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ABSTRACT

This paper describes how a Wayne State University (Michigan) multimedia design team is applying Keller's ARCS (Attention, Relevance, Confidence, and Satisfaction) Model of Motivational Design to the entire process of design, development, and evaluation of multimedia courseware. The ARCS Model has been applied to the prototype module and is being incorporated into all present and future modular designs. The design team is collaborating with faculty members from five universities to design and develop multimedia courseware for college engineering courses to be delivered at a National Science Foundation project located at a manufacturing facility. A brief summary of Keller's ARCS Model is presented. The primary emphasis of this article is the description of the computer-based instruction design process and resulting product design and features as they relate to the ARCS Model. Issues that continue to challenge the design team are also discussed. Tables and figures present: the interface of motivational and instructional design; motivational categories of the ARCS Model; the standard screen design for multimedia development; and menu bar options. (Contains 25 references.) (Author/DLS)

Using the ARCS Model to Design Multimedia College Engineering Courses

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Abstract

The design and development of Computer-Based Instruction (CBI) is a complex process. This paper describes how one Wayne State University multimedia design team is applying Keller's ARCS Model to the entire process of design, development, and evaluation of multimedia courseware. The ARCS Model has been applied to the prototype module and is being incorporated into all present and future modular designs. The design team is working with faculty members from five universities to design and develop multimedia courseware for college engineering courses to be delivered at a National Science Foundation project located at a manufacturing facility. A brief summary of Keller's ARCS Model is presented. The primary emphasis of the article is the description of the CBI design process and resulting product design and features as they relate to the ARCS Model. Issues that continue to challenge the design team are presented in the conclusion.

Establishing an Innovative Engineering Education Program

Just as a well-designed building depends on having a solid foundation, so does an instructional product. Engineering education emphasizes technology and technological innovations. Multimedia Computer-Based Instruction (CBI) is a dynamic, interactive technology. Motivating students with relevancy in instruction increases their learning of theoretical concepts. Combining these three elements--engineering education, multimedia instruction, and relevancy in instruction--can have a significant impact on the way students learn to become engineers.

These simple but profound statements have driven the Greenfield Coalition for New Manufacturing Education in the establishment of a new paradigm for engineering education. Furthermore, it is the unique combination of these factors that was the primary impetus for using the ARCS Model to design multimedia college engineering courses.

Funded by the National Science Foundation in 1993, the Greenfield Coalition for New Manufacturing Education is comprised of five universities, six industry partners, and a private agency. The original commitment was to establish a virtual university at Detroit's Focus:HOPE's Center for Advanced Technologies (CAT), a private agency manufacturing facility originally funded primarily by the U.S. Department of Defense. The university partners (Wayne State University, University of Michigan, University of Detroit Mercy, Lawrence Technological University, and Lehigh University) are committed to providing top-quality engineering curricula; the industry partners (GM, Ford, EDS, Chrysler, Cincinnati Milacron, and Detroit Diesel) are committed to providing equipment, contracts, and advisors; and Focus:HOPE is committed to providing the manufacturing facility, the classrooms, and the candidates for the degree program. The 150 full-time workers in the facility are the students in the "virtual university." The delivery of credit-bearing engineering courses is being accomplished primarily through "Innovative Instructional Processes" (IIPs). Consequently, from the outset the coalition adopted the following goals:

1) Create accredited degree programs--an associate's and bachelor's degrees;
2) Ensure that students will obtain the planned degrees primarily via the coalition's instructional modules;
3) Change from a teacher-student system to a coach-learner approach;
4) Develop a curriculum that will be used not only by the coalition's college but also by the participating universities; and
5) Utilize CBI modules as an integral part of the educational foundation.

In addition, the faculty developers were challenged to incorporate manufacturing relevance into the modules.

In the first three years, the faculty members (25-30 developers) from the partner universities were awarded contracts and were asked to design and develop their proposed CBI modules using Authorware Professional©, an icon-based authoring program. Although most faculty developers were experts in their engineering fields, they were not instructional designers or multimedia programmers. Unfortunately, the faculty developers were not given consistent guidelines, standards, templates, or much of anything in the way of professional support for the design and development of the CBI. Some university faculty members made impressive efforts in their design and development projects. Others floundered, however. Consequently, the various modules were often little more than text-filled page-turners with sparse media, confusing navigation, and limited learner control or interaction. The faculty developers delivered these CBI modules along with their classroom instruction to the candidates at the CAT with varied levels of success.

Establishing a CBI Team to Design and Develop Multimedia Courseware

In October 1996, NSF reviewed the CBI modules and concluded that the Greenfield Coalition should centralize production to improve the "quality and quantity" of the modules. This meant that the entire design and development process would undergo significant changes. To accomplish this major shift, the coalition established a professional multimedia design team comprised of an instructional designer, programmer, and a media specialist. Within six months the team added a graphics designer, writer/editor, multimedia specialist, and second programmer.

A CBI structure, or a basic blueprint, was established as the template for lesson presentation. All elements of a lesson center on the core material, which may be a text, series of articles, CD-ROM or other existing body of knowledge. In essence, then, the new CBI modules would not attempt to contain the entire course, but the CBI modules would be connected to a designated core material and contain only key elements that are best delivered through multimedia. In this new structure, a basic module is defined as having three to five topics with matching learning objectives with 50 to 100 screens (including 3-5 screens for a self-check and 5-15 screens for a module assessment that has a test bank of questions). The student should be able to complete the lesson in 30 to 90 minutes. Each module contains an introduction, stated learning objectives, summary of the core material lesson, illustrations and examples, simulations or "what if" questions, self assessment and a module assessment. In addition, modules may be linked to external software programs.

The learner's activities are tracked by a Computer-Managed Instruction (CMI) system. The student logs on to the client-server system, selects a course from the curriculum, selects a module, then selects activities within the module. The tracking of the learner's log on and selection is accomplished through Solis Pathware©, a product of Macromedia.

Committing to an ISD Approach and a Fully-Featured Prototype

To ensure that the design process and the CBI structure would be implemented effectively, the coalition team made a commitment to (1) an ISD approach and (2) a fully featured CBI prototype.

- Commitment to an <u>ISD approach</u>. The team decided early on that established Instructional Systems Design models and tenets would be the foundation for design and development. The Dick and Carey Model (1996) was applied to the macro design of the entire CBI process. Keller's ARCS Model (Keller1987a; 1987b; 1987c; Keller & Kopp, 1987; Keller & Suzuki, 1988) was applied to the design of the program interface, screen layout, and the CBI lesson presentation and on-line assessment. Furthermore, the ARCS Model was applied to the product evaluation process.
- Commitment to a <u>fully featured CBI prototype based on our CBI structure</u>. This meant that the team would design a CBI structure that would fit all the knowledge areas in the engineering curriculum. Each module would have consistent screen design (menu bar, mapping area, font type and size, text and media placement); standard navigation with alternative navigation methods to emphasize user control; on-line access to information; appropriate use of multimedia (graphics, animation, video, sound, simulations); and ample learner interactions.

ARCS: The Motivational Theory and Model

A core tenet of traditional instructional design theory and practice is that design should be a systematic process (Gagné, 1985; Gagné, Briggs & Wager, 1988; Rothwell & Kazanas, 1992; Seels & Richey, 1994). Because of the acceptance of a systematic approach designers generally follow an ISD model, which not only describes and explains the design elements but also prescribes the required activities to achieve the desired objectives. Educators generally consider motivation a relevant component in both learning and instruction. In his article, "Motivation and Instructional Design: A Theoretical Perspective," Keller (1979) presents a theoretical framework for the inclusion of motivation in the theory and practice of instructional systems design. Keller (1979; 1983) claims that if motivation is to be applied effectively to instructional design, it should be based on solid motivation theory and a systematic process of instructional design. One of the key ingredients in the successful implementation of the newly established Greenfield Coalition process was to apply the ARCS Model to the design of multimedia college engineering courses.

Keller's ARCS Model of Motivational Design (Keller, 1987a; 1987b; 1987c) works with a traditional ISD model.(See Table 1.) The acronym ARCS refers to the four key elements of motivation: A, Attention; R, Relevance; C, Confidence; and S, Satisfaction.

Table 1. The Interface of Motivational and Instructional Design

Phase	Instructional Design Steps	Motivational Design Steps
Define	Pre-project analysis--project	
	Conduct task, job, or content analysis	
	Conduct instructional analysis	
	Identify audience entry behaviors	Conduct audience motivational analysis
	Write performance objectives and criterion measures	Write motivational objectives and criterion measures
Design	Design instructional sequences	Generate motivational strategies
	Instructional methods	Select strategies
		Integrate motivational and instructional strategies
Develop	Select or create instructional materials	Prepare motivational materials
		Enhance instructional materials
	Develop test for learning and performance	Develop test for motivation
Pilot	Implement with test population representatives	
	Conduct formative evaluation	
gaph97	Certify or revise	

Note. From "The systematic process of motivational design" by J.M. Keller, 1987, Performance and Instruction, 26, p. 7.

Most design models include the basic steps of (1) define, (2) design, (3) develop, (4) implement, and (5) evaluate. The ARCS Model combines the last two steps of implement and evaluation into one, "pilot." Others in the field support Keller's claim that the motivational model fits well with a traditional ISD model. For example, Okey and Santiago (1991) demonstrate the model's value by using it with Gagné's Events of Instruction and Dick and Carey's design model. Main (1993) also showed how the motivation model could be used effectively with a traditional design model. Each major category has three sub-categories to be analyzed for the development of appropriate motivational strategies. The process questions guide the designer's focus and selection of strategies. (See Table 2.)

Table 2. Motivational Categories of the ARCS Model

Categories & Sub-categories		Process Questions
Attention		
A.1.	Perceptual Arousal	• What can I do to capture their interest?
A.2.	Inquiry Arousal	• How can I stimulate an attitude of inquiry?
A.3.	Variability	• How can I maintain their attention?
Relevance		
R.1.	Goal Orientation	• How can I best meet my learner's needs?
R.2.	Motive Matching	• How and when can I provide my learners with appropriate choices, responsibilities, & influences?
R.3.	Familiarity	• How can I tie the instruction to the learner's experiences?
Confidence		
C.1.	Learning Requirements	• How can I assist in building a positive expectation for success?
C.2.	Success Opportunities	• How will the learning experience support or enhance the students' beliefs in their competence?
C.3.	Personal Control	• How will the learners clearly know their success is based on their efforts and abilities?
Satisfaction		
S.1.	Natural Consequences	• How can I provide meaningful opportunities for learners to use their newly acquired knowledge/skill?
S.2.	Positive Consequences	• What will provide reinforcement to the learner's successes?
S.3.	Equity	• How can I assist the students in anchoring a positive feeling about their accomplishments?

Note. From "The Systematic Process of Design, " by J.M. Keller, 1987, Performance and Instruction, 26, p. 2.

Applying the ARCS Model to the Design of Multimedia Engineering Courseware

To design and develop the CBI prototype, the Greenfield Coalition CBI design team worked with two professors from Wayne State University on a course in engineering economics. The resulting CBI screen design serves as a model for present and future courseware development. (See Figure 1.) The four elements of the ARCS Model, adult learning theory, and multimedia design were used to guide design decisions.

Attention

Attention, as Keller points out, is the first condition of motivation and a prerequisite for learning. He argues that it is not enough to gain the learner's attention, the "...real challenge is to sustain it, to produce a satisfactory level of attention throughout a period of instruction" (p. 3). Keller's (1987b) definition for attention is "capturing the interest of learners; stimulating the curiosity to learn" (p. 2).

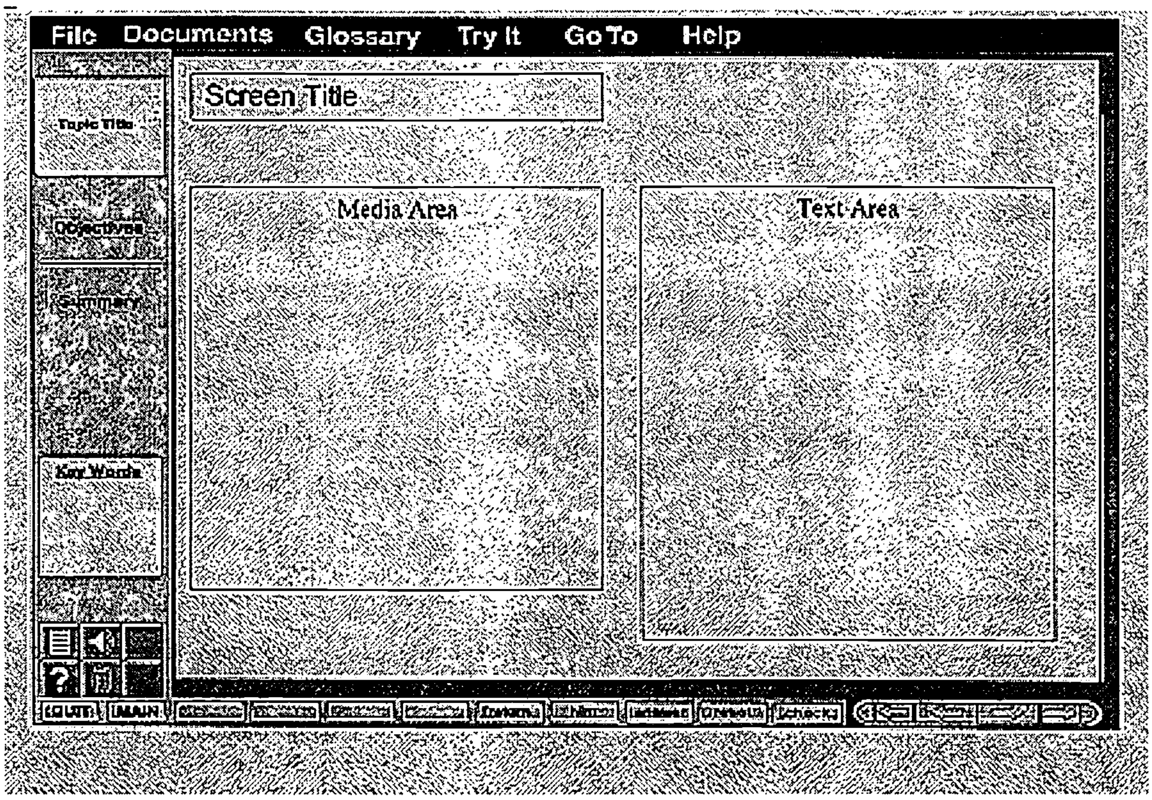
To gain and sustain the learner's attention, the design team incorporated multimedia into the Introduction; provided relevant graphics, video, audio, and animation throughout the lessons; and included ample learner interactions. Attention to the lesson is emphasized with the use of consistent placement of screen title, key words, objectives, summary, appropriate media and readable text. Although it may seem a simple accomplishment, restricting the text display area to ten or less lines of 16-pt. text on a screen was a major hurdle to overcome. Our experience with most professors is that they want to put as much text as possible on the screen. However, to catch and sustain the learner's attention, the text needs catch the reader's eye, be easily readable and understandable. This generally means shorter text elements. (See Figure 1.)

Relevance

Relevance, Keller (1987b) emphasizes, "is a powerful factor in determining what we are motivated to learn, or what we are willing to continue paying attention to after our attention has been aroused or restimulated" (p. 3). Relevance is defined as "meeting the personal needs/goals of the learner to effect a positive attitude" (p. 2). In a recent study with 100 college students, relevance was determined to be the most important motivational strategy (Means et al., 1997). The study investigated the comparative efficacy of intrinsic relevance of instruction and embedded relevance strategies as recommend by the ARCS Model of instruction. The researchers argue that "relevance strategies increase the meaningfulness of instruction by relating it to personal needs" (p. 7).

To increase relevance of the content to manufacturing, the CBI team designed in media (video, audio, animation, and graphics) that illustrated concepts and applications for the adult learner in the context of manufacturing. The faculty developers work closely with industry partners and representatives from Focus:HOPE to find relevant case studies, projects, and other experiential opportunities for incorporation into the module and the entire class. These elements are evident in the screen design shown in Figure 1.

Figure 1. Standard Screen Design for Multimedia Development



Confidence

Confidence, (Keller & Kopp, 1987) involves the learner's "positive expectancy for success" (p. 294). There are many factors that have an influence on a learner's confidence or expectancy for success, but the authors emphasize the complexity of the confidence factor in this statement: "Adults, like children, who are expected to learn a new skill need an opportunity to acquire and practice the skill under conditions where the psychological risks are reasonably low" (p. 294).

Providing learners the opportunity to practice and acquire new skills under low-risk conditions was a key component of the design. To build the learner's confidence, the design team concentrated on establishing three main elements: (1) a consistent, logical interface with ample user control; (2) embedded on-line support of the module; and (3) appropriate interactions.

At the top of the basic screen layout is the Menu Bar with six pull down menus: *File, Documents, and Glossary, Try It, Go To*, and *Help*. The menu bar was selected to imitate the familiar Windows presentation style. The menu options are explained below. (See Table 3.)

Table 3. Menu Bar Options

File	Click *File* to select *Quit, Find*, or *Return to Main Menu. Quit* is alternate navigation that takes the user to the Windows desktop, bypassing the Computer-Managed Instruction (CMI) home screen. *Quit* is also available in the Navigation bar at the bottom of the screen. *Find* allows the user to search for all instances of a word, phrase, or sentence. *Return to Main Menu* allows the user to return to the Computer Managed Instruction (CMI) home screen. *Return to Main Menu* is also available with the *Main* button in the Navigation bar at the bottom of the screen.
Documents	Click *Documents* to display a list of all electronic Portable Document Files (PDFs) that the student can print. The documents are PostScript files that are accessed through Adobe Acrobat Ó. Consistent throughout the courses are the following document types: Module Guide (outline of the lesson), list of key words and definitions for the module, list of objectives for both Module and Topic, and summary. Selected documents that the faculty include are: sample in-class test, list of formulas, and similar printable documents that would enhance their confidence in obtaining needed resource material for the class.
Glossary	Click *Glossary* to be taken to an application, which allows the user to look up all words, and definitions used in the Engineering Curriculum. This feature ties all the courses together. Definitions can be searched by the word or phrase or by the beginning letter of the word.
Try It	Click *Try It* for alternate navigation to select from the topic's interactions, practice exercises, and self-check opportunities. Students must select *Return to Main Menu* to access Self-Check, so the Self-Check will not be encountered as a student progresses through the lesson. These can also be accessed as the student progresses through the lesson. A Factor Calculator that allows the student to change variables for the formulas and view the changes in the cash flow diagram is available in the Engineering Economics modules.
Go To	Click *Go To* for a selection of all screen numbers and titles. This is alternate navigation that allows the user to highlight the screen he or she wants and go directly to it.
Help	Click *Help* to display these options regarding the program: *Program Tutorial, Quick Help,* and *Navigation Methods.*

The Menu Bar options are designed to increase the learner's access to embedded, on-line content information, alternate navigation choices, and guidance about the program's interface.

The left side of the screen is the mapping area, which contains advance organizers. Advance organizers alert the learner to key aspects of the lesson (Ausubel, 1968). At the top, directly under the *File* on the menu bar is the Topic Title of Module. This is displayed on each screen to focus the learner's attention on the section of the module he or she is in. Under the title are two hotspots: *Objectives* and *Summary.* A click on *Objectives* brings up a pop-up window of the topic's objectives. A click on *Summary* brings up the topic's last screen, which contains topic summary information. The *Key Words* list, which is in a box with a scroll bar, contains all the hypertext-words in the module. Highlight and click on a selected word to bring up the definition from a database. (These words are also available in the *Glossary* and *the Key Words* list in the *Documents* Pulldown Menu.)

Below the *Key Words* list are the *Tools* with buttons for: *Notetaker, Audio, Quick Help*, and a *Calculator.* Click on the *Quick Help* to access an interactive help screen of the screen layout areas and navigation buttons. Click on *Notetaker* to access a window that allows the learner to take notes about the topic and file the notes on a floppy disk. Click *Audio* to turn the audio on or off. Click the *Calculator* to access a scientific calculator that enables the learner to compute complex formulas. The *Tools* function pad is designed to ensure the learner has access to the tools needed for the completion of the lesson at all times.

At the bottom of the screen is the *Navigation Zone* that contains the buttons for navigation through the module. The first two buttons are *Quit* and *Main.* Click on *Quit* to return to the Windows desktop and exit the module. Click on *Main* to go back to the CMI home screen to select other activities in the module or to exit. The module's on-line activities (topics, self-checks, and assessment) and off-line activities (reading assignments, labs, case studies, etc.) are located at the Main Menu screen.

Three Application Link Navigation buttons are provided to the right of the *Main* button. *Link* buttons will only be available if the module is designed to have the student access an external program (e.g., Excel) during the lesson. A generic button space is reserved for special buttons (such as *Example* to bring up an illustration or example) that may be needed by different lessons. Interaction navigation is provided when an interaction is displayed. The buttons (*Return, Hint, Answer, and Reset*) will be highlighted for use. The last is the *Check* button that allows the user to access a self-check exercise. Once in the exercise, the button changes to *Score*, so the student can click on it to access his or her numerical score for the Self-Check. The fourth set contains *Standard Navigation* buttons, which allow the user to screen forward and back one screen at a time and to go all the way to the beginning and to the end of the topic.

The *Screen Layout* has four basic areas: *Screen Title*, *Screen Number*, *Media Area,* and *Text Area*. Each screen has a unique title and screen number that is designed to orient the learner to his or her place in the topic, which is an important instructional aid. This screen layout also is designed to focus the learner's attention and to build the learner's confidence because it increases the likelihood of the learner understanding the lesson progression and organization, and decreases the likelihood of the learner getting lost or disoriented (Park & Hannifin, 1993).

The *Media Area* is reserved for graphics, animation and video, and is generally placed at the left of the screen. The *Text Area* is at the right of the screen. The goal is to keep the text focused on one main point with approximately ten lines. Research shows that consistent screen layout with understandable organization increases the learner's learning (Hannafin, Hannafin, Hooper & Rieber, 1996).

Satisfaction

Satisfaction is a category that concentrates on helping learners feel positive about their achievement. This involves combining appropriate external rewards with the challenge of providing opportunities to achieve internal rewards in the areas of natural consequences, positive consequences, and equity (Keller & Kopp, 1987).

To ensure the learner's satisfaction with the interface and the presentation of the lesson, the CBI team emphasized user control with navigation options, helpful guidance and feedback, as well as equitable assessment. The learner is guided through practice exercises (interactions) and self-checks with access to more information, hints, and solutions. The learner may go through a module at his or her own pace and may take the self-check as many times as desired. At the end of a module, the learner takes a module assessment that is matched to the objectives and the self-checks. Since a Computer-Managed Instruction (CMI) program tracks the learner's activity, the learner can access his or her scores. Access to scores is designed in to help increase the learner's satisfaction with the lesson because it provides a sense of completion and an intrinsic reward.

Collaborating with Faculty, Using the ARCS Model to Guide Design and Development

The CBI design team meets with the faculty developers numerous times to plan the modules. The instructional designer is the primary contact with the faculty developers in the design and development of the courseware. The design team prepared and distributed a process handbook and a project notebook, containing electronic and paper copies of planning aids and storyboard templates. The faculty developers are advised to use the ARCS Model in the planning of instructional strategies and content presentation of the screens. Furthermore, a checklist is provided to help in the formative evaluation process.

Implementing the Process

Evaluation of the instructional product while it is in development, is critical to its successful completion. Therefore, the design team incorporated several stages and types of formative evaluation to ensure that the prototype incorporated the desired ARCS elements, followed best practices, and presented a functional, user friendly program interface. Formative evaluation in the form of reviews were conducted at various stages with five users, one content expert, one multimedia expert, and three instructional designers. Evaluation forms based on the ARCS model were used with the sample learners and instructional designers who reviewed the module prototype. Except for the users, all reviewers were experts in their field and were not associated with the design team's efforts. The data collected from these reviews were used to make significant changes to the prototype and all present and future CBI courseware designs will be based on this prototype.

The design team works collaboratively with the faculty developers (approximately 60 from five universities). A primary goal is to keep them informed of the basic building blocks in the new process. First, the design team conducted two workshops for this purpose in the past year. Second, the design team produced and distributed an extensive process handbook that explains the coalition's mission and goals, the design approach, the collaboration process, meeting agendas, and the consistent guidelines for the design and development of multimedia. The ARCS model is a key part of the design process handbook. Third, to ensure that the faculty developers have ample support as they plan and design their course, the design team developed over thirty planning aids that support the complex process of multimedia design.

Central to these planning aids are flow charts and storyboard templates. These serve as the blueprint for the interactive multimedia. The faculty team's PI (Principle Investigator) works with the instructional designer to lay out each screen of the CBI. The instructional designer, and other members of the team, as needed, meet with the developers as often as twice a month to confer on the design process, which requires a lot of feedback and revision. When final versions of the planning aids and storyboards are complete, the developers provide paper and electronic copies to the design team so programming can start.

In 1997, the CBI design team accomplished its first goal: the completion of a prototype and one module for one course. In addition, the design team began planning modules with six other faculty development teams. Two teams have completed storyboarding their first module. In October 1997, the prototype was presented to a NSF review team and given high ratings with a challenge to complete 25-30 modules in 1998. To accomplish this, the design team will double its staff, adding three instructional designers, one graphic designer, and three multimedia programmers. It will be a significant challenge to achieve this rate of production. Based on the positive reviews by NSF, the users, and external experts, the design team is confident that the established prototype and planning process that incorporate the ARCS Model (Attention, Relevance, Confidence, and Satisfaction) into the basic design will continue to provide a solid foundation on which to build.

Conclusion

The design and development of engineering courseware is a collaborative process, involving the Wayne State University Design Team, the university faculty developers, representatives from industry and Focus:HOPE. The prototype design, which is based on the ARCS Model Elements of Attention, Relevance, Confidence and Satisfaction, will be used in all future CBI course development. While still under development, the prototype was reviewed by students in the engineering program at Focus:HOPE as well as by experts in instructional design and multimedia. The data collected from the reviews led the team to make changes in the screen graphics, colors, button shapes and placement. The basic screen design and interface were given favorable reviews for their ease of navigation, on-line access to help, and high level of user control.

The challenges that face the design team and the faculty developers are many as we work together to use the ARCS Model in the design and development of computer-based college engineering courses. Meeting the production schedule is one of the most pressing challenges. However, the following challenges are also important:

- Designing computer-based lessons that are of sufficient challenge and depth for a college level course.
- Connecting the subject's conceptual theory to relevant applications.
- Providing sufficient problem-based learning opportunities, interaction, feedback, and on-line support of the lesson.
- Maximizing the possibilities of multimedia while adhering to sound learning theory.
- Staying current with new technology and translating the CBI modules to other instructional delivery media such as the World Wide Web.
- Determining the effectiveness of the CBI modules' instruction by evaluating the students' learning.

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NOTICE

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