A Community to Develop Materials for an Engineering Learning Environment

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Abstract

Faculty members attempting to create materials for collections of engineering education content in a digital library face several challenges. Lack of training in sound pedagogical practices, a shortage of training in the effective use of educational technology, short supply of required resources and time to produce completed and tested works, and a lack of emphasis on improved teaching in the university faculty rewards systems are the major obstacles to materials development. To remedy this situation, this project endeavors to create an active, engaged, and sustained virtual community of engineering educators who energetically contribute to and share materials from a common collection of courseware.

The virtual community will take form as an incubator in which faculty are trained in sound pedagogical practices e.g., developing learning goals and assessment techniques. Next, participants will be schooled in the effective use of technology in many different teaching/learning situations including: classroom presentation, self-study, distance and distributed learning, experiential learning, etc. Once trained, faculty will then develop a portion of a collection of courseware modules in their area of expertise. Guidelines will be provided so that modules can be integrated with one another from both the standpoint of technology as well as the pedagogical approach being used. Members of the virtual community of contributors subsequently become the testers of the courseware modules with each of the contributors using a subset of modules to conduct courses back at their home campuses. As soon as a baseline collection in a topic area is established we will present national workshops on how to adopt and adapt the materials in the collection. NEEDS will be used to catalog and make the collections available. This paper describes the research effort that is being undertaken to establish a community of developers. The work is in its early stages.

Introduction

> *"It is imperative that information about what is effective and ineffective be shared quickly and widely, so that our limited resources can be used prudently."*
> *TechEd 1999*

Instructional technology enables new modes of learning—via courseware, course web sites, collaborative communication, and in ways we have only begun to imagine. Educators around the country and around the world are developing

technology-based materials to support their courses. The potential benefits of instructional technology are well known and include: addressing multiple learning styles; promoting active learning; scaffolding learning; interactivity; geography-independent collaborative learning; enhancing visualization; and extending the reach of a typical course. Because anyone and everyone can be a publisher on the Internet, educators and students are experiencing an overload of information coupled with materials of widely varying quality. There is "currently no lack of 'great piles of content' on the Web, there is an urgent need for 'piles of great content'." [1]

Faculty members attempting to create high quality materials for collections of engineering education content in a digital library face several challenges. Lack of training in sound pedagogical practices, a shortage of training in the effective use of educational technology, short supply of required resources and time to produce completed and tested works, and a lack of emphasis on improved teaching in the university faculty rewards systems are the major obstacles to materials development. To remedy the situation, this project endeavors to create an active, engaged, and sustained virtual community of engineering educators who energetically contribute to a common collection of courseware materials.

Across most disciplines, there is a high activation barrier that must be crossed by faculty who wish to use digital learning materials in their courses. These materials are costly to develop, in terms of time and money. There is little re-use or incentive for re-use, which results in duplicated development. Adding educational resources to a digital library collection makes those resources easier to locate but also tends to highlight additional challenges in selecting the appropriate resource. The contents of digital collections vary widely and often do not contain a means for faculty to learn how best to make use of them (though various support structures are under development by participants in the National Science, Math, Engineering and Technology Education (SMETE) Digital Library program). Many of the digital learning materials do not include instructor's guides, training for faculty, or assessment information on the impact of the materials on student learning. Moreover, the introduction of new instructional methods into the classroom may be hampered by technical issues (lack of equipment or bandwidth), the need to re-design course materials, and inadequate guidance in aligning learning resources with teaching goals. These barriers are heightened by the time constraints that faculty face as they learn to use new materials. [2,3,4,5] The challenge, then, is to develop a process to allow faculty to quickly identify and select quality materials and to tailor them to fit the learning environment that exists on their campus.

The virtual community will take form as an incubator in which faculty are trained in sound pedagogical practices e.g., developing learning goals and assessment techniques. Participants will be schooled in the effective use of technology in many different teaching/learning situations including: classroom presentation, self-study, distance and distributed learning, experiential learning, etc. Once trained, faculty participants will develop a portion of a collection of courseware modules in their area of expertise. Guidelines, tools and support will be provided so that modules can be integrated with one another from both the standpoint of technology as well as the pedagogical approach being used. Members of the virtual community of contributors subsequently become the testers of the courseware modules with each of the contributors using the set of modules to conduct their courses at their home campuses. As soon as a baseline

collection in a topic area is established members of our team will present national workshops on how to adopt and adapt the materials in the collection.

The efforts of the community will go a long way in solving the multiple challenges related to the development and use of high quality courseware. Problems in the high cost of the time it takes to develop a collection capable of satisfying a single course's needs are overcome by the fact that the entire community contributes. Similarly, the not-invented-here syndrome is overcome and faculty from a broad community will more readily use materials developed elsewhere. Adoption/adaptation workshops induce others to use the materials as well as to participate in developing additional and extended materials. Finally, rigorous peer review and broad publication of the materials contributed to the collection will move the faculty rewards system towards properly recognizing the scholarly development efforts.

The process outlined above is mediated and facilitated through the use of technology. The National Engineering Education Delivery System (NEEDS) and the SMETE.ORG Alliance[1] will be used to catalog and make the collections available. Reviewers will be used to judge the quality of modules and collections, and to provide formative feedback to developers. The Premier Award processes [6] already in place have established a structure for the review process. Developer training will take place both in hands-on workshops as well as through the use of synchronous and asynchronous web-based mechanisms. Relationships with professional societies and publishers will make this effort a sustainable enterprise.

The primary product of the community will be the technology, the process and the framework to help developers come together, share the burden of content development, test the effectiveness of works in progress, and consign these works to a digital repository where others can use them. The initial part of the project will also produce a significant collection of technology-mediated materials in at least two areas of the engineering curriculum. Initially, topics are being selected from the areas of Statics and the introductory courses for Electrical and Computer Engineering.

Throughout the formation and operation of the virtual community, participants will be observed and the processes will be documented in order to effect improvements and extend the process beyond the treatment of the original two fundamental topic areas. We are conducting an in depth case study of faculty developers of learning resources to answer the following research questions:

1. What kinds of training and support services are necessary to best support faculty in developing high quality digital learning resources?
2. What are the characteristics of learning resources that foster and encourage their adoption and adaptation by others?

[1] SMETE.ORG is an e-learning partnership that offers a comprehensive collection of science, mathematics, engineering and technology (SMET) education content and services to learners, educators, and academic policy-makers in K–12 and higher education. SMETE.ORG was formed through funding by the National Science Foundation and partnerships with professional educational organizations, academic institutions and commercial e-learning companies. The partnership's Web site, www.smete.org, serves as the integrative organization and distribution mechanism for pedagogical material through its federation of SMET digital libraries. Providing direct access and delivery of instructional resources, SMETE.ORG promotes educational reform through participatory communities of learners.

3. What kinds of training and support services should digital libraries offer to best support faculty in adapting or adopting digital learning resources?

Through this project we hope to gain an understanding of the in-person and computer mediated social supports necessary to ensure broad use and wide-scale acceptance of the materials produced as well as the development process. This study will further bolster the acceptance of the materials repository, the National SMETE Digital Library (NSDL), by science, mathematics, engineering and technology (SMET) educators. Our investigation will build upon our previous work with two of the engineering education reform coalitions (SUCCEED[2] and Synthesis[3]), our experiences with NEEDS—A Digital Library for Engineering Education, and our research conducted by the Institute on Learning with Technology.

More specifically the community will:

- Identify specific topics from the areas of Statics and the introductory courses in Electrical and Computer Engineering that are candidates for improvement through the development of digital learning materials.
- Train developers in sound pedagogical methods, best practices for using technology in the learning environment, assessment procedures, and the use of development tools.
- Define a common user interface and set of ancillary tools usable in all community developed courseware modules.
- Develop at least 50 courseware modules.
- Evaluate the new courseware modules based on a proven set of criteria using a peer review process.
- Use the courseware modules in regular courses and collect assessment data for analysis and subsequent feedback into the development process.
- Conduct in-person and ongoing online workshops and training for faculty describing mechanisms for adoption or adaptation of the newly developed materials.

- Develop and disseminate a manual of best practices for effective contribution to the unified collection of materials.
- Assess the success of the community efforts by identifying learning improvements and any increases in faculty efficiency.

Providing Quality Materials: The Premier Award and Peer Review of Learning Resources

A discussion of quality materials often evokes strong reactions on the part of participants. It is important to recognize that quality means different things to different people and different things to the same person at different times. Research has shown that faculty users of a digital library such as NEEDS want a range of "quality" in the overall collection, but that they want to "find the

[2] The SUCCEED coalition consists of Clemson University, Florida A & M University, Georgia Tech, North Carolina A & T University, North Carolina State University, University of Florida, University of North Carolina at Charlotte, and Virginia Polytechnic Institute & State University.
[3] The Synthesis Coalition consists of: California Polytechnic State University, San Luis Obispo; CornellUniversity; Hampton University; Iowa State University; Southern University; Stanford University; Tuskegee University; and the University of California, Berkeley.

right thing" at the right time [2]. In response to user requests, contents of the NEEDS collection range from materials under development to fully reviewed, high-quality digital learning resources. To enhance discovery of the appropriate resources for instruction, NEEDS implemented pedagogical descriptors in the resource's descriptive metadata and built support structures to encourage discussion about the learning resources themselves (through user comments and online threaded discussions).

At the highest level, NEEDS focused on the development of the *Premier Award for Excellence in Engineering Education Courseware* as a process to identify exemplary courseware. In partnership with John Wiley & Sons, Inc. and other industrial sponsors, the *Premier Award* was developed to recognize outstanding non-commercial courseware designed to enhance engineering education. Now in its sixth year, the *Premier Award* has recognized 11 outstanding courseware packages and widely disseminated them to engineering educators [6].

Key to reviewing courseware for the *Premier Award* was the development of evaluation criteria. Through the Quality Review of Courseware effort NEEDS and Synthesis examined existing schemes of software, courseware and paper review. We adopted those aspects that were deemed most appropriate for a rapidly changing environment of courseware creation, in particular, and multimedia technology, in general. To develop these criteria, NEEDS worked with numerous experts including students, engineering educators, instructional designers, cognitive scientists, and learning theory experts [7,8]. The evaluation criteria focus on an overall evaluation of the resource by balancing its design with use (see Table 1).

Table 1 - Evaluation Criteria for Engineering Education Courseware

Instructional Design:	**Software Design:**	**Engineering Content:**
• Interactivity	• Engagement	• Accuracy of content
• Cognition/conceptual change	• User interface and navigation	• Organization of content
• Content	• Interactivity	• Consistency with learning objectives
• Multimedia use	• Multimedia use	
• Instructional use/adaptability	• Technical reliability	

These evaluation criteria will also be used as the basis for a holistic, journal-type, peer review used to evaluate courseware developed in this project and added to the NEEDS collection. The evaluation will be formative as well as summative. A segment of the community is also developing a mechanism for performing online peer reviews through the facilities of the MERLOT digital library collection. MERLOT will allow us to vastly increase the dissemination of the courseware materials.

Development of Digital Learning Materials

Research on how innovation succeeds, combined with current research on what SMET faculty want in a SMETE digital library [9], suggests that we need to organize a community of materials developers and enable participants to contribute to a collection of high-quality digital learning materials for engineering education. Further we must support and work with faculty who are interested in adapting or adopting the new learning materials. Each faculty developer will be assigned specific topics to address and will contribute five to 10 courseware modules to a common repository. The materials will be developed under common pedagogical goals and will employ a common user interface. Materials will be tested in the learning environment and peer reviewed. A second wave of faculty will be invited to develop additional courseware modules to fill gaps or extend the materials developed in the first round. The interface template, the best practices of the community, user's guides, and other development materials will be used to facilitate more efficient development in the second round.

We also will conduct an in depth case study of faculty developers of learning resources to answer the following research questions:

1. What kinds of training and support services are necessary to best support faculty in developing high quality digital learning resources?
2. What are the characteristics of learning resources that foster and encourage their adoption and adaptation by others?
3. What kinds of training and support services should digital libraries offer to best support faculty in adapting or adopting digital learning resources?

Through this research we hope to gain an understanding of the in-person and computer mediated social supports necessary to ensure broad use and wide-scale acceptance of the materials produced as well as and understanding the development process. This study will further bolster the acceptance of the materials repository, the National SMETE Digital Library (NSDL), by science, mathematics, engineering and technology (SMET) educators.

Defining and Operationalizing the Research

Training Materials Developers

The processes of teaching, learning, and the design of instructional materials are all interrelated and tightly coupled. Current educational research results describe several learning characteristics such as: active, constructive, individualized, culturally situated, and it takes time. [10,11] Appropriate teaching methods and corresponding instructional design can accommodate each of these characteristics of learning. Computing and communications technology can be integrated into the instructional design to facilitate the teaching process. By

> *"…for the computer to bring about a revolution in higher education, its introduction must be accompanied by improvements in our understanding of learning and teaching.*"
> --Nobel Laureate Herbert Simon (Kozma and Johnston, 1991)

using a set of guidelines, in the form of an instructional design/development model that assists with the process of design, an effective learning environment can be constructed. Developers will be required to answer questions similar to those in the following list:

- What do I want my students to learn?
- How can I best help my students to learn?
- What technologies can help and how?
- What student assessment measures are best?
- What evaluation measures for learning environments are best?

The answers to these questions and others will form the basis for guidelines used throughout the courseware module development process. Guidelines will be built as a shared vision in order establish a commonality among materials.

Developers will participate in a workshop describing strategies for designing effective learning environments. This workshop will train developers in sound pedagogical methods, best practices for using technology in the learning environment, assessment procedures, and the use of development tools.

Defining a Common User Interface

When using technology-based tools, many of the usage skills such as navigation are dependant on experience with similarly organized/operating packages. The ability for a student to move seamlessly from using one courseware module to another saves the time to learn operational skills and allows the student to focus on learning the subject matter.

We will define a common user interface and set of ancillary tools usable in all community developed courseware modules. A template will be developed to provide developers an easy mechanism to implement the user interface. To the extent possible, the source code for the user interface will be provided to the developers. A general design philosophy and style will prevail throughout all of the modules. Having them designed to this standard makes the overall collection of modules more "user-friendly".

Module Development

Courseware modules will consist of a variety of presentations and will likely be multimedia in nature. Modules may consist of interactive web pages based on Java scripts or other simulation tools, allowing students to try various design or analysis scenarios. Some modules will consist of animations that assist students in understanding difficult concepts or visualizing situations they have never encountered. Other modules may consist of video presentations showing design examples in the real world or discussions with renowned experts in a field. Synchronized streaming media presentations may also be used to bring the power of a video presentation integrated with a selection of still images, simulations, animations, and hyperlinks all into one interactive presentation package.

Each participating developer will be expected to produce between five and 10 new courseware modules based on the community design strategies. Target topic areas for each module will have been assigned to individual developers according to the process described above. Developing partners will be assigned to review materials as they are being assembled. Discussion lists will also be used to share results, difficulties, successes, tips & tricks, etc. among developers.

During the time developers are working on module implementation, several follow-up moderated discussions will be conducted with the faculty and their support personnel. It is important to link the online training and discussions with participants from the in-person workshops, because research suggests that discussions are more effective when the participants have met and established a level of trust with one another [12].

Evaluating Courseware Modules

Technology-based courseware modules must be of high quality in order to insure that they positively affect the students who use them and the faculty who integrate them into their courses. Courseware modules must meet reasonably high standards in order to be acceptable and usable in a large number of engineering courses across the country. To guarantee high quality, each new courseware module will be reviewed under the proven set of criteria described above. The evaluation process will be a peer review performed by volunteers knowledgeable of the subject matter and of the effective use of technology.

Adoption/Adaptation

To set the stage for the work proposed here, NEEDS faculty pilot tested a workshop titled "Evaluating, Selecting, and Using Computer Enhanced Learning Technologies and Courseware in Engineering Education" at the 2000 & 2001 Frontiers in Engineering Education (FIE) conference and at the annual Coalitions Conference. The workshop participants were mainly faculty who had taught for over six years, and were predominantly in electrical engineering. Participants felt that that their goals for attending the workshop were met, and would recommend it to others. They especially appreciated the opportunity to practice selecting materials in NEEDS and learning more about criteria for finding particular courseware. To improve the workshop, participants strongly suggested that it be longer, that it provide more in-depth coverage of the criteria for excellence, and that they get more practice selecting learning materials. Workshops similar to these will be given to assist faculty in using the collection of modules.

Extending the Developer Community

Addressing the need for high quality, unified, technology-based materials for the diversity of different courses taught in the engineering education community is a huge undertaking. This project endeavors to make the first step in unifying and organizing the materials, establishing a process and determining its effectiveness within a narrow focus. The logical next step is to enlarge the developer community and expand the target subject areas. Using the results gathered from the first stages of our project, we will design and prototype materials for in-person workshops tentatively titled "Developing and Using Courseware Resources for Introductory Engineering Courses" to be offered at both FIE and ASEE conferences in 2002 and 2003.

Workshops are offered to provide training to faculty seeking to participate in extending the collection of materials in the two initially targeted subject areas as well as for those interested in joining the community to work on future subject areas targets. We will provide training on how to use the template, and tools, along with the development and pedagogical philosophy to produce materials that can be integrated into the collection.

Not all faculty attend ASEE or FIE conferences. In order to ensure that we have broad participation in the development community during the second phase, we will develop and disseminate an online manual describing best practices for effective contribution to the unified collection of materials. At the same time we will actively seek new potential developers through web searches, literature review, personal contact and other mechanisms for connection.

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