

Best Practices in the Design, Development and Use of Courseware in Engineering Education

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Abstract - This paper discusses best practices in the design and development of engineering education courseware by examining the courseware recognized through the *Premier Award for Excellence in Engineering Education Courseware* since 1997. Led by NEEDS—A Digital Library for Engineering Education and supported by industry, the courseware recognized through the *Premier Award* covers most engineering disciplines; ranging from case studies to collections of Java applets; addresses both formal and informal learning; and targets learners at multiple levels. The *Premier Award* evaluation criteria are transformed into best practices in design and development of engineering courseware. Through illustrative examples drawn from the submissions recognized by the *Premier Award*, courseware developers will be able to improve their designs leading to potential increases in learning effectiveness.

Index Terms – NEEDS, Premier Award, courseware, learning objects, engineering education, best practices, evaluation criteria

INTRODUCTION

As engineering educators are increasingly using and developing courseware—computer-based educational materials—to use with their students, it is important to understand how high quality courseware should be designed, developed and used. By extracting and illustrating best practices, from high-quality courseware, we can provide exemplars to demonstrate good design and encourage improved development of courseware [16].

The *Premier Award for Excellence in Engineering Education Courseware* “recognizes high-quality, non-commercial courseware designed to enhance engineering education” The *Premier Award* is organized by NEEDS—A Digital Library for Engineering Education and sponsored by John Wiley & Sons, Autodesk, MathWorks and Microsoft Research [1]. This *Premier Award* was created to recognize the efforts of courseware developers in producing high-quality courseware and to promote and advance the evaluation of the

quality of courseware. The *Premier Award* results in *Premier Courseware* selected in an annual competition by judges representing engineering faculty and students, instructional designers and industrial sponsors. The judges evaluate the courseware as well as the required submission documentation that details how the courseware address the criteria. The submission package includes assessment data on student learning and oftentimes includes testimonials of instructors and learners using the courseware. The *Premier Courseware* each have distinctive strengths, representing a breadth of styles, sophistication, pedagogies and use of multimedia, that encourages incorporation of the courseware into a range of learning environments.

This paper first provides a profile of *Premier Courseware*. Then, guided by the *Premier Award* evaluation criteria [1], the paper discusses best practices for courseware design and development by highlighting exemplary features from courseware recognized by the *Premier Award*.

PREMIER COURSEWARE PROFILE

Since 1997, 16 courseware packages have been honored as *Premier Courseware* and six more recognized as finalist candidates. Table 1 provides a profile of the courseware recognized by the *Premier Award* by award year, primary subject area and target audience.

TABLE I
PREMIER COURSEWARE PROFILE

| Title | Year | Primary Subject | Targeted Audience |
|-------------------------------|------|--------------------|-------------------|
| Jeroo | 2004 | Computer | UG, K12 |
| MecMovies | 2004 | Mechanical | UG, GRAD |
| Electronics Curriculum | 2003 | Elect. /Computer | UG, |
| Pavement Guide Interactive* | 2003 | Civil | UG, PROF. |
| J-DSP* | 2003 | Elect. /Computer | UG, K12 |
| Interactive Groundwater | 2002 | Civil | UG, GRAD. |
| Principles of Mat's Handling* | 2002 | Materials/Metal. | UG, PROF. |
| BEST SiteSim* | 2002 | Geological | UG, GRAD. |
| Signals, Systems & Controls | 2001 | Elect. /Computer | UG |
| In Hot Water Case Study* | 2001 | Industrial/Mech. | UG |
| Vis-MoM* | 2001 | Mechanical | UG |
| Virtual Car* | 2001 | Multi-Disciplinary | UG |
| West Point Bridge Designer | 2000 | Civil | UG, K12 |

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|-------------------------------------|--------------------|--------------------|-----------|
| Project Links | 2000 | Multi-Disciplinary | UG |
| Engineering Graphics | 1999 | Multi-Disciplinary | UG |
| Cracking Dams | 1999 | Civil | UG, K12 |
| Della Steam Plant Case Study | 1998 | Industrial/ Mech. | UG |
| MD Solids | 1998 | Mechanical | UG |
| Structural Eng. Visual Encyclopedia | 1998 | Civil/Construction | UG, PROF. |
| Virtual Disk Drive Design | 1997 | Mechanical | UG |
| Electric Drill Case Study | 1997 | Mechanical | UG |
| Bike Dissection Case Study | 1997 | Mechanical | UG, K12 |
| Mars Navigator | 1997 | Aerospace | UG, K12 |
| * Finalist Candidate | GRAD=Undergraduate | | |
| UG=Undergraduate | PROF=Professional | | |

Although the target audience of most *Premier Courseware* is undergraduates, many courseware were designed to be used in K12 and by professionals.

FROM EVALUATION CRITERIA TO BEST PRACTICES

The basic concepts and principles behind the *Premier Award* evaluation criteria have essentially remained the same since their initial development in mid-1990s [4]. The evaluation criteria are arranged into a set of categories that address the instructional design, software design and content of the courseware to be evaluated. Through a process of reflection and discussion, the individual criteria are refined and focused at the end of each judging competition to describe the highest standards that can be expected from engineering courseware.

The use of the evaluation criteria were promoted as prescriptive statements, or best practices, for the design, development and use of courseware in engineering education [4]. In the next sections we transform the evaluation criteria into best practice statements and provide illustrative examples drawn from the *Premier Courseware* and finalist candidates.

Best Practices and ABET Criteria

An important facet of engineering education in the early 21st century is the relationship of teaching and learning activities to the accreditation process. A strong feature of the best practices that are described here is their relationship to the ABET accreditation criteria. The *Premier Award* evaluation criteria were developed prior to, and have evolved concurrently, with the criteria used by ABET to accredit engineering departments, often referred to as ABET Criteria 2000. The strength and broad applicability of the *Premier Award* evaluation criteria enable us to accurately and appropriately map *Premier Award* evaluation criteria (and Best Practices) to corresponding ABET accreditation criteria. In the examples that follow we will relate the best practice to the appropriate ABET criteria.

BEST PRACTICES IN INSTRUCTIONAL DESIGN

The category of Instructional Design addresses the basic question of whether the courseware facilitates learning. It covers areas such as learning objectives, interactivity, cognition and conceptual change, content, use of multimedia and instructional use and adaptability.

The effective pedagogical application of the courseware is also a key consideration in overall instruction design strategy.

In practice, courseware are designed for various instructional uses such as in lectures, during recitation sections, as self-paced study, as reference material, as supporting exercises/explorations in studio classroom environment, as virtual experiments in laboratory situation for the student to perform alone or in a group.

A common feature in *Premier Courseware* developers is that they have an understanding of instructional design theory that guides their development process. As evidenced by documentation and assessment data and analysis that each *Premier Courseware* developer submits along with their courseware, many developers are guided by an understanding of learning styles and learner profiles such Bloom's taxonomy and the Myers-Briggs Type Indicator.

Best Practice: Courseware should have a clear statement of and support for appropriate learning objectives and goals.

A clear statement of learning objectives, combined with actual support for, learning objectives and goals enables the users of courseware, whether they be instructors or learners, to understand what the courseware is expected to cover and more importantly how to assess their use of the courseware.

In addition to meeting their individual objectives and goals, most *Premier Courseware* also contain learning objectives and outcomes that directly align with one or more ABET accreditation criteria. Most notable among these goals statements is: to increase conceptual understanding of a specific subject area; to gain calculation skills; and to gain higher-level cognitive skills of reasoning, critical thinking and problem solving.

A distinguishing characteristic of *Premier Courseware* is that their developers specifically list their learning objectives and goals in their documentation and more importantly ensure that the courseware supports and enables them. This focus on learning objectives is readily evident from their documentation including their statement of purpose and the assessment data that is included. The following paragraphs give example of these principles exemplified in past award winners.

BEST SiteSim "enables students to simulate hydro-geologic or geologic [analysis based upon] site information and...a budget, much as an engineer might...in the real world. ... With *BEST SiteSim*, students choose and integrate a variety of diverse, imperfect information, adhering to a budget, to help prepare them for solving problems encountered in their engineering career." Through the case studies and scenarios, students are able to demonstrate the learning objectives defined by the *BEST SiteSim* developers including an understanding of abstract skills such as the "application of geology and optimization of investigation strategies", "confidence in dealing with ambiguity" and an "emphasis on real-world concerns". Through the simulations in the courseware, students are able to achieve and demonstrate their mastery of the learning objective to have a "sense of vertical and lateral continuity of subsurface units".

Cracking Dams, as its name implies investigates how cracking occurs in dams at three different complexity levels with objectives and goals appropriate to each level. For

beginning users, from Kindergarten through 4th grade and those seeking a general introduction, the courseware sets the goals of providing a basic background about dams and the causes, processes and results of cracking. These objectives are clearly stated as the learner steps through the courseware and the straightforward, non-technical descriptions make it easy for the learner to comprehend the materials and meet the learning objectives and goals. For advanced users such as undergraduates, *Cracking Dams* provides similar learning objectives and goals but expects the learner to demonstrate a greater level of sophistication, as expected, through complex simulations where finite element methods are used to model dam behavior during cracking.

Best Practice: The learner should be actively involved in the learning process via interaction with the courseware and other learners.

For the learner to be actively involved, courseware should respond appropriately and meaningfully to learner actions and enable the learner to control his/her own pace and mode of learning. In addition to interacting directly with the courseware, interaction with other learners, as part of an entire experience is an important factor in the design and use of courseware in engineering education. [ref to criteria]

MecMovies [8] is “an extensive collection of useful examples, discussion of theory and games designed to complement introductory Mechanics of Materials Courses”. [ref to citation] *MecMovies* provides animated explanations for topics in Mechanics of Materials that require the learner to interact with the courseware. The learner can control the pace of the theoretical presentation and can view calculations or visualizations to aid in their understanding of the topic. The learners can demonstrate their understanding through interactive exercises that require them to enter numerical values and select appropriate visual representations of topics, such as Mohr’s Circle and stresses and strains. Thus *MecMovies* is a good example of courseware activities facilitating active engagement of the learner.

Interactive Groundwater [7] is an “interactive software environment that allows the simulation of 2-D area and cross-sectional flow and transport in aquifers”. *Interactive Groundwater* builds upon the level of interaction demonstrated by *MecMovies* by allowing the learner to control the learning process by performing real-time groundwater modeling, visualization and analysis tasks.

Interactions with fellow learners and instructors are an important facet of the learner being actively involved in learning. Some *Premier Courseware* achieve this through activities designed to engage small groups of learners in discussions or interactions outside of the courseware. Case studies such as *In Hot Water* [9] —which “investigates alternatives for enhancing cooling tower performance and how decisions based in engineering theory have series financial and operational implications—and *Della Steam Plant* [9] —which illustrates problems in a turbine-generator unit and two conflicting solutions—both provide in-class activities for instructors. Or take the case of *West Point Bridge Designer* —

is “a tool for visualizing the structural behavior...and the engineering design process” [ref to citation] of building a bridge—is the basis for a national competition in which teams of middle schools students collaborate to win a college scholarship.

One *Premier Courseware* provides a tool, integrated with the courseware, to facilitate interaction between learners and instructors. *Electronic Curriculum* “includes twenty-four interactive learning modules [in introductory electronics] and utilizes two novel educational technologies (*Scribe* and *WebTeam*).” *Scribe* provides a means to capture, review and modify a student’s use of an interactive learning module while *WebTeam* allows learners to collaboratively explore, design and test. “A great strength of the approach used in *Electronic Curriculum* is that it augments the instructor’s ability to discern and address students’ key conceptual blocks and to monitor student performance.”

Best Practice: Learning should be integrative and transferable.

For learning to be significant and long lasting, the learner must be able to demonstrate or apply the concepts in meaningful ways and must be able to transfer that knowledge beyond what is specifically covered in the courseware. Additionally the courseware may support reflection, deep thinking, knowledge integration or making connections. [6]

This best practice is a difficult one to measure as by the nature of the best practice, the learner would need to be assessed well “after” the use of the courseware to determine if the learning was “long-lasting”. Nonetheless, most *Premier Courseware* provide opportunities and mechanisms that enable learning to be long lasting.

The nature of the experiential learning, “integrating experiment, perception, cognition and behavior” [reference to Kolb], that occurs in case studies provides opportunities to demonstrate the development of higher-order cognitive skills—which in turn can demonstrate significant and long-lasting learning. In the *Virtual Disk Drive Design Studio* the learner enters an “immersive, virtual design environment in which the learner designs ACME Engineering’s newest disk drive.” In this courseware, learning can be significant and long-lasting because the learner must synthesize how the interplay of the individual technologies (e.g., read heads, platter materials, etc.) contributes to the cost and performance characteristics in the design studio [11]. In the *Bicycle and Electric Drill Dissection Multimedia Case Study*, the mechanical dissection exercises highlight the importance of functional specifications in design and how they map into specific functions and final design solution [10]. Or in case studies such as *In Hot Water* and *Della Steam Plant* with real-world problems in actual settings, learning can be significant and long lasting because of the skills and understanding required to synthesize solutions to the problems presented [9]. Additionally, the open-ended nature of the design problems described in these case studies and the real-world examples also address important ABET criteria.

Best Practice: Content should be well chosen and structured.

It is clearly important that the content be appropriate for the intended learning objectives and audiences. The structure of the material must also be such that the material can be easily assimilated. It is often the case that the content should be ordered in a way as to guide the learner through it, while still allowing the learner control over their pace. The content should also be conveyed clearly and build upon and communicate required prior knowledge. [ref to criteria]

Ten Principles of Materials Handling “introduces the primary concepts of materials handling”. The content is structured as a matrix with multiple entry points to guide users through each of four layers of practice—Discover, Explore, Contrast and Extend—for each of ten principles. The Discover Layer allows learners to discover a principle by watching a situation that clearly illustrates application of that principle. The four layers provide significant structure to the content, as an example of this best practice. The Explore Layer allows learners to explore the principle in more depth by examining key aspects of the principle. The Contrast Layer presents a couple of cases that illustrate improper and proper application of the principle being studied. The Extend Layer discusses the same principle in a different context to promote generalization of the learning principles.

WSDOT Pavement Guide Interactive is a “virtual ‘encyclopedia’ of pavement knowledge”. Designed to meet the needs of working professionals and university students *Pavement Guide Interactive* provides a large amount of information (275 web page, 2,500 images, 50 animations, 14 videos and 11,000 hyperlinks). The comprehensive nature of the courseware, combined with its strong internal structure and organization into modules, address the needs of both of its target audiences and serves as an example of this best practice.

Project Links “provides a comprehensive environment of learning materials that link fundamental mathematics topics to applications in engineering and science. *Project Links* numerous modules provide the breadth that enables learners in mathematics to link to appropriate, motivating engineering examples for the mathematics as well as providing details on the mathematics behind a wide range of engineering disciplines. The breadth, coupled with their topic groupings (either by mathematics or engineering) and detailed status indicators (indicating development status) provide a good example of well-chosen and structured content.

Best Practice: Multimedia should be used effectively to promote learning objectives and goals.

Multimedia—video, audio, animations, simulations, etc.—is an important component of courseware; it provides alternatives to purely text-based content and enables the learner to visualize content in new and novel ways, perhaps addressing a particular learning style. However, as the technology to produce multimedia continually improves and bandwidth to deliver it increases, it continues to be important to ensure that if multimedia is used, 1) it is used appropriately and not gratuitously, 2) does not provide ambiguity or misconceptions, 3) it is of high visual and aural quality and 4)

overall it helps learners construct inter-related (e.g. visual and numerical) knowledge.

Mars Navigator —interactive courseware about Mars, Aerospace Engineering, Astronomy and JPL Mars Missions; *Demonstration in Signals, Systems and Control* [12] —“web-based modules that contain numerous Java applets covering a wide range of concepts in signals, systems and control.” [ref citation] and *MecMovies* each use multimedia to help the learner visualize a difficult concept. *Mars Navigator*’s animations and simulations help learners visualize the Mars Pathfinder and Global Surveyor missions. The Java applets in *Demonstrations in Signals, System and Control* help the learner visualize the complex mathematics in signals, systems and control. And the *MecMovies* “animations and illustrations...often reveal the internal effects produced in solid objective in ways not possible through classroom sketches or textbook drawings.”

In *Visual Mechanics of Materials (VisMoM)* [2], interactive sections use multimedia effectively to visually portray relationships between different content. “Relationships between material/load and stress/strain/deformation are interactively displayed as the user moves the cursor over the different pieces of the content. This kind of interaction is designed specifically to use multimedia to develop connections (scaffolds [6]) between the different pieces of Mechanics of Materials puzzle.”

Best Practice: The courseware should be able to be used in a variety of settings.

The use of courseware according to its design intent—stated learning objectives and audiences—would by definition be the only use the developer can evaluate and assess. The developer should plan on providing appropriate documentation and understanding of how to evaluate the use of the courseware in this setting. However, the true strength of the usability of courseware to enhance teaching and learning is that its use is not limited to the developer of the courseware. Because anyone, anywhere can make use of good courseware—designing courseware so it can only be used in a single or very limited settings should be avoided. Often times other instructors or learners will devise novel uses of courseware that were not in the original design intent, but are nonetheless appropriate uses for the courseware.

It has been our experience with the *Premier Award* that a defining characteristic of the award-winning software is that multiple audiences can use them in multiple settings. For example, the interactive problems or exercises in the *Electronics Curriculum* might be used in a studio classroom or by a learner in the library or *West Point Bridge Designer* might be used in a national competition for middle schools students or in a Statics class with undergraduates. Similarly the *Structural Engineering Visual Encyclopedia*, as its name implies, might serve as a reference source used by an instructor in the classroom, or by a practicing engineer.

BEST PRACTICES IN SOFTWARE DESIGN

The category of Software Design addresses the basic question of whether the courseware functions effectively from a software standpoint. It covers areas such as engagement, learner interface and navigation and technical reliability. [ref to criteria]

Best Practice: The courseware should hold the interest of a diversity of learners.

Beginning in the early 1990s, numerous engineering educators began to focus on the importance of learning styles and their impact on learning. Learning styles coupled with what educators observe about attention spans, expectations about “production-value”, and the tone and situations presented all have a large impact on the development of courseware. These factors combine to mean that courseware must be “engaging”. In other words, courseware should be: stimulating and challenging, responsive (perform quickly), visually appealing and should not contain stereotypes.

The user interface, images and colors used in courseware can contribute to the “engagement” felt by learners. In *Cracking Dams*, engineering principles are made accessible to students from kindergarten through 4th grade by the use of “Dammy the Beaver” as a guide and the illustrations used throughout the courseware. Similarly, *Jeroo* [3], which introduces learners to the basics of object-oriented programming, uses an effective metaphor of an animal, a Jeroo, that can hop in one of four directions, cannot swim and is able to carry objects in its pouch. The author’s assessment has shown that this metaphor coupled with the tools provided by *Jeroo* helps learners, especially middle school girls, enthusiastically approach object oriented programming.

Best Practice: The learner (user) interface and navigation should make the courseware easy to use.

The learner, or user, interface and the navigation structure of the courseware are how learners interact with the courseware. Courseware should be consistent in its design and response to learner actions, should not confuse the learner and should enable the learner to form a “mental map” of the courseware. [ref criteria]

An example of a good learner interface can be found in the *Virtual Disk Drive Design Studio* [11]. To provide the background information on disk drives, an image of a disk drive is used to navigate to each of the sections (e.g., read heads, platters, etc.)—not only is this engaging but it also helps reinforce the physical relationships of the components that will be helpful when “designing” ACME Engineering’s newest disk drive.

Best Practice: The courseware should be technically reliable.

Technical reliability is an assumption of any good software -- courseware is no exception. There should be no obvious bugs and the software should be reliable and not “crash”. One of the best mechanisms to ensure reliability is for developers to perform a structured and extensive testing program so that

each portion of the courseware and all of the alternatives in the possible interactions are exercised and found to operate correctly.

An extension to this best practice, is that developers should use hardened “commonly” available tools such as Web browsers (e.g., Internet Explorer, Netscape or Firefox), applications (e.g., Adobe Acrobat PDFs or Microsoft Word Documents), digital video formats (Apple QuickTime or Microsoft Windows Media Video/Audio) and plug-ins (e.g., Macromedia Flash) to deliver their content.

Some courseware modules are successfully implemented by using object-oriented programming languages like Java and Java script. In *Demonstrations in Signals, Systems and Control* [12], and *Java-DSP* [15], Java Applets are used to enable on-line simulations and web-based computer laboratories for use in digital signal process courses. In *Engineering Graphics*, interactive games and quizzes are effectively implemented using Java script.

Best Practice: The evaluation of the courseware and its impact on learning outcomes should include appropriate stakeholders and assessment methods

Assessment of the use of courseware is very important “to predict success, measure value and prove worth”. Best practices in developing an assessment plan require addressing issues such as types of learners and levels of evaluation, data collection details; and methods for analyzing the data and the results. A comprehensive assessment plan needs participation from student and instructors, and possibly coordination at departmental and institutional levels. It takes time, requires expertise and costs money [5],[14]. For several *Premier Courseware* modules, the assessment project was conducted by a third party organization such as an evaluation consortium.

The motivation for *Premier Courseware* development vary widely, with the following being most frequently cited: to enrich the learning experience, to enhance teaching/learning environment, to engage a diversity of learners and to provide an increase in ABET-related student’s learning outcomes.

Most *Premier Courseware* evaluated learning improvements by pre/post assessments at a minimum. Some looked at improvement in retention of underrepresented students (e.g., *Della Steam Plant Case Study, Bike Dissection*).

Several included a triangulation of both qualitative and quantitative methods. For example, in *Interactive Groundwater*, the evaluations considered the whole-system learning that linked performance tasks with integrative activities, such as defining problems, making assumptions, integrating sciences, constructing arguments and articulating results. The assessment is an embedded, integrated and seamless part of the learning environment.

SUMMARY AND CONCLUSIONS

This paper discusses best practices in the design and development of engineering education courseware by examining the courseware recognized through the *Premier Award for Excellence in Engineering Education Courseware*. By reading and understanding the illustrative examples given

above and drawn from the courseware recognized by the *Premier Award*, courseware developers will be able to improve their designs leading to potential increases in learning effectiveness.

Examining courseware recognized by the Premier Award leads to the following observations:

- Learning objectives, goals and assessment strategies are critical aspects of good courseware design.
- Courseware design and use can be and should be related to ABET accreditation criteria.
- Case studies can be effective types of courseware—they can demonstrate real-world problems and situations requiring effective synthesis and analysis.
- Games can be effective in engaging students' attention in courseware and they can be designed to enable the learner to demonstrate his/her understanding throughout the game.
- Presenting comprehensive content can be effective and should be accompanied by effective structure and navigation.
- Interactive animations and simulations can be important features of courseware—they enable learners to learn in multiple ways by connecting calculations and numbers with physical representations.
- Courseware should be flexible—in the settings, audiences and objectives for which it is used so that it may be easily adopted and adapted by others.

The process of moving from the effective design of award winning courseware to the effective use of courseware is somewhat straightforward. Best practices in design should be matched with effective learning experiences. The documentation provided by the courseware recognized by the *Premier Award* illustrates practices that contribute to the effective use of their courseware. These effective practices include a clear statement and understanding of the learning objectives and goals, selection and use of the appropriate tools (in this case their courseware) in appropriate settings and methods of assessing the learning objectives. Based on the reports of the authors' practices, a simple model for effective learning experiences using courseware can be described as a set of questions that must be answered: what are the objectives, how can these be achieved (what tools, learning settings, etc.), and how can the objectives be assessed.

OBTAINING COPIES OF THE PREMIER COURSEWARE

Reviews and descriptions of the *Premier Courseware* can be found at www.needs.org. Although many of the modules are available on the web, individual copies of the *Premier Courseware* are also available on CD free of charge from NEEDS. Please email premier@needs.org with your name and mailing address and indicate which year(s) you would like to receive. Please be aware that only a limited number of copies of the 1997-1999 Premier Courseware are available.

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REFERENCES

- [1] Agogino, A. M., & Muramatsu, B. "The National Engineering Education Delivery System (NEEDS): A multimedia digital library of courseware", *International Journal of Engineering Education*, 13(5). (1998). Premier Award: <http://www.needs.org/80/needs/public/premier/>
- [2] Borchert, R., Jensen, D., and Yates, D., "Hands-on and Visualization Modules for Enhancement of Learning in Mechanics: Development and Assessment in the Context of Myers Briggs Types and VARK Learning Styles," *Proceedings of ASEE Annual Conf.*, Charlotte, NC, June, 1999.
- [3] Dorn, B. and Sanders, D., "Using Jeroo to Introduce Object-Oriented Programming", *Proceedings of the 2003 IEEE/ASEE Frontiers in Education Conference*, Vol.1, November 2003, pp. T4C 22 – T4C 27.
- [4] Eibeck, P.A. "Criteria for peer-review of engineering courseware on the NEEDS database. IEEE Transactions on Education", *Special Issue on the Application of Information Technologies to Engineering and Science Education*, 39(3). 1996
- [5] Horton, W., "Evaluating E-Learning," *American Society of Training Development*, Alexandria, VA. 2001.
- [6] Hsi, S. and A.M. Agogino, "Scaffolding Knowledge Integration through Designing Multimedia Case Studies of Engineering Design," *Engineering Education for the 21st Century: Proceedings of Frontiers in Education, FIE'95, ASEE/IEEE*, pp. 4d1.1-4d1.4.
- [7] Li, S. G. and Q. Liu: "Interactive Ground Water (IGW): An Innovative Digital Laboratory For Groundwater Education and Research", *Computer Applications in Engineering Education*, 2003, Vol. 11(4):179-202.
- [8] Philipot, T. A., "Comprehensive Evaluation of Animated Instructional Software for Mechanics of Materials," *Frontiers in Education Conference 2004*, Session T1A,1-6.
- [9] Raju, P.K., and Sankar, C.S., "Teaching Real-World Issues Through Case Studies", *Journal of Engineering Education*, 88 (4): 501-508. (1999).
- [10] Regan, M., S.D. Sheppard, "Interactive Multimedia Courseware and Hands-on Learning Experience: An Assessment Study," in press for *ASEE Journal of Engineering Education*.
- [11] Richkus R., A. M. Agogino, D. Yu, and D. Tang, "Virtual Disk Drive Design Game with Links to Math, Physics and Dissection Activities *Proceedings of FIE'99, ASEE/IEEE*, CD ROM ISBN #0-7803-5646-2, pp. 12c3-18 to 12c3-22.
- [12] Ross, M.J. and W. J. Rugh "Interactive Mathematics on the Web: *MathML for Signals and Systems Demonstrations*", to appear in the *IEEE Control Systems Magazine*.
- [13] Sanderson, A.C., Millard, D.L., Rosenberger, T., Jennings, W.C., and Sanderson, S.W., "Multimedia Interactive Learning Modules for Design and Manufacturing Education", *Frontiers in Education Conference*, Salt Lake City, UT, November, 1996.
- [14] Sheingold, K. and Frederiksen, J., "Using Technology to Support Innovative Assessment," *Technology and Education Reform*. Ed. Barbara Means. Jossey Bass Publisher, 1994.
- [15] Spanias A., Ahmed K., Papandreou-Suppappola A., and Zaman M., "Assessment of the Java-DSP (J-DSP) On-Line Laboratory Software," 33rd ASEE/IEEE FIE-03, Boulder, Nov 2003
- [16] Tront, J.G., Muramatsu, B., and McMartin, F., "Evaluating Quality in Computer-Enhanced Learning Materials in Engineering Education," *Proceedings of the 2003 International Conference on Engineering Education*, Valencia, Spain.