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# The National Engineering Education Delivery System (NEEDS): A Multimedia Digital Library of Courseware*

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*NEEDS is the architecture for courseware creation, delivery and evaluation developed by the Synthesis Coalition to enable new pedagogical models based on Internet-mediated environments for learning. The NEEDS Database provides an access mechanism for students and faculty to a diverse range of engineering educational materials. The current courseware focuses on adding synthesis concepts through the curricula, with emphasis on mulitdisciplinary content, teamwork, hands-on experience, open-ended formulation and solving, and case studies of 'best practices' from industry. The database consists of collections of modular, digital courseware and courseware elements. The user is able to access and use courseware developed nationwide. In addition, the existing courseware and courseware elements can be adapted to local use in whole or by distilling several modules and joining them together to create a new customized module. The Synthesis Coalition now has the directive of making the NEEDS database available to other NSF Undergraduate Engineering Education Coalitions and other universities nationwide. NEEDS is available on the World Wide Web (WWW)) at:http://www.needs.org/. The NEEDS Editorial Board has been established to develop a comprehensive review procedure that will result in three tiers of courseware on the NEEDS database: non-reviewed, endorsed and premier courseware. We expect that the process of reviewing the courseware on NEEDS will not only benefit the users of the NEEDS database, but will also benefit authors by recognizing the scholarly and creative efforts that they have expended in developing effective, high-quality courseware. To this end, a new NEEDS Premier Award was recently initiated with partial funding from John Wiley & Sons, Inc. The winners were announced at the 1997 ASEE/IEEE Frontiers in Engineering Education Conference (FIE'97). The NEEDS project highlights interesting challenges to technology in education. How can electronic courseware meet the diverse needs of curricula among a cross-section of universities? How can educators modify their role to take advantage of new technologies and research on learning styles? What courseware access modes suit the needs of author, teacher and student? Can an infrastructure designed for static courseware be adapted to dynamically changing information on the World Wide Web? How can academe and industry work together to make effective use of the information technologies for engineering education and how can sustainable partnerships be maintained?*

## INTRODUCTION

OVER the last three years we have seen the explosion of the Internet and worldwide networked communications. The existence and movement towards this global network for the development and presentation of digital information is causing businesses and universities to rethink the method in which they provide information. The advent of low cost, widely accessible computers and high bandwidth networks is opening the door for new methods to enhance and possible transform the traditional education process. The advent of digital courseware and electronic supplements to education are becoming widely accessible by students, faculty and learners in general.

As engineering educators, we are seeing the traditional use of computers transformed from analysis tools (e.g. computer programs for numerical computation) to the use of information technologies in environments that realize engineering as a complex sociotechnical activity (e.g. multimedia case studies of engineering design). Engineering educators are being pulled into the new paradigms of information delivery by our students. The use of these state-of-the-art computer and information technologies challenge the traditional lecture model and force us to rethink student-teacher roles in the learning process. We are beginning to realize the paradigm shift from the teacher-centric lecture model to learner-centric, technology-assisted learning model that allows the student to control the learning process, with professors and instructors serving as mentors and guides.

The global network is also pushing the limits of publishing. For the education community, the

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quantity of material available in digital form is increasing daily. Faculty are putting their educational materials on network servers and on the World Wide Web. Much of this material is available to anyone with access to the source server. What role will traditional book publishers play in this digital world? What role will traditional software publishers play? Should authors receive remuneration for their intellectual property? If so, how? What is the value added by partnering with publishers and software companies? From the user's perspective, how can such partnerships improve the quality and accessibility of the educational material?

## THE SYNTHESIS COALITION

In the USA the Synthesis Coalition, with funding by the National Science Foundation and industrial partners, developed the NEEDS (National Engineering Education Delivery System) infrastructure to facilitate undergraduate reform efforts. The Coalition comprises eight diverse institutions: California Polytechnic State University at San Luis Obispo, Cornell, Hampton, Iowa State, Southern, Stanford and Tuskegee Universities, and the University of California at Berkeley [1–3]. For more information visit our World Wide Web site at http://www.synthesis.org.

## THE NATIONAL ENGINEERING EDUCATION DELIVERY SYSTEM

The NEEDS architecture consists of two branches held together with a unifying database (Fig. 1). On one side is courseware creation and development. On the other is delivery and learner access and interaction. The unifying trunk of the infrastructure is a database of engineering courseware with worldwide access for search, browsing and retrieval. The NEEDS database provides multiple access modes to courseware in order to meet the varied demands of our user community: authors, teachers and learners.

*Vision*

It is our vision that NEEDS, or some institutionalized evolution of NEEDS, will be the one-stop shop for digital educational resources for the engineering education community. This community includes traditional undergraduate colleges and universities as well as the entire education pipeline from K-14 to graduate school, continuing education and beyond. With students as our target audience, we are finding that they are increasingly demanding greater sophistication from faculty. Our students are realizing that information technology can be a time saver and the network allows course resources to be accessed anywhere, anytime. We have seen the use of class home pages by professors transformed from

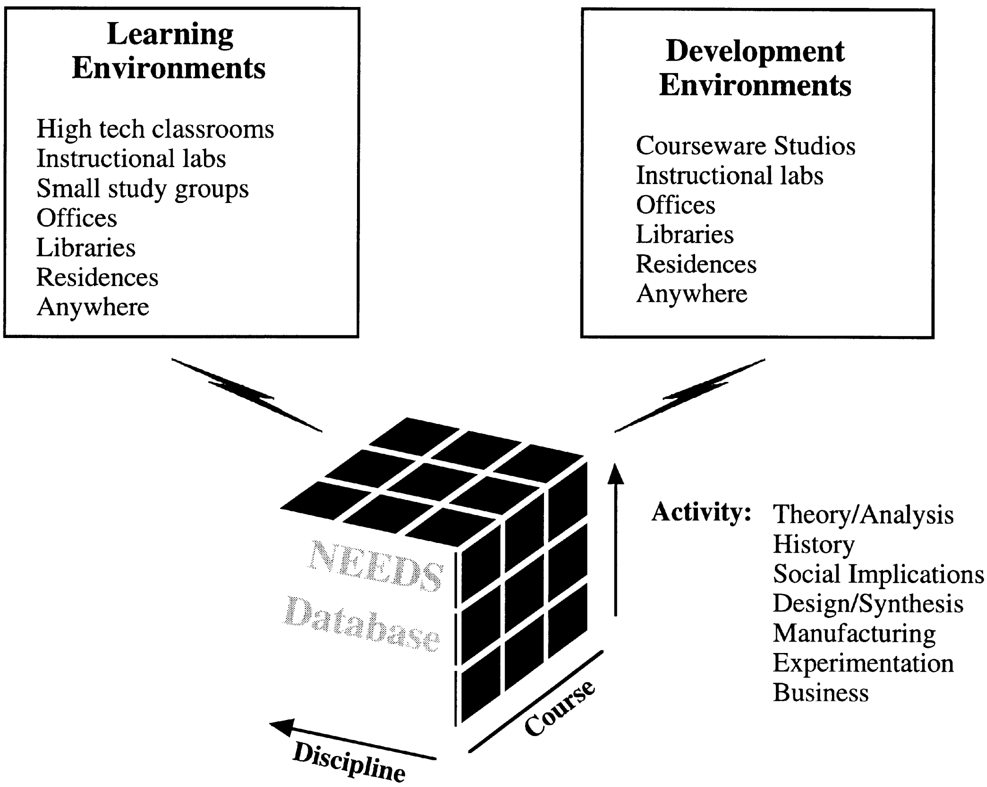


Fig. 1. The NEEDS database is linked to learning and development environments though the Internet. The database can be searched through a free text search and through a free text search and through a structured query. All courseware is cataloged in a modular fashion in order to capture the courseware curriculum dimensions shown above and allow reuse of courseware elements in other courseware.

simply putting the syllabus on-line to incorporating hypertext and hypermedia to providing additional information from annotated copies of lecture notes, copies of in-class demonstrations (through digital videos), homework assignments, solutions, etc. These resources can then be made available to the student at home, in the library, in an on-campus computer laboratory or in the classroom.

*NEEDS enables new pedagogical models*

NEEDS also serves as an enabler for expanding the role of computation from that of an analysis tool to one of an enabler for technology-enhanced learning. Well designed courseware can reach students in multiple ways and be flexible enough for a range of different learning styles. Courseware can take advantage of a rich variety of means of presenting information (e.g. visual, audio, dynamic) and interacting with the information (e.g. scaffolding, engagement, structured feedback), and can build on multiple methods of organizing the material (e.g. general reference source, hands-on enhanced laboratory manual, targeted curricular content). Hypermedia allows the author to accomplish these goals by connecting together presentations that integrate text, video, sound and analysis or simulation software within an organizational framework that encourages students to progress in directions of both breadth and depth [4, 5].

Once created, digital courseware can be easier to share and distribute with all the students than paper media. Once an instructor erases the blackboard in a lecture, the image is gone forever. Digital lecture notes, video, tutorials and other courseware can be played back later for review and reinforcement. With the addition of a threaded dialoging system called 'SpeakEasy', NEEDS will soon be able to provide a means for supporting worldwide discussion on the courseware and its content as well [6].

Synthesis has found that courseware can greatly enhance constructivist and experiential learning approaches. For example, the Kolb model [7] of experiential learning (Fig. 2) is of particular importance to the physical sciences and engineering as it is designed to promote integrative learning by cycling students through four cognitive/experiential modes that are key to success in professional practice: reflective observation, active experimentation, concrete experience and abstract conceptualization. Synthesis courseware is designed to complement traditional material which is heavy in analysis and abstract theory by filling the gaps and motivating the full Kolb cycle of learning. Examples of general areas of Synthesis courseware are described below [8]:

1. *Case studies* of design projects from industry highlight 'best practices', including strategies for solving open-ended problems. Specific topics include team building, life cycle design, social context for design and organizational aspects of engineering [9]. These multimedia cases are often coupled with hands-on 'dissection' activities [10, 11] in which students work in teams to take apart the engineered product highlighted in the case.
2. *Laboratory guides and experiments* use computers to integrate laboratory handouts with the collection, analysis and display of data. Mathematical theory is enriched with experience by linking together mathematical solvers, data collection and analysis facilities [12]. This courseware provides the core for integrative design and synthesis projects in which computing or embedded computing play an important role, such as in mechatronics design [13–16].
3. *Concept modules* teach specific engineering concepts and are useful where visualization is an important aspect. For example, dynamic systems are simulated for better visualization of theoretical concepts; dam inspection courseware couples analytical information to strong visual clues provided by real-world images [17–20].

*Implications in courseware creation and archival*

The main goal for NEEDS is to facilitate this revolutionary and continuing change in the class-

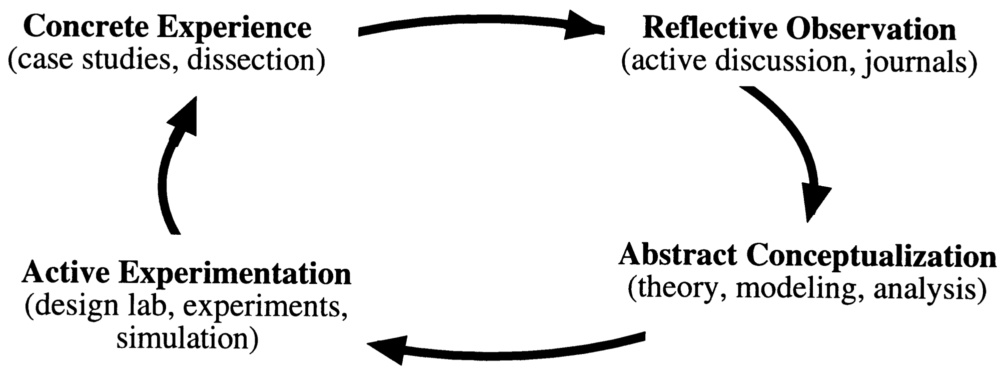


Fig. 2. The Kolb model for learning annotated with courseware type designations for each aspect of the experiential learning cycle. Integrative learning is promoted by cycling through four different cognitive modes.

room. NEEDS must support the storage and dissemination of the general content of the engineering curriculum along with improvements that address known shortcomings of this curriculum in a framework that enhances the ability of a student to apply experiential learning techniques. It must act as a shared resource across the entire engineering education community to rapidly transfer these new technologies into the national curriculum. Experience has taught us that a modular approach to courseware development is the only way for this material to be useful across even as small a group of institutions as that embodied by Synthesis. Courseware modules within NEEDS are thus designed for ease of revision and effective reuse in a wide range of settings, including classrooms, laboratories and other student environments (Fig. 1). In addition this courseware must be designed to encourage active learning and accommodate different learning styles among a diverse student population (Fig. 2). Thus the imperative is on an information system that can satisfy these diverse goals. NEEDS has evolved into an effective tool from the multiple viewpoints of all of its users [8].

### *NEEDS as a virtual library of multimedia digital courseware*

The NEEDS architecture moves the focus of learning beyond the boundaries of the physical locality of the classroom by enabling anywhere, anytime learning—learning on demand. NEEDS and on-line educational resources place the student in control of the learning process. The Internet allows the motivated student and proactive professor to provide supplemental instructional aids. The student is no longer limited to the textbook chosen by the instructor, nor the in-class lecture notes. The Internet and self-publishing realized through home-grown courseware, commercial courseware shipped with textbooks or sold as supplements, class home pages, etc. allow the student to pick and choose from those materials that will assist him or her in understanding the information, learning and learning how to continue learning.

The NEEDS search features are currently being transformed from that of a simple bibliographic search over authors, title, computer type and keyword searches to a system of classification that is geared towards the engineering student as the end-user. In order to make the information available to the student in a meaningful way, we will be providing thesaurus and hierarchical search options based upon topics traditionally found in engineering classes.

### *Using the NEEDS database*

The WWW has become a popular means of creating, displaying and navigating hypermedia documents using information servers with standard file and document formats (HTML—hypertext markup language) and a standard protocol for serving and browsing these files (HTTP—hypertext transfer protocol). The NEEDS database home page can be reached at: http://www.needs.org/.

The navigational tools, server databases and client software developed for NEEDS build on and expand the best national efforts in storing, accessing, indexing and transmitting elements from digital libraries. The search options for the bibliographic database (Fig. 3) include a full text search over standard library headings using the WAIS (Wide Area Information Services) indexing algorithm. The result of a query will be a prioritized list of courseware, courseware elements, collections of elements and other educational material. From each catalog record, the user can download the item selected (courseware, elements, etc.) or link to an image browser of the courseware, called NINa (NEEDS Idea Navigator). In some cases the user can also link to WWW/HTML versions of the courseware.

NINa (NEEDS Idea Navigator) is a browsing and retrieval tool that allows users to search courseware multimedia elements (pictures, movies, screen dumps, animations) in order to browse the courseware before downloading and to obtain the individual elements within the courseware. The multimedia elements in NINa are stored in an SQL (Structured Query Language) database

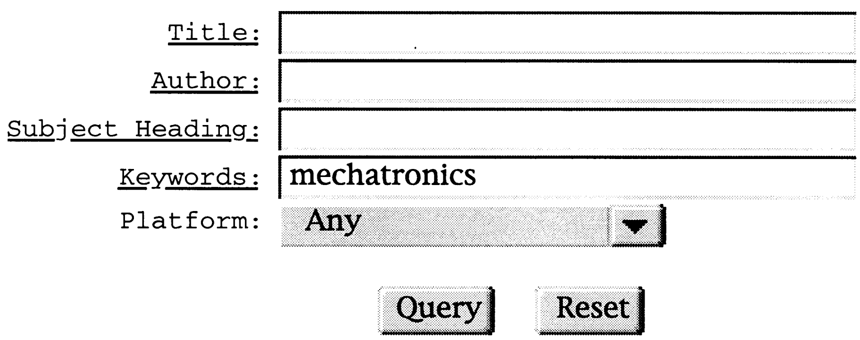


Fig. 3. Bibliographic Database Query—Search Over 'mechatronics'.

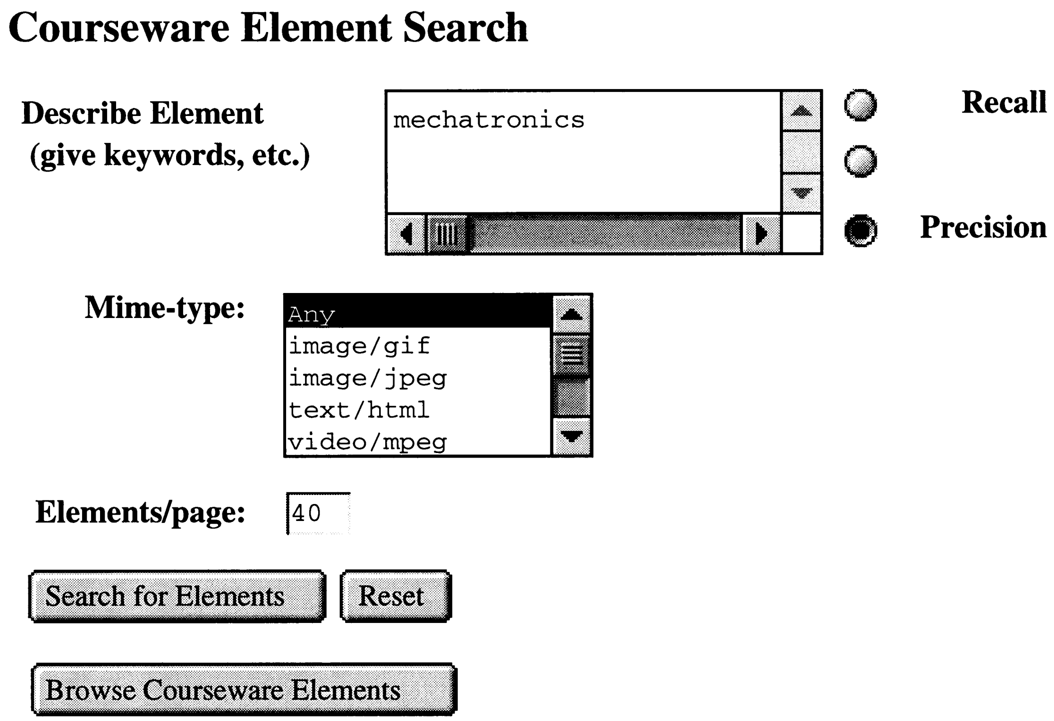


Fig. 4. NINa Query—Search Over 'mechatronics' elements.

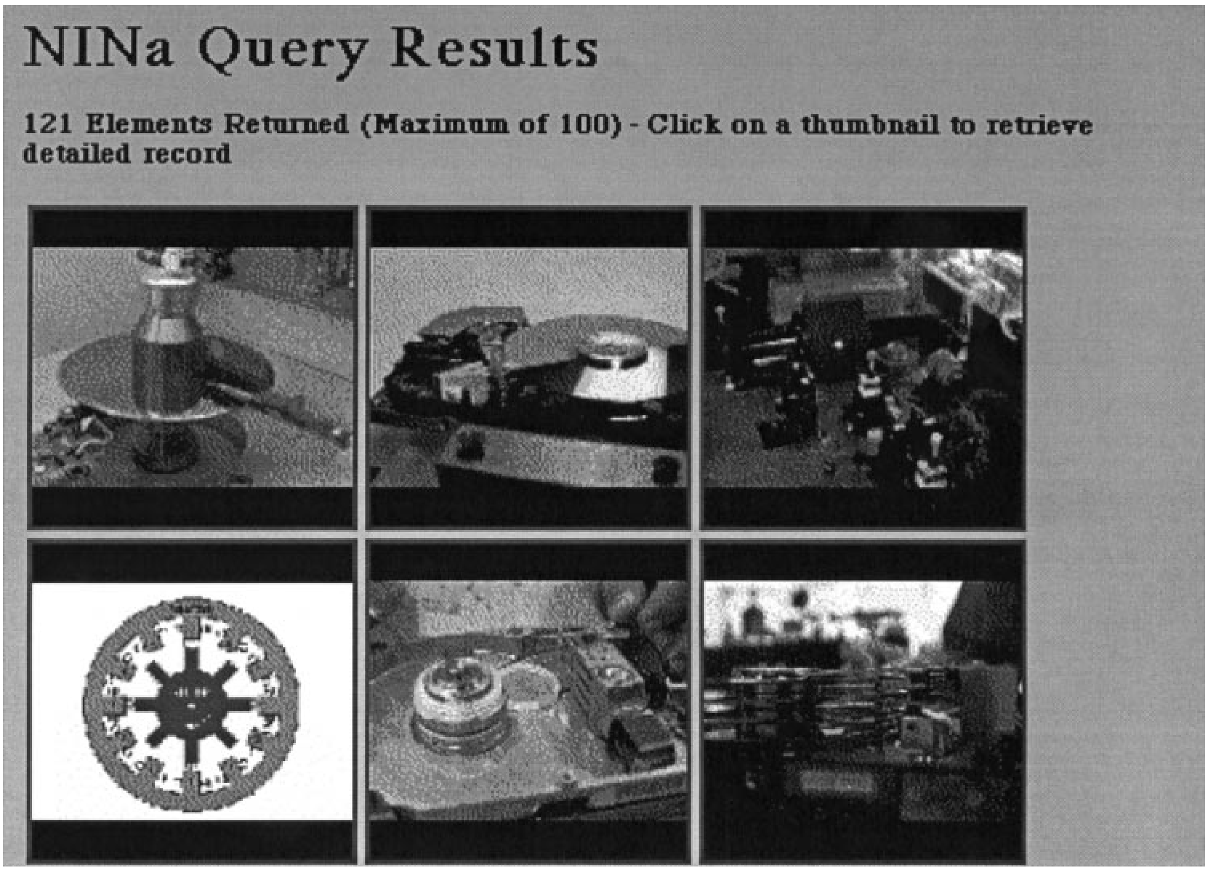


Fig. 5. NINa Query Results—Search Over 'mechatronic'.

with a user-friendly WWW interface which allows the user to search over keywords and element types (Fig. 4). The user has the choice of viewing the courseware element in a tile format (Fig. 5) of thumbnail images or viewing the results with a mixture of text and thumbnail images. Either way, a click on the thumbnail downloads the courseware element to the local computer and displays the image or tries to launch the needed application program.

## QUALITY REVIEW OF COURSEWARE AND NEEDS SUBMISSION PROCEDURE

Courseware on NEEDS, as with any scholarly effort, requires review to assure quality and provide recognition [21]. A NEEDS Editorial Board has been established with members from many of the NSF Coalitions and other institutions with experience with the review and evaluation of courseware [e.g. 22–24]. The first step in developing a review procedure was to first examine existing schemes of software, courseware and paper review, and then adopt those aspects that were deemed most appropriate for a rapidly changing environment of courseware creation in particular and multimedia technology in general. Based on this initial study [20], the NEEDS Editorial Board is developing and implementing a comprehensive peer review procedure that will result in three tiers of courseware on the NEEDS Database: non-reviewed, endorsed and premier courseware. Our goal, in the peer review process, is to establish that courseware has correct technical content, is easy to use and is potentially useful to instructors other than the author.

*Endorsed and premier reviews*

The peer review process that we are developing must consider the trade-offs between scope, completeness and expertise of the peer review with the time required to assess improved learning through use of courseware. This important trade-off differentiates the *endorsed* from the *premier* designations in the review process. The endorsed process will be subject to a peer review to evaluate the engineering content, author descriptions of content and recommended pedagogy, user interface and aesthetic aspects, and its potential usefulness to the instructors other than the author. Review for the premier level is reserved for the exceptional piece of courseware that represents a particularly creative or innovative use of multimedia courseware for instruction. There must be documented efficiency that the courseware has measurably increased student understanding of the given topic with respect to traditional lecture/textbook format or has reached a broader range of students. Authors for a premier level of review must submit student assessments of the courseware and additional documentation of effective pedagogical application of the courseware. In addition, the courseware will typically have been used and assessed by at least one instructor other than the author [21].

*Review procedure for NEEDS courseware*

Authors submit courseware to the NEEDS database through the NEEDS manager. This may be done through the on-line form system available on the NEEDS home page. Authors will be given the option to request a peer review of their courseware at this time. Figure 6 shows a flow chart of the NEEDS review process. Even non-reviewed courseware will be subject to a minimum level of evaluation by the NEEDS staff and cataloger to guarantee that the courseware operates and has sufficient information for operation and for cataloging. If the author requests a peer review, the courseware will be sent to the NEEDS Editorial Board and to the NEEDS database in parallel, initially with a non-reviewed status. Similar to a paper review process for 'best paper' or 'honors quality' the editors and reviewers may recommend that certain courseware be further evaluated for a premier award. The author may be asked to submit more information if he or she is interested in being evaluated for premier status.

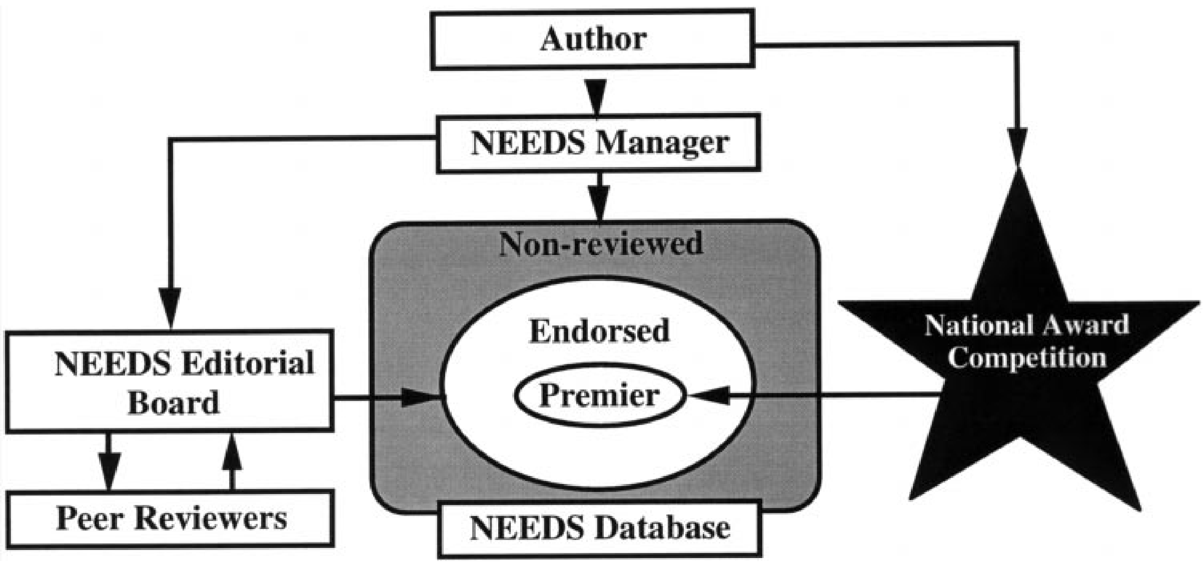


Fig. 6. Flow of courseware through the evaluation system for the NEEDS Database [20].

*First NEEDS premier awards*

The Premier Award for Excellence in Engineering Education Courseware was first introduced at the 1996 ASEE International Conference on June 22, 1996. The goal of the award is to 'recognize high-quality, non-commercial courseware designed to enhance engineering education'. The top 10 courseware packages (Premier winner and runner-ups) will receive cash and/or equipment gifts and honors. The winners will be announced at 1997 ASEE/IEEE Frontiers in Engineering Education Conference. Evaluation criteria are: engineering content, evidence of learning effectiveness and design features (instructional use, engagement, cognition, interface and navigation, multimedia effectiveness, appropriate interactivity and portability.) For more information, readers are referred to URL:http://www.needs.org/premier/.

## SUMMARY

The only certainty is uncertainty, and we predict dramatic changes in the performance and costs of instructional technology. We are moving from instructor-centric to student-centric use of instructional technology. The exponential growth in the Internet and network technologies and services has dramatically increased accessibility to make the 'anywhere, anytime' model of technology-enhanced learning a real possibility. Synthesis has developed NEEDS as a shared resource for archiving and sharing courseware that supports reforms in engineering education. In order to be in the forefront of the evolving landscape of networked information technologies, Synthesis has developed strategic partnerships with the digital library research and deployment projects, computer companies, and software and textbook publishers. For example, Synthesis has initiated an experiment with John Wiley publishers to make texts available as network resources alongside courseware modules. This promises to reveal interesting patterns of use that will direct the development of a networked model for educational publishing. Clearly the next few years will see new partnerships in delivery of television, power, telephone and education. Actually the technology is here—we are limited by legal, social and commercial constraints. The roles of the university and its libraries and museums are changing, as are the roles of the traditional textbook and software publishers. It is important that we all move forward together to develop new models that place the education of our students first.

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