# Collaborating with Human Factors when Designing an Electronic Textbook

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## Abstract

The development of on-line engineering textbooks presents new challenges to authors to effectively integrate text and tools in an electronic environment. By incorporating human factors principles of interface design and cognitive psychology early in the design process, a team at Sandia National Laboratories was able to make the end product more usable and shorten the prototyping and editing phases.

A critical issue was simultaneous development of paper and on-line versions of the textbook. In addition, interface consistency presented difficulties with distinct goals and limitations for each media. Many of these problems were resolved swiftly with human factors input using templates, style guides and iterative usability testing of both paper and on-line versions. Writing style continuity was also problematic with numerous authors contributing to the text.

## Introduction

By incorporating human factors principles of interface design and cognitive psychology early in the design of an electronic engineering textbook, the development team was able to make the end product more usable and shorten the prototyping and editing phases. This electronic textbook was a comprehensive package for all types of learners with linear descriptive reading passages for sequential learners, hypertext for global learners and a computational mathematics tool for experimentation and active learning.

The development of on-line textbooks presents new challenges to authors to effectively integrate text and tools in an electronic environment. We have categorized ways to incorporate human factors into the textbook project in three major sections: project management, design framework, and iterative testing cycles. Here is a brief outline of examples of this approach.

## Project Management
### Project Definition

The primary motivations for this electronic textbook project were to develop a means of handling a growing stack of documentation that was self-referencing, to update old documents, and to set up a system for expansion. The topics to be addressed initially were nonlinear finite element analysis, material modeling and Sandia's PRONTO finite element code [Taylor and Flanagan, 1993, 1994]. The scope was to develop a well-defined documentation system that all Sandia engineers, both readers and developers, working with finite element codes would want to use. Two benefits of this system were considered high priorities: 1) to shorten the learning curve for all levels of students (users) and 2) to decrease the maintenance cost of continually updating the reference materials.

One of the unique aspects of this project is that human factors and usability issues were considered during the pre-development and development phases. Human factors experts were integral to the project team along with the subject matter experts, the programmers, and documentation and clerical specialists. The early involvement of human factors altered the design and work flow for the project, in part because the focus was continually on the user. The project was driven by a user-centered design approach [Norman and Draper, 1986]. For example, the first step was to identify the audiences and the environments in which the documentation would be used.

The audience was identified in groups: code users, code developers (especially needed for verification), code system managers (for installation instructions and system needs), material property testers (obtaining material properties needed for certain mathematical models), new graduate students (just beginning to learn the theory - MS level), and advanced students (familiar with much of the first level theory, ready to do research - PhD level). The size of the focus target audience, inexperienced users with an MS degree, was estimated to be 100 users at the start of the project, possibly expanding to 500 users within twelve to eighteen months.

### Project Plan

This textbook was designed to be modular, so that subsections could easily be updated. The framework was described as a set of bricks (modules) to build structures (books, manuals) where the same bricks could be used in multiple structures. There was an over-arching glossary, to be accessed from every brick, and indices that were specific to a structure. This interactive computer-based textbook provides an introduction to non-linear finite element applications. The goals used to develop a framework for the PRONTO code documentation project are to: be rapidly configurable to facilitate the addition of new capabilities from

internal and external research user community; shorten the learning curve to impact Defense Programs and industry productivity; provide a platform for the functional storage of analyses, results, capabilities and lessons learned; provide a platform for widely disseminating codes into defense, industry, and academic communities; leverage Sandia's investments by establishing Sandia as a leader in the development and dissemination of functional scientific and engineering tools; and provide an interactive package using hypermedia, real-time execution of simple problems, as well as the ability to view videos of stored solutions that could be packaged into a format to be published using CD-ROM technology.

The project team also wanted to design the textbook so that it would be easy to break out parts for use as texts in a classroom setting. The design of the textbook was structured to provide foundations for graduate level courses in finite element theory, material modeling using finite elements and other courses.

A timeline was drafted to prioritize steps in the textbook development: document format (3/95), command descriptions for PRONTO (5/95), example problems in proper format (10/95), theory section for PRONTO (4/96), integrated product in CD-ROM format (10/96). These priorities were based on the immediate needs of the majority of the target audience at Sandia National Laboratories who sought quick access to the information.

## Usability Testing Plan

The project team recognized the importance of regular iterative testing of the interface and the navigation controls by the target audience. The first round of testing addressed user expectations for the on-line version being designed. These testing results actually provided the design framework for the first version of the on-line command description pages. For example, users requested examples of how each command was employed, as well as hyperlinks to the theory section and related commands from each page. Users also wanted to be able to edit input decks to modify sample subroutines and view the results graphically 'on the fly.' These user requests helped the design team to focus on the tasks the users might be able to perform on-line, and maximize the potential of the electronic textbook technologies for this audience.

## Design Framework
### User Interface Design

In the initial project planning meeting, the team diagrammed the full scope of the system as envisioned by the project manager. This included the theory manual volumes, which link to examples and code implementation (PRONTO manual); the PRONTO manual with its command descriptions (green pages), which would link

back to the theory and examples; and tutorials, for new user training, also hyperlinked to all of the other manuals.

## Style Guidelines / Templates

The on-line version was created using custom paragraph styles to accommodate automatic revisions and a conversion to paper formats. This use of style guidelines and layout templates was formally introduced in the project plan early in the development to ensure modifications would only be required in one format, either on-line or on paper. Since a primary motivation for using the on-line version was that recent changes could be made on-line, the migration to a paperless documentation system was firmly grounded in the philosophy that paper documentation would be printed only rarely. It was determined that the on-line version would be primary and that the conversions would only need to be one-way, from on-line to paper. The on-line version created format issues unique to the electronic media, specifically, navigation issues.

## Navigation Flow Analysis

The most pervasive problem that arose during each iteration of testing, was user disorientation when leaving one section and entering another. Despite the enforcement of style guidelines, so that page format was consistent, users were not confident as to how to return to the previous section. Users repeatedly asked for visual cues and typically used book metaphors when they described cues; therefore, we incorporated two icons, in the shape of a book and a page, to help establish local and global navigational cues. These icons have markedly helped new and experienced users create a mental model of the structure of the textbook within the first few minutes of navigation.

The design of this electronic textbook allows users to jump from a finite element modeling command in an example problem, to the text that describes the command and its parameters, or to the theory section explaining the derivation, or to the implementation section to learn how the code was developed. This example-to-implementation documentation system will allow other Laboratories, universities, and industry to use our code as a development testbed and provide easier tools for students to use in learning advanced, non-linear finite element modeling theory.

## Iterative Testing Cycles and Formative Evaluation
### Design of Evaluation Methods

In the past five years, Jakob Nielsen has popularized the notion of 'discount usability methods' and informal testing of graphical user interfaces [Nielsen, 1993]. Many of the methods recommended by top usability experts require lengthy task

analysis and full-time staff members to interpret data and complete reports. These formal testing methods are not realistic for institutions without a standard testing facility. Sandia National Labs does not have a testing facility; therefore, informal methods prevail.

Our approach on this project was quite informal and interactive [Mayhew, 1992; Nielsen, 1993], where team members evaluated the newest version of the interface, and listed potential trouble spots and suggested questions we needed to pose to the target users. This brainstorming led to draft test plans. Through observation of testers while they performed realistic scenarios with the modules and then by posing specific questions while pointing out features of the interface, we evaluated the textbook with active user involvement.

Regular Implementation of Testing

The testing schedule had peak periods in tandem with development, so that as a module was modified, a test plan was drafted and shared with the team. Once the plan was refined, the appropriate testing audience was identified: managers, experienced users, novice users, human factors experts. The test was run on one subject to ensure that the plan was realistic within a reasonable time period, usually 30 to 45 minutes. The number of subjects available who were experienced users of the code was quite small, so the total number of subjects was usually three to five. Occasionally, a human factors expert would evaluate the usability with no actual users and provide recommendations based on style guidelines and interface design principles. Many times testing reports were submitted to the project team the same day testing was performed in order to quickly make the improvements and focus on new issues. A list of the tests performed is shown in Table 1.

**Table 1: List of Usability Tests Performed**

| Date | Tested | Subjects |
|------|--------|----------|
| 3/96 | Examples, Navigation, Mental Model | Users |
| 11/95 | Green Pages Layout | Users |
| 9/95 | On-line Navigation, Glossary | Human Factors |
| 8/95 | On-line/Paper Format Conversion | Human Factors and Users |
| 7/95 | Green Pages Layout | Human Factors and Users |

**Conclusion**

The benefits of including human factors into the design to improve learning and usability of instruction are evident in the time and cost savings of development time of this electronic textbook. Skills in instructional design, cognitive

psychology, technical communications, documentation, human factors, usability testing, and task analysis all help to create a comprehensive development team when designing instructional technology.

**Acknowledgments**

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