expected that identification involves:
 - a meaningful self-descriptive name for the challenge / opportunity,
 - a brief elaboration / discussion of what is involved, and
 - information about the location in the paper where the challenge / opportunity occurs.
- **Explain the significance** of the proposed addition or improvement. Students are expected to determine the significance and specify its affect on the success of applying this information in performing Accessibility Engineering. It is important for critiques to go considerably beyond just dealing with editorial issues such as grammar, spelling, or any changes that could be made by just adding a few words. It is expected that the discussion of significance involves a good reason why this challenge or opportunity should be discussed in class.
 - Challenges can be significant if they pose risks to the technical information in understanding of the readings or if the student has strong grounds to disagree with major points in the reading.
 - Opportunities can be significant if they involve omissions that need to be explained for someone to be able to understand the readings.
- **Suggest what should be done** about this challenge or opportunity. This should be the starting point for a discussion in class. It is expected that suggestions include a summary of what the student thinks about or needs to know about this challenge or opportunity. Students are encouraged to provide particular references to support their suggestions.

Critiques are e-mailed to the instructor the night before the first class of the week. Each critique item is marked out of a maximum two points and the marks of the five best (if more than the minimum five are submitted) are recorded as the mark for the critique (out of a maximum of ten points). (Thus, students are encouraged to include more than the required minimum of five items). The following criteria are used in marking individual critique items:

- 0 points – for missing or irrelevant discussions
- 1 point – for incomplete or weak discussions
- 2 points – for very good to excellent discussions

In addition to this marking, all 2 point critique items are evaluated to see whether they are suitable as the basis for class discussion. The suitable critique items are considered 2+ items. A record of the +'s obtained by each student is kept as a partial indication of the student's contributions to the class.

Once marking is completed, the instructor consolidates all of the 2+ critique items for use in class discussions. The actual method of using these items evolves throughout the course, helping students to deepen their involvement in the discussions and with the materials being discussed. As the course progresses, less and less detailed information is used to start the discussions.

In early weeks, the complete text of 2+ critique items is presented to the students in class and volunteers are asked to comment. Usually, the most comments come from the author of the critique item.

After a few weeks, only the suggestions from the 2+ critique items are presented to the class and students are expected to take turns (e.g. based on their seating arrangements) discussing items in the set, so that all students participate in the discussion. This has the added benefit of providing models of good critique items to other students.

By the middle of the course, students are only provided the meaningful self-descriptive names of critique items written on individual cards that they randomly draw. Turn taking is now based on a sequence number that is indicated on each card.

Towards the end of the course, the instructor replaces individual critique items with questions that help consolidate ideas from individual critique items.

The emphasis of discussions of critique items is on developing informed, critical thinking skills relating to Accessibility Engineering within the students. Therefore the amount of comments made by the instructor and teaching assistant should be limited to introducing major discussion points missed by the students. The instructor's role is to focus more on integrating student points and on steering the discussion than on lecturing to the points for the primary reading.

Each week also has one or more secondary readings that can supplement the reading assigned to be critiqued. Ideally the students should read and consider these readings. However, from a practical standpoint, it is recognized that most if not all of their reading time for the week will focus on the primary reading. Thus, it remains to the instructor to provide a short summary of any main points in these secondary readings that have not been covered. Depending on the extent of discussions on the critique items, there may be little time to present this summary.

3.3 The Weekly Topics

3.3.1 Week 1 Introduction to Accessibility Issues

The goal of Week 1 was to recognize that we all have disabilities in some aspects of our life and that these disabilities may hinder accessibility to certain aspects of life. Achieving this goal involved: identifying our own disabilities and needs, accepting the disabilities and needs of others, and developing an initial approach to accessibility.

We specifically avoided any attempt to limit, prioritize, or evaluate the set of disabilities claimed by people. In this way, we recognized that all of us have some disabilities and that what really matters is to identify barriers we have that prevent full access to some aspect of life due to designs that require abilities that we do not possess. By expanding our set of disabilities far beyond those that are recognized in approaches such as US Section 508 [34], we were able to have all participants recognize that providing accessibility is more than just an accommodation – it is a fundamental expectation of appropriate design. In this way we also avoided providing artificial boundaries on accessibility, opening up the course to investigate all aspects that could contribute to greater accessibility. We also avoided any tendency to argue “my disability is more important than yours”.

3.3.2 Week 2 Universal Accessibility

The goal of Week 2 was to go beyond consideration of the needs of individuals and recognize the needs and implications of achieving universal accessibility.

Since we had already achieved consensus on the importance of universal accessibility, we focused on some of the major issues identified in student critiques of Stephanidis' paper on "From User interfaces for all to an Information Society for All" [31]. These included considerations of:

- how dialogue abstraction and design patterns can be used to separate between communication needs and media specific implementations of communications (an analysis issue),
- tradeoffs between platform independent solutions and platform specific solutions (a design issue),
- the potential for using information about user abilities, preferences, and needs in customizing interaction (a design), and
- the extensive range of user testing needed to ensure accessibility to the widest possible range of users (an evaluation issue).

By containing a range of issues relating to various activities in a systems development life cycle, this discussion was used as a general introduction to the need for considering analysis, design, and evaluation in accessibility engineering.

The class then discussed a critique prepared by the instructor on Keates' paper on "Pragmatic research issues confronting HCI practitioners when designing for universal access" [25]. This discussion both served to consider another introductory point of view and to provide students with a concrete example of the level and style of critiquing that was expected of them.

3.3.3 Week 3 Sensory Limitations

Week 3 started detailed treatment of analysis related issues. The goal of this week was to gain an understanding of the major types of disabilities that are typically considered within the scope of accessibility concerns. We investigated the needs of individuals with visual, auditory, and physical disabilities by discussing one research paper and a summary of user accessibility needs.

Considerations coming from student critiques of Jacko's conceptual framework for individuals with disabilities [23] included:

- moving away from medical issues to abilities and disabilities,
- differences between models, profiles, and individual needs,
- matching abilities to tasks,
- conflicting needs in multi-user environments, and
- the need for development methods to satisfy differing user needs and capabilities.

A discussion of ISO/IEC JTC1 SWG-Accessibility's *User Needs Summary* [16] (that originally focused on supporting the development of accessibility standards) led to recognizing that:

- there is an extremely large number of user needs to consider to achieve universal accessibility, and
- even comprehensive sets of user needs (such as the one discussed) may miss some user needs, and thus the analysis for

a project should be sure to investigate the actual needs of its intended users, not just adopt a predefined set of needs.

3.3.4 Week 4 Methodologies for Providing Accessibility (Part I)

Week 4 started investigations of how accessibility considerations can be integrated within various types of systems/software development methodologies. It focused on an example of a process-oriented methodology and on the use of principles in providing high level guidance to development and evaluation.

Considerations coming from student critiques of the Canadian *Accessibility Domain Architecture* [8] included:

- the difference between providing accessibility as part of design and needing to provide accommodations to overcome design limitations,
- the importance of operating systems providing accessibility features that can be used consistently by multiple application programs,
- the difference between providing multiple formats and providing flexible formats, and
- going beyond presenting content accessibly to make all navigation and interaction accessible.

The strengths and weaknesses of using principles to guide development [9] were also discussed.

3.3.5 Week 5 Methodologies for Providing Accessibility (Part II)

Week 5 continued investigations of ways of integrating accessibility within systems/software development methodologies. It focused on examples of model-based and forms-based methodologies.

Considerations coming from student critiques of the Universal Access Reference Model [4] included:

- the effect of the environment / context of use on accessibility,
- the use of shared context in helping to make communications accessible,
- the effect of interactions between interaction channels (including multiple channels that make use of the same modality) on resulting accessibility, and
- the difference between a user's preferences and a user's needs.

Discussion of a forms-based approach [29] recognized that extensive documentation does not guarantee that resulting systems will be accessible, only that a lot of time will be spent on creating the documentation.

3.3.6 Week 6 Accessibility Standards

Week 6 considered international standards dealing with the accessibility of information and communication technology.

Due to both the timing of its development and the involvement of the instructor as its co-editor, students had the unique opportunity to create informative notes and examples for inclusion in ISO 9241-20 [10], a high level accessibility standard applying to information and communication technology. Critiques resulted in twenty-four notes and ten examples being added as well as five significant rewordings to existing guidelines in the standard.

The class then compared the detailed guidance on software accessibility contained in ISO 9241-171 [11] with the more general guidance in ISO 9241-20 and discussed how both standards might be applied to various development activities. (Because of the unique situation this year, it is expected future years will concentrate more on the application of standards than on the improvement of them.)

3.3.7 *Week 7 Cultural & Linguistic Adaptability*

Week 7 dealt with requirements, strategies, and implementations relating to cultural and linguistic accessibility (CLA). While many people may feel that CLA is beyond the bounds of traditional accessibility, language is considered an accessibility issue in Canada [8].

Considerations coming from student critiques of a set of CLA guidelines [20] included:

- the difference between using guidelines for evaluation and those for design,
- the wide range of cultures (including: ethnic, professional, age-related),
- the sharing of contextual information with users from other cultures,
- the need to deal with cultural limitations and differences in the use of various symbols,
- the use of metadata to help interpret symbols, and
- the range of issues involved in translating text properly.

The class then considered how to include cross-cultural accessibility within development [24].

3.3.8 *Week 8 Analyzing and Evaluating Accessibility*

Week 8 dealt with techniques and technologies for evaluating accessibility related issues.

Student critiques focused on the Common Accessibility Profile (CAP) approach to identifying media related accessibility issues [7]. They focused on various detailed technical issues and limitations of CAPs. A lively discussion was held noting how the CAP standard [19] actually addressed many of the issues and limitations they identified in the conference paper that they read and critiqued.

The class then discussed the strengths and limitations of automatic accessibility tools based on their ADE experience with using a web accessibility evaluation tool and the second reading for the week [1].

3.3.9 *Week 9 Accessibility Features of Specific Technologies*

Week 9 dealt with various W3C Web Accessibility Initiative guidelines [35, 36, 37, 38] and with the use of metadata registries to support the standardization of the meaning of various common types of content [5, 22].

Discussions resulting from student critiques of the Web Content Accessibility Guidelines [37] included:

- the uses and abuses of “scoping of conformance”,
- the uses and abuses of baselines in evaluating accessibility,
- techniques and limitations to making text understandable, readable, and translatable,

- techniques for expanding abbreviations and automatically substituting for difficult or unknown figures of speech, and
- techniques for error avoidance, minimization, and correction.

The discussion of metadata considered both the inclusion of metadata (and alternate data) within designed content and the identification of suitable metadata (or alternate data) from content that does not have its own or sufficient metadata (or alternate data).

3.3.10 *Week 10 Assistive Technologies*

Week 10 dealt with various issues relating to finding and using assistive technologies.

Discussions resulting from student critiques of the AT-IT Compatibility Guidelines [3] included:

- possibilities for application program interface (API) specifications that would be reserved for the use of assistive technologies,
- the importance of using standard features in operating systems, and
- issues that arise when devices share access to resources.

This discussion was supplemented by a consideration of new work that is moving towards solutions for these issues [6]

After briefly considering the role and the range of assistive technologies [28, 33], the last class was spent with a guest presenter demonstrating some state-of-the-art assistive technologies.

3.3.11 *Week 11 Adaptive Technologies*

Week 11 dealt with various strategies of individualization, including customization and automatic adaptation.

Discussions resulting from student critiques of Stephanidis’ paper on Supporting Interface Adaptation [32] included:

- managing the conflicting needs of consistency and adaptation (including avoiding confusing the user when adapting),
- limitations and concerns with portability and storage of user profiles (including on-line profiles and using profiles on publically available systems),
- possibilities and limitations with the system “learning” about the user (including detecting where a user needs assistance and where adaptations may be helpful), and
- limiting instances where the system interferes with the user (including mistaking the user’s tasks or pressuring the user to speed up).

Further discussion dealt with the role of modeling in designing individualizations [26].

3.3.12 *Week 12 Advanced Research Topics*

Week 12 combined considerations of a variety of cognitive issues both for developers and users. The primary reading focused on the role of context in unifying designs for all. The other two readings dealt with some of the issues in trying to support persons with cognitive disabilities.

Discussions resulting from student critiques of Stary’s paper on “A Structured Contextual Approach to Design for All” [30] included:

- how to evaluate our development processes to ensure we keep improving,

- how the structuring of tasks can affect the design and the resulting accessibility,
- how to manage contradictions that come up during development,
- how to deal with current, planned, and unplanned contexts of use, and
- the role of optimizing in development.

Discussions regarding developing systems for persons with cognitive disabilities focused on the wide range of different cognitive disabilities and the lack of a clear structure of user needs comparable to the user needs identified for persons with physical disabilities [2]. One of the major concerns discussed how to make the required “different simplicity tactics for different users” accessible to the particular users who need them [27].

3.3.13 Week 13 Project Presentations

The university term is 13 weeks in Canada. The goal of Week 13 is to determine the students’ understanding of their own project and to expose other students to aspects of accessibility that are beyond those already covered in the course. Week 13 consisted of 20 minute presentations about their projects by each of the students. This included 5 minutes for handling questions from other students and from the instructional team.

3.4 Lab Experiences

The ADEs mentioned above made up the lab experiences for this course. These ADEs are designed to be accessible to a wide range of users and are intended to help students understand the needs and expectations of users with disabilities.

The ADEs cover a wide range of issues and options in accessible computing. Five ADEs were designed for this course (another seven are currently under development). They explore web accessibility, testing for accessible design, using a screen reader, issues specific to users with cognitive disabilities, and the built-in accessibility settings and services available with modern operating systems.

Although some of these individual exercises are based on materials or exercises available via the web, these source materials can be hard to find and are not otherwise available as a comprehensive set that represents the widest possible range of accessibility issues and options. Further, while different exercises from different sources may not be consistently presented, the ADEs are consistently formatted and follow a standard structure.

The ADEs were developed so that they could be completed within a one hour tutorial and to fit the need to rapidly develop student understanding of the issues surrounding accessible computing beyond a theoretical understanding. The activities were intended to provide tutorial information as well as hands-on activities. To the extent possible, the ADEs were intended to be platform-independent (to allow students to complete them either in the computer facilities provided for the course or on their own computers). Upon completion, the ADEs required students to submit a report on their experience for marking purposes.

Due to limitations in the computing facilities provided for the course, the activity on screen readers used VoiceOver version 1, the screen reader available with the Macintosh 10.4 “Tiger” operating system. Likewise, the activity on built-in accessibility settings and services was specifically designed for exploration of the Windows

XP operating system. Future development of these ADEs and changes to computing facilities is expected to make these activities more platform-independent.

Comments from students were solicited during and after completing each ADE. These evaluations of the existing set of ADEs helped in revising the common structure, in revising the specific contents of existing ADEs, and in identifying and developing new ADEs for use in future courses.

The ADEs are designed to follow a common structure of four major sections:

The first major section of every ADE is an introduction to the topic. Usually this introduction consists of a multimedia presentation. Primarily intended to motivate the students and to open their mind to the topic area of the ADE, the introductions also outline the goals of the ADE and may include a brief presentation to relate the ADE to topics within the class syllabus.

The second major section is the interactive activity (IA). IAs are used to engage students through first hand experiences with some representative aspects of the accessibility issue or option being explored. There is no attempt to teach the students all they should know about the topic. Rather, the set of activities are intended to encourage students to explore the topic more fully on their own, both through available technology and literature resources. Most ADEs have multiple IAs. The ADE provides unifying guidance on using individual activities whether they come from other sources or were built in-house by USERLab. A key consideration in the selection and design of each IA is the amount of interaction involvement that it provides the student. Various techniques are used for creating interaction in different IAs, including: simulations, using actual tools, and interactive dialogues.

The third major section is a reflection activity. Students are asked to reflect on their experiences and to consider how they can apply them to the design of accessible computing. Specific questions about each IA focus on what was learned and how their experience might be applied to improving design accessibility. Students may also be asked to specifically reflect on how they felt during the activity.

The last section of every ADE provides recommendations for further activities that students can do on their own as well as a list of other resources that can provide further information and may also form the basis of readings to support course projects. While it is hoped that students will choose to follow-up selected activities and references, there are no particular expectations placed on the students.

The ADEs are publicly available at <http://userlab.usask.ca/ade>.

3.5 Projects

Projects provide students with an opportunity to either complete an accessibility research project or to apply accessibility engineering to some particular development project. Project ideas can come from class discussions or from individual student suggestions that are discussed with the instructor.

Undergraduate projects can be done with or without developing software as long as they contained significant application of accessibility to some problem area. Some of the initial suggestions for undergraduate projects included: doing a professional quality accessibility evaluation of an organization’s web site, analyzing and designing how to include accessibility within other software /

usability engineering methods, and developing and evaluating accessibility methods for particular problems.

Graduate projects go beyond undergraduate ones, by requiring the development of some useful software to demonstrate or apply the aspect of accessibility that was researched by the student. Some initial suggestions for graduate level projects included: creating additional ADEs, and creating tools to assist individual users. Undergraduate students were also allowed to do partial versions of graduate project topics.

The project involves three formal stages: a proposal, research and development of the project, and a presentation of results to the class. Students are strongly encouraged to discuss possible project topics with the instructor as part of developing their proposals.

Proposals require a title, a justification of the uniqueness and significance of the proposed work, an analysis of relevant background materials, a planned methodology, and a description of the type of deliverables that will result from the project.

Once a proposal is accepted by the instructor, it becomes a learning contract that forms the basis for evaluating the student's project. Developing good quality deliverables ensures the student of a good mark. Additions to or deletions from the set of agreed upon deliverables will have a major impact on the student's mark.

4. THE RESULTS

The course produced a variety of results that can be used to evaluate its success.

4.1 Quality of Critique Items

Each week, a sufficient number of excellent 2+ items were obtained to require all of the available class time in their discussion. Due to the large number of excellent items, the instructor was able to become more and more selective of items deserving of a 2+ as the course progressed.

In the first week, students averaged 2.7 excellent items per critique (EIC). This rose slightly to an overall average of 3.1 EIC over the duration of the course. Two weeks where the average went below 2.5 EIC had particularly short and narrowly focused primary readings. Three weeks achieved averages above 3.5 EIC.

4.2 Providing Expert Advice

Students in the course were offered the rare opportunity to provide advice to international groups of accessibility experts.

The ISO/IEC Special Working Group-Accessibility (SWG-A) User Needs Summary (UNS) is a major computer accessibility document that has been developed by a large group of accessibility experts over the last few years. In September 2006, Version 1.0 was issued, recognizing that it has achieved a significant level of stability and completeness. However, SWG-A also recognized that there might be room for further additions.

After discussing the UNS in class, students were given the opportunity to contribute to its evolution.

The instructor was asked by ISO/IEC SC35 User Interfaces (SC 35), of which he is an expert member, to find a way to include cultural and linguistic issues into the UNS (during the week that the class was discussing this very issue). He sent an e-mail request for cultural and linguistic user needs to the students and received six suggestions.

After discussing them in class, he forwarded five reworded suggestions to ISO/IEC SC35, which then refined and forwarded all five to the SWG-A for possible inclusion [15]. At their April 2007 meeting, SWG-A accepted all five with revisions, recognizing that four of them were completely new and that the fifth was a new need to be added to an existing category.

4.3 The Projects

Students in this course produced a range of high quality projects dealing with a variety of accessibility issues and options. Three of these projects have formed the basis for new ADEs in the areas of: cultural and linguistic issues, secondary encoding, and assisting vision. One project has produced a tool to help blind database developers create entity-relationship diagrams that can be used by sighted developers. Three of these projects have led to further research, resulting in conference papers.

4.4 The Students

This course has significantly influenced some of the students. Three of the nine students are now interested in graduate work in the area of computer accessibility. The project to help blind computer developers is currently being expanded into a software engineering tool for UML diagrams as the basis for one student's master's thesis. Two of the undergraduate students are now considering becoming graduate students to further their understanding of this field.

5. CONCLUSIONS

We have found that teaching accessibility engineering goes beyond providing students with an awareness of accessibility issues and helps prepare them to make real contributions to improving the accessibility of information systems. By having students critique a selection of suitable papers, they learn how to both use and question the information in those papers. By following an engineering life cycle, students acquire the skills and organization to successfully apply this learning to research and development activities. The results of our course surpassed our expectations and help validate accessibility engineering as a discipline whose time has come.

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