

***Usability and Design Considerations for  
Computer-Based Learning and Assessment***

Michael Harms  
Jeremy Adams

Pearson

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**Abstract**

The overall success of computer-based products and systems is dependent to a significant extent on their usability and usefulness in the intended context. User Centered Design (UCD) combines research-based methods with product design practices in ways that support the creation of useful and usable products and systems.

In this paper we discuss common design and usability considerations in the development of computer-based learning and assessment products, and the associated information management tools used to manage and deliver them. The application of UCD as a "science of design" (i.e., a research paradigm directed at systematically understanding, evaluating, and documenting usage requirements) will be considered in the context of designing and deploying web-based assessment and learning tools.

***Defining User Centered Design (UCD)***

User Centered Design (UCD) is a term used in recent years to describe an approach that has been around for decades under different names, such as human factors engineering, usability engineering, human-centered design, and more recently user experience engineering. UCD incorporates a multidisciplinary collection of methodologies and theoretical perspectives that can be used to design a wide range of products or services, from consumer products, to industrial devices, to work processes and environments. The term is most frequently applied to the design of technology products, such as software, web sites, computer-related devices, and mobile communications products.

However, UCD represents not only a research paradigm for designing usable products and systems, but just as important, a philosophy that places the user at the center of the process (Rubin, 1994). UCD views the user as a focal point for analysis to understand the overall requirements for effective design. The products, processes, and knowledge required by the user to achieve their goals are viewed as an interacting system for achieving specific tasks, and the ease or difficulty of completing those tasks is treated as a metric defining related aspects of product quality.

Recent views have extended this definition to include the affective, or emotional, perceptions of users as an index of the quality of design. (Lund, 2007) The “user experience” is seen as a holistic indicator of the degree to which a product design, in combination with other products, processes, and systems, meets the needs of the individual users in ways that encourage continued use. This extends the traditional “systems view”, which focuses primarily on usability and usefulness in a context, and more explicitly recognizes the role of aesthetics and social perceptions in the evaluation of product quality.

User-centered design incorporates a continuum of research perspectives, ranging from qualitative inspections of designs, to formalized and precise methods for performing quantitative analysis of behavior. Methods which can be applied in the study of learning and assessment applications in both the laboratory and real life settings include (1) *usability testing methods* – design evaluation by observing subjects representative of the target user population as they perform real tasks; (2) *inspection methods* – structured review processes by usability experts using established design guidelines; and (3) *inquiry methods* – field based or ethnographic methods focused on understanding the context of use.

### ***Historical Foundations of UCD***

UCD has its roots in efforts during the 1970's and 1980's to develop a science of "software psychology". The goal was to establish a psychological approach to understanding software design and the use of computer systems, as well as to guide system developers in considering human factors when designing technology products (Carroll, 1997). The disciplines

of computer science and psychology, in combination with classical experimental methods, formed the basis for a multidisciplinary perspective for studying human interaction with technology.

Early research emphasized a reductionist approach to behavioral analysis, in which complex phenomenon were decomposed into their component parts. Component behaviors were studied using classical experimental methodologies with the assumption that understanding low-level behaviors and capabilities would provide insight into the performance of real-world tasks. A number of related models focused on identifying low level goals of computer users and studied simple computer actions such as keystrokes and the use of input devices. Much of this early work was focused on developing general descriptions of human-computer interaction, on creating design guidelines to aid system developers, and creating techniques for the verification of the usability of systems. (Carroll, 1997)

However, by 1990 it became clear that models emphasizing low-level behaviors had been ineffective in providing practical frameworks for improving system design at a broader level of understanding interaction within natural work settings (Carroll, 1995) and for more complex behaviors.

Throughout the 1990s, theoretical perspectives expanded to incorporate a stronger social and contextual orientation. Anthropologists and sociologists began to contribute to a domain that had been largely dominated by cognitive psychology. Behavior was increasingly viewed from more of a systems perspective that emphasized the interacting role of contexts, task requirements, and user characteristics.

Research techniques began to incorporate field methodologies, such as ethnography, contextual inquiry, and work analysis procedures, along with new approaches to both quantitative and qualitative analysis of user needs and behaviors.

As usability engineering practices gained more acceptance, the focus shifted to the practical application of research principles in designing useful and usable products. Since the 1990s, UCD has gained prominence as a research-based design methodology based on the following four principles:

- 1) early focus on user requirements,
- 2) iterative development of design solutions,
- 3) systematic validation of requirements and designs,
- 4) emphasis on designing for the entire user experience.

In recent years, usability engineering methodologies such as UCD have become an essential part of modern product development processes.

### ***Usability in Learning and Assessment***

The overall success of computer-based products and systems is dependent to a significant extent on their usability and usefulness in the intended context. As new technologies are integrated into current assessment and learning practices, issues of ease-of-use are more commonly encountered. This includes not only the computer-based assessment and learning tools, but also the web-based systems used to coordinate, deliver, and monitor the logistics of learning and assessment processes.

A frequent challenge in the development of computer-based tools and technologies is the design of effective user interfaces. It is well established that user interfaces must be designed with consideration of the knowledge, expectations, information requirements, and cognitive capabilities of end users. However, creating useful computer-based tools requires more than just designing usable interfaces. Understanding tasks and processes for the entire range of potential users is critical to successfully managing design tradeoffs. Defining user needs, characteristics and expected contexts helps ensure that we are “building the right product, the right way”.

This is complicated by the fact that web-based tools delivering learning and assessment can range from highly interactive graphical and multimedia-based environments to workflow-driven, web-based data management applications. Roles, age groups, and levels of expertise of users can also vary significantly. Computer-based assessment and learning tools, along with the web-based systems used to coordinate, deliver, and monitor them, must be designed to accommodate a wide range of domain specific requirements to ensure ease-of-use.

In the context of learning and assessment, the design characteristics and the issues that are commonly encountered will be further discussed in three functional categories: computer-based assessment, computer-based learning, and online information management.

**Computer-based Assessment:** Recent technological advances in computer-based testing have created opportunities to deliver assessment items that measure learning in new and innovative ways. Increasing availability of technology in schools and advances in the field of educational assessment has created opportunities for new assessment practices, materials, and processes (Almond, Steinberg, and Mislevy, 2002). As assessment moves beyond traditional paper-based approaches and begins to incorporate new computer-based capabilities, new requirements will appear. Internet delivery of large-scale tests, simulation-based problem solving, and more complex open-ended formative assessments to guide learning and instruction will become more sophisticated – while demands for efficiency and validity remain. (Almond, Steinberg, and Mislevy, 2002) However, the added capabilities provided by computer-based testing technologies also have the potential to introduce unforeseen design challenges related to interface usage characteristics and new types of media.

Design for computer-based testing can be thought of in terms of either the delivery tool or the specific test item content that is delivered. A central requirement for computer-based assessment delivery tools is ease-of-use with minimal training. Navigation, task-flow, and integrated features such as software-based calculators, highlighters, and embedded supports must be intuitive and support test-taking strategies in order to provide optimal measurement characteristics. Ideally, test delivery tools will provide a usable, intuitive experience that creates a roughly equivalent experience among students.

However, in practice the cognitive and physical abilities of students differ greatly. In addition, computer proficiency can vary significantly within and across age ranges in ways that may not be directly linked to academic achievement. The inclusion of students with disabilities in computer-based testing also expands the range of potential users that must be considered. Systematic usability research allows relevant differences in user requirements to be defined and documented so appropriate design choices can be made.

Field methodologies and on-site experimental methodologies are often used to study assessment because they allow data to be collected in an authentic educational context. Since many testing situations include actual, or perceived, time pressure and expectations of students, observing testing in ecologically valid settings provides a more realistic representation of expected behavior.

**Table 1: Challenges in designing Computer-Based Assessment:**

- Requires very intuitive, easy-to-learn interface and navigation
- Interface should not distract from test content
- Support for wide range of test-taking strategies
- Student variability within and across age ranges
- Accommodating students with disabilities

Computer-based test items can also include design features that must be considered. Current testing technologies allow the inclusion of multimedia and interactive simulation-based content in online assessments. This allows alternate presentation of content or the measurement of procedural knowledge in more realistic, graphical ways. In both cases interacting with the test item requires additional interface controls within the content. In some cases, the control can be unique to the specific item it is embedded within. Similar to test delivery tools, the controls within simulation or multimedia items must be intuitive and consistent across items. This includes not only the appearance, but also the behavior of similar control elements. Visual feedback provided when similar objects are clicked or manipulated should be the same. Whenever possible, design conventions should also be consistent with the software interface used by the test delivery tool.

**Computer-based Learning:** Educational software for computer-based learning and games often share common characteristics because computer-based learning content is frequently presented in a game-like format. In some cases, multimedia or simulation-based assessment content can share the same characteristics with computer-based learning content. However, assessment situations create an explicit requirement that students interact with content in a controlled setting. In contrast, computer-based learning tools are frequently used in an

unsupervised context, and usage is more voluntary. As a result, effective learning applications must be both usable and enjoyable to keep students interested in learning content.

A primary goal of computer-based learning is to create engaging content that encourages voluntary use but also embeds goal-directed learning activities within the recreational context. This frequently creates challenges for designers because of the subjective nature of design characteristics that are “fun” and the fact that these characteristics vary significantly across age ranges.

***Table 2: Challenges in designing Computer-Based Learning include:***

- Often use graphical and game-like design conventions
- Must be simultaneously usable and challenging
- Enjoyment and engagement are subjective characteristics
- Design can be age and gender specific
- Product success is tied to learning objectives rather than simply task completion

Like productivity applications, games require mastery of content and features to achieve an objective. However, contrary to common usability assumptions, games create enjoyment by challenging the user; often taxing the user's memory and performance limits (Lazzarro & Keeker, 2004) and then providing performance feedback on their level of success. UCD methods apply to most aspects of both games and educational software, but the intent of recreational contexts is to create a different kind of experience than assessment or productivity software. Usability is still a critical factor underlying good design but traditional measures of efficiency, effectiveness, and satisfaction must be thought of differently to apply to learning contexts. For example, measures of effectiveness might be defined based on the degree to which learning was facilitated and not necessarily whether a student successfully completed tasks. A situation in which a student completes a learning task quickly and with little effort might represent less effective learning. Conversely, a situation where a student had difficulty achieving a task but mastered learning content throughout the process might be viewed as a success. In these cases, the criterion for success is closely tied to tradeoffs between learning objectives and usability objectives, and is thus more abstractly defined.

However, like assessment software, a distinction can be made between the mechanism for delivering content and the learning content itself. Nielsen (2002) asserts that children want content that is entertaining, funny, colorful, and uses multimedia effects. However, for navigation and homepage design, the user interface should be unobtrusive to allow access to content as simply as possible. “Children enjoy exploration and games, but it should not be a challenge to operate the website itself. The content should be cool, but the design must offer high usability or kids will go elsewhere.”

**Online information management:** Web-based tools for coordinating and managing the deployment of large-scale assessment and learning tools are largely administrative, but they play an important role. These systems help manage the complex interactions within state-level educational systems and throughout the “extended organization” including districts and schools, as well as partners and suppliers.

Availability of web-based technology allows large-scale assessment and learning to be deployed and coordinated in ways not previously possible. Online information management has the potential to increase efficiency by streamlining workflow and by providing direct access to information and functionality previously only available at a centralized source. However, as work activities become increasingly decentralized, the importance of understanding user roles, tasks, and work contexts is increased for work distributed across geographically separated sites

Traditionally, centralized administrative tasks have been supported by informal or manual processes. Information is managed using multiple task-specific tools or paper-based activities prior to being collected and managed as a bulk processing activity at a central location. However, the presence of widely available, real-time access to web-based information and functionality has potential to alter the manner and timing of work activities, and requires end users to develop new skills. Traditional processes, roles and tasks may need to be adjusted to best take advantage of new capabilities.

In addition, work activities may be performed infrequently, and roles and responsibilities may be handed off over time. For example, in large-scale assessment work activities are often performed based on testing cycles. As a result of the time interval between cyclical tasks, users

may be slower to attain expertise and may need to relearn aspects of tasks each time they are performed. Interface designs and usage conventions should be consistent to allow expertise in using a system to transfer across tasks. Terminology and text descriptions should be consistent with what is used in an end-user environment to ensure easy interpretation of interface functionality.

Designing intuitive web-based information management tools also requires a comprehensive understanding of work processes, policies, and user roles. User and task characteristics can vary significantly across usage environments, so effective design solutions need to accommodate variability.

**Table 3: Challenges in designing Online Information Management tools include:**

- Designing features for coordinating distributed work
- Wide range of user roles
- Understanding relevant business processes and policies
- Accommodate variability in process across use contexts
- Designing for exception cases
- Tendency towards complex task-flow driven user interfaces
- Usage can be cyclical and infrequent

Developing online information management technologies to support work in groups, to ensure effective task coordination, and to ensure data quality requires consideration of both the context of use and the background, expertise and role-specific requirements of individual users. Problems can occur when designs (a) solve the wrong problem, (b) have the wrong features for the right problem, or (c) make the right features too complicated for users to understand (Nielsen, 2008). Usability research methodologies applied to these projects tend to focus strongly on documenting and understanding process and task requirements to identify required features.

***Summary and Conclusions***

UCD represents a combination of theory and practice that has been successfully applied to a wide range of domains, and product types. A major focus is on understanding the influence

of user characteristics, tasks, and use-contexts on real-world behavior, and using those insights to create more useful and usable computer systems. However, the field also seeks to combine research-based methods with product design practices in ways that extend both.

At a practical level, the emergent nature of the design process makes identifying and validating design requirements both important and difficult. UCD is a research-based tool for managing the complexity of a process in which everything, including the problem definition, is constantly evolving. (Carroll, 1997) As a research discipline, it has progressed towards becoming a “science of design” that can both guide design activities, and extend theoretical perspectives.

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