Mainstreaming Usability in Lower Level Undergraduate Design Courses

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***Abstract*—Usability is an important and well recognized consideration within the design process in fields such as industrial design and human factors but until recently has received more limited attention within engineering. The topic of usability is often relegated to the senior capstone design project where the project topic might not be amenable to a broad in depth discussion of the topic. This paper emphasizes the need to include usability in lower level design courses and suggests possible methods for including the topic in both lecture and project based design courses without substantially altering the existing overall course objectives.**

Keywords—usability; course projects; human centered design; users; stakeholders;

I. INTRODUCTION

Usability may be broadly defined as the requirements of a design that are based upon user characteristics and the context of use. The concept of usability is incorporated into such terms as participatory design [1], human centered design and inclusive design [2]. One characteristic of usability is that it directly involves the stakeholders who will be using the device or product being designed. Usability has long been viewed as a very important factor in the field of industrial design as well as in the fields of ergonomics [3] and clinical sciences such as Occupational Therapy [4]. From the standpoint of engineering, usability has routinely been considered in the design of prosthetics [5] and assistive devices [1]. The Human, Activity, Assistive Technology (HAAT) model has been widely used in developing devices to aid persons with disabilities [6]. This model emphasizes usability by considering the human capabilities, the activity and the context in which the device will be used. Usability implies that a design must be compatible with human physical and mental characteristics including their activities and environment.

There are usability standards for everyday products which relate to the ease of operation and contain design requirements for context of use and user characteristics. ISO 20282 focuses on products with an interface that the user can operate directly or remotely to gain access to the functions provided [7]. The intended users of ISO 20282 are usability experts, ergonomists, product designers and others. While relatively few engineers will be engaged in the design of everyday products, a much broader spectrum of engineers will be involved in design of devices that involve user interfaces in complex environments and thus would benefit from the considerations expressed in this standard.

In mainstream engineering the focus on usability has been considerably more muted. From an educational standpoint, usability is implied, but not specifically mentioned in ABET Criterion 3(c) [8] which states that student outcomes must document "an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environment, social, political, ethical, health and safety, manufacturability and sustainability".

Usability is often addressed to some extent in senior capstone design projects. There are two potential disadvantages of delaying consideration of usability until the capstone project. First, the specific topic of the capstone project may not offer the opportunity to incorporate realistic user issues into the design process. While some senior design projects, such as those sponsored by the National Science Foundation, have a very strong human centered design component [9], other topics may involve relatively limited consideration of user needs beyond purely technical considerations. In this latter situation, expanding the project topic to involve more user centered issues may be viewed as artificial. Industrially sponsored senior design projects may be highly defined in terms for functional outcomes and may not offer realistic opportunities to consider a wide variety of user inputs/preferences. In addition, delaying substantive introduction of usability until the capstone project tends to limit the student's overall exposure to and understanding of this important topic. One method for improving student understanding and exposure to the topic of usability would be to introduce the topic much earlier within the design curriculum. Earlier introduction of the topic might also allow students to become involved in more than one project involving usability and thus experience the topic from multiple perspectives. This paper describes methods for introducing usability into lower level design courses.

II. BACKGROUND

From a historical perspective the importance of usability within design education has continued to evolve. In 1981, Mann [10] reviewed the history of design education and advocated presenting design in as authentic a context as possible. He noted that engineering exists to satisfy human needs and advocated introduction of engineering design experiences at all levels of the curriculum. He further noted the need to involve students in the resolution of relatively unstructured engineering situations. More recently there has been renewed interest in incorporating user needs and preferences into the engineering design process. Recently the Journal of Mechanical Design devoted an entire issue to this evolving topic [11]. Papalambros [12] has noted that the human element should now be explicitly brought into design research. Within the design process, usability is generally recognized as an important consideration in developing design specifications. Several recent studies of usability have focused on the capstone design experience. In a 2015 study, Mohedas et al. [13] found that within a capstone course, student perceptions of stakeholder utility depended upon their pre-course expectations of its value. In another study of senior engineering students who had completed or nearly completed their capstone design experience Mohedas et al. [14] studied the approaches and behaviors taken by novice designers as means of possibly explaining why some novice designers are more successful than others. They concluded that the more successful designs focused on developing product requirements which came from information supplied by a wide variety of stakeholders. Maier et al. [15] studied senior design projects and concluded that effective communication between designers and users is particularly important and should be strengthened to foster overall project success. They further noted that communication is particularly important at the problem definition stage of the design. Atman et al. [16] compared experienced designers (experts) to student designers and found that in initially scoping the problem the experts spent more time and gathered significantly more information from more sources. In combination, these studies indicate that better designs result when there is a concerted effort to engage multiple stakeholders in the design process and that it would be beneficial to introduce students to user issues prior to the capstone project.

Given the increasing importance of explicitly including user needs and preferences in the design process, perhaps it is more appropriate to look at how best to introduce the topic of usability into the already crowded undergraduate design curriculum. There appear to be two major constraints. First, introduction of the topic must occur in a substantive, relevant manner that fits well within the existing course structure and material. Second, reasonable coverage of the topic must be accomplished in a time efficient manner. This paper primarily focuses upon introducing usability into project based introductory design courses but also presents methods than can be used in case study based course formats. In each situation, including usability can be accomplished without substantially altering the overall existing course objectives and structure.

III. METHODS

Project based format: Project based, introductory design courses offer an ideal environment for introducing usability and human centered design to large numbers of students. Design problems at this level are less sophisticated and are usually chosen with the goal of leading the students through the entire design process. It is relatively easy to select design problems which involve a substantial user interface and therefore require user input as part of the design process. By their very nature, projects based upon the design of toys, products for the elderly and for people with disabilities involve substantial usability issues. These types of projects frequently require a combination of the following considerations; assessment of user abilities, design of the user interface, anthropometrics, personal preferences, and changes in the user's condition including physical and cognitive abilities. These types of projects automatically encourage and often require contact with typical users and others associated with their care or education during the development of design specifications and product requirements as well as in evaluation of final designs.

This approach has been used to introduce the topic of usability into the following three project based design courses

- ES 1020 Introduction to Engineering, 1st year engineering students, enrollment 45-50.
- ME 2300 Introduction to Engineering Design, 2nd & 3rd year ME students, enrollment 35-40.
- ME 3506 Rehabilitation Engineering, 3rd and 4th year ME & BME students, enrollment 25-30.

A primary goal in each of these courses is to enable teams of students to experience the entire design process including prototype development and evaluation. Students usually work in teams of four. In order to insure substantial consideration of usability, project topics in each of these courses are restricted to three general areas; the design of toys, products for the elderly and devices to assist people with disabilities. Within these constraints and context, it is relatively easy for either the instructor or the student teams to develop design projects which clearly involve a significant user interface and therefore require obtaining considerable user input as part of creating effective solutions. In addition to the actual users, the design teams may have to gather information from parents, caregivers, special education teachers, therapists and social service agencies. These user contacts help to define the problem, provide input into the design process, provide evaluation of preliminary design ideas, test the prototype designs and provide suggestions for improving the design.

It is expected that students will seek information from a wide variety of sources including technical reports, standards, peer-reviewed literature, patents and trade literature. One lecture period is set aside for a research librarian to give formal instruction in information seeking methods [17]. Additionally the students will need to develop some rudimentary knowledge of topics such as human factors including user abilities and personal preferences, anthropometrics, ergonomics and safety.

Usually the instructor devotes one class period in each course to an overview of this material and a summary of sources. As an alternative, an instructor could use one of the several lower level design texts which contain significant material on these topics [18-21]. Further details about the structure and operation of these courses have been previously published [22-26]. Briefly, over differing periods of time each of these 3 project based courses has evolved into a generally similar format based upon four person design teams where each team member also serves as a company officer; Chief Executive Officer, Chief Technical Officer, Chief Information Officer and Chief Manufacturing/Financial Officer . The professor and teaching assistant assume the roles of the venture capitalists funding the company. Periodic progress reports are required in all 3 courses. In addition, ME 2300 and ME 3506 also require periodic design reviews with the venture capitalists. The larger enrollment in ES 1020 prevents scheduling design reviews with the individual project teams. All three courses promote having each team define their project topic within broad project statements such as "Design a toy for a child with a disability" or "Design a device to assist an elderly person". In ES 1020 and ME 2300 the instructor also supplies one or two more well defined project topics for those teams who feel the need for a more structured project description or who initially propose complex projects that cannot be reasonably completed within the allotted course time frame. Most teams in ME 2300 develop their own project while a majority of teams in ES 1020 (first year students) chose one of the instructor defined projects. Since ME 3506 is an intermediate design course and enrolls more mature students (juniors and seniors), all project teams in this course are now required to develop their own project topic. All student groups are required to give a final oral presentation where they demonstrate their 1st generation working prototype and are also required to submit a final written report.

These types of project topics automatically incorporate a strong focus on usability and therefore require the design process to be user-centered. In addition, the design specifications may have to include subjective factors such as human perceptions, personal preferences, aesthetics and social influences. Since the potential user populations can be and often are heterogeneous, the students may be confronted with developing design specifications that are "messy" when compared to purely technical specifications and requirements. The course requirements for physical realization and evaluation also encourage recruiting potential users and knowledgeable parties to evaluate prototypes of the final designs.

Case study format: Case studies offer an alternative or complementary means for introducing usability and the importance of the user interface within lower level design courses. There are several examples of situations where advances in consumer technology have resulted in decreased usability for segments of the population. For example, TV remote controls and other consumer electronics have created increased functionality by developing a more complex user interface with smaller buttons. However, elderly persons often have diminished vision and/or difficulty targeting small buttons. The elderly may also have diminished cognitive understanding. Fig. 1 shows an adaptation for a TV remote control that reduced its complexity and made it usable for an elderly person. The buttons are larger in size, color coded and have raised tactile symbols on each button.

Fig. 1. A case for a TV remote that makes it usable for persons with cognitive and physical disabilities.

Conversely there are examples where products originally developed for smaller specialized user populations have become widely used mainstream products. Some notable examples are large grip kitchen utensils and Dragon® Naturally Speaking.

IV. RESULTS

The following recently completed projects illustrate typical projects in each course and the usability issues that needed to be addressed in developing a prototype design.

ES 1020: Students in this first term, first year course generally lack formal engineering courses. However, many students will have a background in CAD. Most projects in this course involve basic geometric and kinematic concepts. Some typical past projects are puzzles and games for children who are blind or have low vision (Fig. 2), a swing away laptray for a child's wheelchair and a manually operated curb climbing attachment for a wheelchair pushed by an elderly attendant [26].

Fig. 2. Matching block game with color coding, raised symbols and Braille.

ME 2300: Most students in this course will have completed courses in statics and stress analysis. In addition, a majority of the students will have completed an introductory CAD course, a basic manufacturing/machining course and be familiar with rapid prototyping. Some typical past projects are a free standing cane which also functions as a grabber to retrieve items from the floor (Fig. 3), modification of a TV remote control for a person with both cognitive and physical disabilities (Fig. 1), and a rapid prototyped key holder to assist persons with limited grip strength (Fig. 4).

Fig. 3. Combination of a free standing cane and grabber.

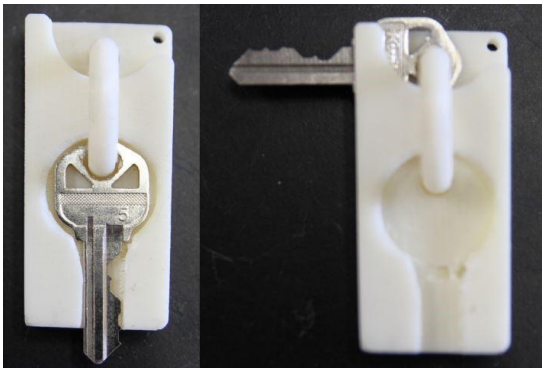

Fig. 4. Rapid prototyped key holder for a person with limited grip strength.

ME 3506: Almost all students in this course have taken a prior project based introductory design course, either ME 2300 or an equivalent. Some typical past projects are a hands free, battery powered, tumbler that assists in drawing liquid through a long straw that was developed for persons with a high level spinal cord injury. Another project created a method for creating user specific handles for eating utensils.

Student course evaluations for all 3 courses are very positive. Student course evaluations forms for the author's ME 2300 class for the 5 year period 2010-2014 were examined. One hundred eighty three students were enrolled in the course during this five year period and 138 students completed the WPI course evaluation form. One question requests a response to the statement "The instructor's organization of the course was…" The student's response is an integer between 1 (very poor) and 5 (excellent). Table I summarizes the 137 responses to this question based upon a 5 point Likert scale.

TABLE I. Summary of ME 2300 student responses regarding course organization for 2010-2014

Score	5	4	3	2	1
N=137	59	57	19	2	0
Percent	43.1	41.6	13.9	1.5	0

The students were not directly asked about the limitations on the project topics. However, unsolicited comments on the evaluation forms were strongly positive about the project topics while only a few students (1-2 per year) expressed a desire for a broader range of topics.

V. DISCUSSION

Attention to usability is critically important if a designer's efforts are going to come to fruition. Thus it is important that undergraduate design education place a strong emphasis on including usability as a fundamental part of the design process. The degree to which usability can be incorporated into the capstone project is variable [13]. In addition students bring preconceived views of the value of stakeholder input to the capstone project [14]. Earlier introduction of usability into the engineering design curriculum would reduce these current shortcomings. Furthermore, there has been an increased recognition that all engineers need to develop a much clearer understanding of usability as it pertains to engineering design [11]. Usability issues also present the opportunity for students to confront design criteria that are "messy" and less structured that traditional purely technical criteria. In the past, undergraduate engineering education has downplayed the importance of usability and industry has relied upon experts with specific training to conduct usability studies. Today with increased emphasis on innovation and entrepreneurship, product development is being shifted towards smaller companies. These smaller companies will likely have to rely upon the skills of their own engineers, rather than outside consultants, for incorporating usability into their products. This paper demonstrates the ease by which usability can be included in lower level design courses without substantially altering the overall course objectives. Introducing usability into lower level design courses, when combined with the capstone design experience, will likely lead to graduates who have a much deeper understanding of this important topic.

VI. SUMMARY

In recent years the topic of usability has received increased attention within the engineering design curriculum; however it is still not a mainstream topic. The extent to which the

capstone design projects introduce usability is highly variable and dependent upon the actual project topics. Lower level design courses offer a unique opportunity for introducing all students to the topic of usability without substantially altering the existing course format. It is relatively easy to find or to develop case studies for lecture based courses which demonstrate the importance of usability. For project based design courses, substantive consideration of usability can be effectively introduced by imposing modest constraints on the project topics Given the importance of incorporating user needs within the design process, increased attention should be focused on introducing the topic of usability earlier within undergraduate design curriculum.

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