The Bridge Connecting Theory to Practice - A Case Study of Universal Design Process

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Abstract. In a typical design process, the decision making process by which desirable and predictive outcomes are achieved is clearly defined by problem definition, goals and objectives setting, design criteria development, design solution generation and evaluation of the solutions. In contrast, the current literature on Universal Design typically jumps from Universal Design as an ideal and set of principles to Universal Design as an artifact. Without interpreting Universal Design principles into specific design criteria, it is not possible to understand design intent, reliably evaluate design outcomes, replicate design processes or outcomes, or generalize findings to other products and environments. In this paper, an universal design process has been proposed and illustrated in a case study of a universally designed voting system in which Universal Design has been applied throughout the design process in a consistent and explicit way to produce a desirable Universal Design outcome.

Keywords: Universal design · Design process · User interface

1 Introduction

Universal Design is a well-accepted concept for designing and evaluating products and environments that are accessible to and usable by all people regardless of their abilities. It has often been referred to more as a design process rather than a product/environment itself [1]. Since it begins with considering all users, the outcome of universal design is less stigmatizing because the design solutions would reduce or eliminate barriers so that all users can use it without requiring additional device or service. The benefits of universal design make it being used as an approach to solve certain design problems and evaluate designs of products as well as environment, however, the process of how universal design is applied to design decision making and evaluation of products is vague. In contrast of everyday design process where an explicit design process is documented through certain phases as problem definition, goals and objectives setting, design criteria development, design solution generation and evaluation of the solutions [2], the

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UD literature fails to document a similar or even detailed design process that demonstrates how universal design informed design decision-making, what decisions were made and why during the design process. Without a clear understanding of how UD impacted the design outcome through the design process, there is neither a way for others to understand how to apply or appreciate the value of universal design in making design decisions or evaluating design outcomes.

From the design process perspective, Universal Design process is merely a process of designing a product or environment. Thus, the process of Universal Design should be no different than it in typical everyday design. In a typical everyday design process, development of design criteria is a key step in the design process. Design criteria not only reflect project goals, but also determine the starting point for the generation of design solutions, guide design decisions and in some cases are used to evaluate how well the outcome achieves project goals. To this extent, design criteria are the bridge between project goals and outcomes. Compare to everyday design process, the documented UD process repeatedly fails to provide information about design criteria and other phases of the design process. Rather, generic Principles of Universal Design and their associated guidelines are typically substituted for specific perspective or performance-based criteria, leaving a wide gap between design intent and design outcome. Without clearly articulated perspective and/or performance-based design criteria, there is no way to make informed and replicable design decisions, determine whether design goals have been achieved or reliably evaluate the outcome of the design process. In universal design process, to ensure the design outcome being universal design as well as meeting the project-specific design goals, design criteria should be explicitly established and how they impact design process throughout different design phases should be documented.

In this paper, a case study of a universally designed voting system - EZ Ballot, is used to illustrate how project-specific design criteria were interpreted from generic universal design principles and guidelines. These UD-based design criteria demonstrate how design decisions were made to meet the design criteria and how design solutions were generated based on the criteria and clearly articulated design decision-making process. Moreover, because design criteria transcend the UD Principles, they represent the relationship between different guidelines within the same principle and the relationship between different principles. More specifically, the paper will demonstrate how certain principles and guidelines are associated with different aspects of ballot design (i.e., input, output and system logic), yet the design criteria are specific to one of the three aspects.

2 Background

2.1 Application of Universal Design: Principles and Guidelines

Successfully applying Universal Design in a design process to achieve the desirable outcome of design for all abilities can be challenging. First, universal design is a broad concept that different researchers have interpreted it in different ways. It has been elaborated as an information society being more participatory, cooperative and sustainable,

are based on a set of principles developed from both social and individual perspectives in economic, political and culture dimensions [3]. It has also been elaborated as an approach to allow people with disabilities to be able to use standard products because they are generally cheaper and more accessible marketwise than those specialized products [4]. Finally, it has been divorced from the typical everyday design process, often being introduced toward the end of the process, which results in "extra" design features driven by the consideration of "all people". As a result, universal design features appear as add-ons to a previously well-designed product [5]. Moreover, without a consideration of universal design from the beginning of the design process, the potential for achieving a universal design outcome that accurately reflects user needs is difficult [4] Like the process used to create typical everyday design, the process used to create universal design should be applied from the very beginning to the end, where it will contribute to defining problems, setting goals and objectives, defining design criteria and evaluating the outcome.

In operationalize universal design so it can be applied in the design process, seven principles and sets of guidelines were developed by 10 experts in 1997 [6]. Nonetheless, these principles and guidelines are intentionally broad and vague so as to be applied to the design of any interface, product or environment. As a result, the application of the principles and guidelines in any specific design necessitates the development of tangible project-specific design criteria. The progressive interpretation of principles and guidelines into design criteria/recommendations is illustrated in a design process focusing on Universal Accessibility in HCI (Fig. 1) [7].

Within the world of information technology, design features are manifested as functionalities of a system (e.g., visual display or audio output). However, embedding considerable functionalities does not ensure usability of the system [8]. Rather, usability is defined by the characteristics of those features (e.g., high contrast display or loud audio output). As illustrated in the figure, generic principles have been interpreted into specific design recommendations that are not only tied to design features but also tied to characteristics that direct how the feature is manifested. Based on this model, universal

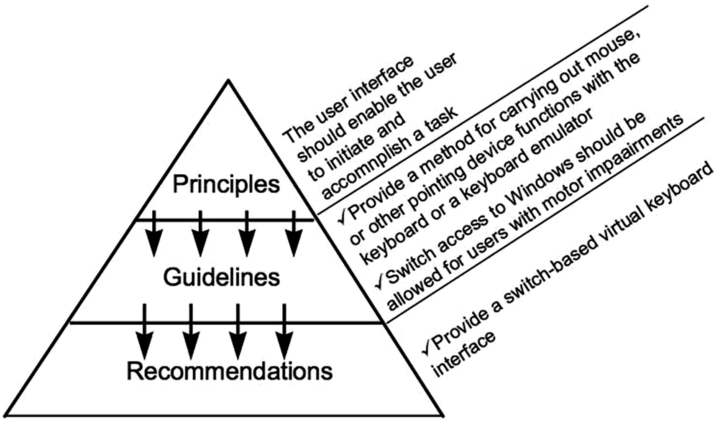

Fig. 1. Progressive interpretation of principles and guidelines into design criteria/recommendations.

design principles and guidelines can be applied to generate more project-specific design criteria that could better guide the generation of design solutions to meet the project goals. In addition, developing more concrete, project-specific design criteria would make evaluation of the design more explicit since clear measurements have been established as in the design criteria.

2.2 Lack of Design Criteria Development in Universal Design Process

Although universal design has been extensively discussed in the literature at the conceptual level of principles and guidelines, documentation of how universal design has been operationalized and integrated into the design process is lacking. Clearly, the development of design criteria that articulate the specific characteristics of a design is a necessary condition for operationalizing universal design. However, the literature is either silent on the design criteria or criteria are insufficiently defined to determine whether the design outcome is universal. Moreover, where the development of universal design criteria is documented in the literature, it has been based on the needs of special populations, rather than the whole population [9–11].

In addition, studies that documented design criteria were, most often, focused on general recommendations for characteristics of generic design features such as large text size and high contrast elements, without regard for the design context as a whole. As a result, the design criteria are isolated from each other in terms of their relationship to the different functionalities they are supposed to accommodate. These design criteria have also failed to associate accommodations with project-specific context. For example, in a study of designing mobile phones for older adults, [9] the functional limitations of older adults have been examined separately and design criteria which were proposed to accommodate those functional limitations are only associate with one functionality each. This approach of developing design criteria overlooked the fact that to complete most of the mobile phone use tasks, different functionalities will need to work together. Focusing on accommodations of each individual functionality without associating them with task-related requirements and considering the interaction between different functionalities can result in a set of insufficiently developed design criteria which is only accommodating individual functionalities without considering how would users complete the task. Furthermore, although the group of older adults is an good sample to practice universal design with since they usually have multiple deficits of functionalities, the design criteria developed from the studies of older adults do not sufficiently imply that other groups of users have been included for a product or environment to be universally designed.

2.3 Universal Design-Informed Criteria for Evaluation

Universal design principles have not only been applied to the design process to achieve more universally designed outcome, they have also been applied to the evaluation process to assist users, designers, and researchers to assess the usability and inclusivity of products and environments. However, using the generic universal design principles to assess products does not provide sufficient evidence of a product being universally

designed [12]. In addition, while such generic evaluation might determine the universality of a design, unless it is linked to the characteristics of design features, the evaluation is not useful for modifying the design or informing the design of future products.

Linking Universal Design with specific design features and characteristics can be very helpful for identifying ideal solutions to a design problem. The report, *International Best Practices in Universal Design* reviewed standards from all over the world that were used as design/evaluation criteria for to determine best practices of Universal Design [13]. Using task-relevant scenarios to develop an association between specific design characteristics (as the tangible manifestation of design criteria) and human functionality to determine the usability of each design, the report was able to determine the extent to which a set of design criteria was universal. Although it is merely the examination of standards to identify the best practice of Universal Design, the methodology provides insight into the way universal design can be seen as a set of considerations regarding human functionality, task context and the design features/characteristics.

Another successful example [14] of applying universal design into the evaluation process is an evaluation for universal building design in which experts from different disciplines gathered to evaluate a building based on Universal Design principles. In this case, experts were asked to apply the seven principles of universal design through a consideration of tasks, human functionality and design characteristics to assess five main categories of features within the building. As a result there were profound increases in the number of usability issues found in the evaluation compare to the evaluation where experts were asked to identify usability issues based only on construction drawings. It has been proven, once again, that Universal Design can become useful to a great extent when it is used in a way that tasks, human functionalities and characteristics of features have been all taken into consideration.

2.4 Proposed Universal Design Process

Without the development of project-specific design criteria based on universal design existing literature has failed to document how universal design can be operationalized so that it can be applied to the design process. To overcome that shortcoming, the Universal Design Process proposed here (Fig. 2) demonstrates how Universal Design can be applied to design process through developing project-specific criteria based on seven Universal Design principles. In the proposed process, the design criteria are developed based on the consideration of not only the usability aspects (Principles 2–7), but also the equitability aspect (Principle 1) of universal design. Principle one, which is about equitable use, is the most important principle that distinguishes universal design from assistive technology, accessible design or other usability principles. The uniqueness of universal design is the idea of providing the same means of use for all users is embodied in principle one [15]. This should be considered through the design criteria development phase to ensure that all users could be able to use the product or environment that has been designed. In addition to that, the design criteria should be as explicit as possible to associate with specific design decisions. The design decisions, in turn, are typically represented by one or several design characteristics. Associating design criteria with characteristics allows designers to deal with design problems in a more tangible

and contextual way that it provides the opportunities to articulate the interaction between different design features and characteristics according to the task context to maximize usability for all. Compared to the existing universal design process in which design decisions were guided by theoretical universal design principles/guidelines that served as implicit (albeit generic) design criteria or criteria were developed to accommodate human functionality individually without considering the task context, the proposed process connects the theory of universal design to design decisions through the development of explicit design criteria.

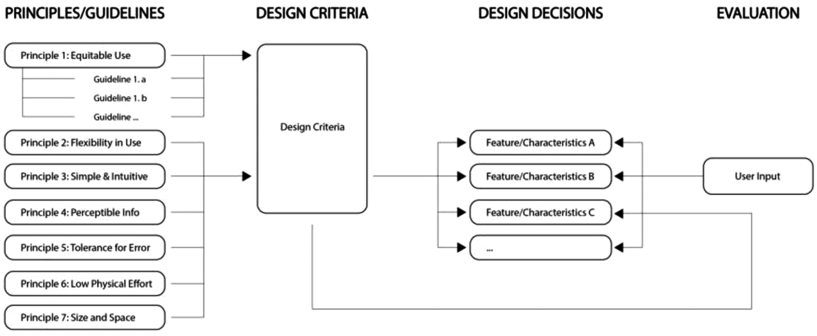

Fig. 2. Proposed universal design process

3 Case Study: EZ Ballot

EZ Ballot is a universally designed voting system with multimodal input and output that facilitates participation of voting by allowing voters to go through the voting process by simply answering "yes" and "no" questions [16] (Fig. 3). It simplifies the voting process conceptually that voters can vote on this system regardless of their abilities. The proposed Universal Design Process was employed in the design of EZ Ballot to maximize universality of the design outcome. In the design process, design criteria associated with characteristics of features in the voting system were developed based on the seven Principles (specify the version of UD Principles have been used for assessment) of Universal Design. By linking design decisions with Universal Design Principles, the design rationale was revealed through the illustration of the interaction between design features and characteristics. Details of the interaction between design features and their characteristics are described in the tables along with the principles from which each of these design decision were derived. The design criteria have been embodied into the relationship between the characteristics within a design feature as well as the relationship between characteristics and Universal Design principles.

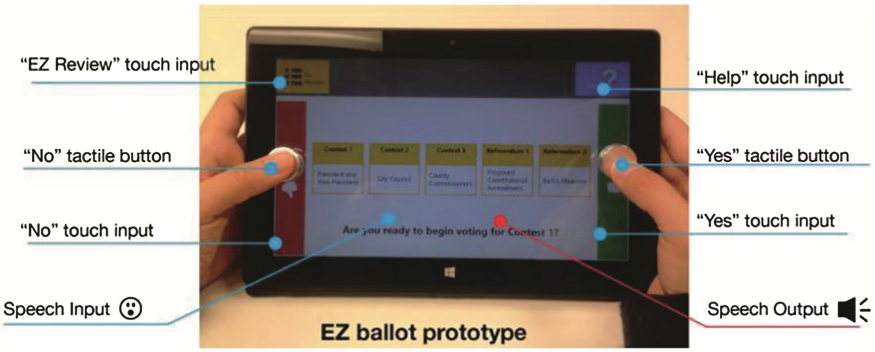

Fig. 3. EZ Ballot, a universally designed voting system

In Table 1, screen layout is characterized by the detailed description of how the layout is presented which includes the location of buttons, placement of progress and candidate indicators, and the rationale of putting the most used "Yes" and "No" buttons most accessible. Buttons are located along the edges of the tablet so that people with vision loss or having a hard time of locating onscreen buttons will benefit from it since once they have located the buttons they could use them comfortably by slightly moving their fingers from the edges to press the buttons, which is derived by Universal Design guideline 6a and 7b about allowing users to maintain a neutral body position and make comfortable reach to all components regardless whether they are sitting or standing. The rest of design features and characteristics (Tables 1 and 2) basically followed the same rule that characteristics are described explicitly to explain how design features are presented and followed by the corresponding principles and guidelines that a characteristic is derived from.

In categorizing the characteristics and design features, it is interesting to note that the characteristics associated with a feature are not always a characteristic of the feature itself, but may be a characteristic that links a feature to the larger context. For example, size, color and shape are characteristics of interface buttons, whereas the location of buttons is a characteristic of screen layout at a larger scale. This relationship provides designers and researchers a deeper insight of how different elements interact with each other at different scales.

4 Discussion

Developing a clear association among design features, universal design-based criteria, design decisions derived from the design criteria and design characteristics that result from those decisions, illustrates how universal design can be operationalized within the typical everyday design process. Within any design feature, different characteristics may meet universal design principles in different ways. For example, the feature of touchscreen buttons in Table 1 has five different characteristics such as being sensitive to force, being big in size and so on that were derived from five different Universal Design principles. It is the characteristics of design features that describe how Universal

Table 1. Relationship between system input/output(i/o) features, characteristics and universal design principles.

Feature	Characteristic directed by Design Criteria	Principle /Guideline
Screen Layout	Locating buttons by the edges of tablet	6a, 7b
	Ballot Progress Indicator is on the top but with different background color	3d
	Candidate indicator is at the side of candidate box	3d
	Most used "Yes" and "No" buttons are located by the sides of tablet	3d, 5a
	Secondarily important "Help" and "Review" buttons are located at the corners of the tablet	5a
Touchscreen Buttons	Sensitive to force	6b
	Redundant in icon, text and color	4a
	Touchable Look (with colored background, text label and icon on the button)	3b
	With big size	2c, 7c
	Locations of buttons are left with enough space between each other	2c, 7c
Physical Buttons	It can be pushed down and bounce back to ensure the intentional input	5d
	It can be push down and bounce back to give feedback of action	4a
	Regular button look to offer affordance	3b
Audio	Simultaneous with visuals	4a
Text	Big in size and in high contrast	4c
	Descending in size for different information	3d
Touchscreen Cover	With cut-outs to show locations of "yes" and "no" buttons	4a
Stylus	Compatible with touchscreen	3b
Input Methods	Offering different input methods, i.e. touchscreen, stylus, physical buttons	2a

Table 2. Relationship between system logic features, characteristics and universal design principles

Feature	Characteristic	Principle /Guideline
Under-voting Reminder	Provided at the end of each contest	5b
Verification Prompt	Instant	5c, 3e
Instruction	Context-sensitive; constant (is offered all the time)	3a
Process	Piece-by-piece (question-by-question)	3a
	User-controlled pace of proceeding	2d
Review	EZ Review (which offers real-time ballot review)	3e
Progress Indicators	Color-coded, numeric, such as "1 of 3"	3e

Design has been applied, which is to say that the key of achieving a universally designed outcome is to use Universal Design to inform design decisions on design characteristics. By explicitly describing the characteristics of a design feature with related Universal Design principles, it also allows other designers and researchers to examine the design rationale behind the outcome so they can benefit from knowing how Universal Design can be applied.

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