

Using the National Engineering Education Delivery System as the Foundation for Building a Test-Bed Digital Library for Science, Mathematics, Engineering and Technology Education

C. Project Description

C.1.0 Introduction

Two key National Science Foundation (NSF) reports, “Systemic Engineering Education Reform: An Action Agenda” and “Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology,” urge the formation of a national resource to provide access to quality courseware and to disseminate successful educational practices [57-58]. Since the early 1990’s, NEEDS — the National Engineering Education Delivery System — has provided these services for the *engineering* education community. In response to the Digital Libraries Initiative – Phase 2, section C.III, “Planning Test-beds and Applications for Undergraduate Education” we propose to build upon NEEDS as the foundation for a test-bed Digital Library for Science, Mathematics, Engineering and Technology Education (SMETE).

We propose to:

- (i) Develop a test-bed Digital Library for Science, Mathematics, Engineering, and Technology Education (SMETE Digital Library). By using the existing the NEEDS digital library as a foundation, we will be able to provide courseware¹ cataloging, indexing, searching and downloading to the science and math communities. In partnership with the nine campus University of California System and with assistance from NSF in identifying target projects, we will catalog the courseware necessary to form a test-bed SMETE Digital Library.
- (ii) Initiate development of a SMETE Digital Library user community. We propose to begin developing a broad SMETE Digital Library user community of science, mathematic and engineering developers, adapters, adopters and learners. We will use focus groups in science and math to perform a needs assessment, which will explore basic issues regarding system functionality, standards, reviews, etc. We will determine what features of NEEDS currently satisfy these requirements and what features are desirable, but missing or inadequate in the current system. In addition, we hope to identify the potential value of a full-scale SMETE Digital Library.
- (iii) Evaluate the test-bed SMETE Digital Library. We propose to develop evaluation processes, methods and protocols to be applied in the development of a full-scale SMETE Digital Library. We will prototype these processes in evaluating NEEDS and the test-bed SMETE Digital Library.
- (iv) Develop recommendations for NSF’s continued development of a SMETE Digital Library based upon our needs assessment and test-bed evaluation.

¹ NEEDS defines courseware as instructional software and related educational material, such as videos, hardware and textbooks as well as an instructor’s guide and recommended pedagogical applications. Courseware can range in size from individual applets to term-long courses. It may be distributed by CD-ROM or World Wide Web sites.

C.2.0 NEEDS — The National Engineering Education Delivery System

C.2.1 The Current System

Synthesis: A National Engineering Education Coalition² (www.synthesis.org) has been at the forefront of engineering education reform since 1990. NEEDS is the distributed architecture developed by Synthesis to enable new pedagogical models based on Internet-mediated learning environments [3, 9]. The emergence of the World Wide Web (WWW) in the early 1990's as a viable means for national and international sharing and re-use of education materials fundamentally changed our view of the way education and learning can be delivered. Internet-mediated learning environments provide mechanisms for the learner to be *anyone, anywhere, at anytime*. NEEDS currently catalogs courseware and other instructional technology developed nationally and internationally to provide a resource where both instructors and learners can search, access, and download educational materials. In addition, NEEDS supports a multi-tier courseware evaluation system including a national award competition — the Premier Award for Excellence in Engineering Education Courseware [29].

C.2.1.1 Background on the NEEDS Database

NEEDS is built upon international standards for data description (USMARC and emerging metadata descriptors) and data access (http and the World Wide Web), because they allow access to all users [69, 82]. NEEDS uses a robust structured query language (SQL) relational database to store and index courseware records. The underlying framework for these courseware records is based upon a standard library format for indexing and storing documents (USMARC) [69, 82]. The USMARC standard lets us apply a wealth of cataloging experience gained in the library community. Key to continued success is evolution, which currently includes adoption of the metadata descriptors developed by the Educom Instructional Management Systems (IMS) project (database fields in use by NEEDS for at least the last two years are nearly identical with metadata descriptors recently recommended by IMS) [42].

Our experience with NEEDS has led us to add self-cataloging features for author-initiated addition of materials into NEEDS. In addition, consistent with library cataloging standards, we perform a basic review of courseware as it is cataloged. We provide this review to insure that the courseware record has certain required fields — e.g., a title, author, publisher and platform (e.g., PC, Mac, or WWW); to perform a standard check for viruses; and to verify that the program can be operated on the intended platform(s). We use this basic functionality check in place of forced editorial oversight before courseware archiving; we have learned that it is counterproductive to introduce too many barriers to the cataloging process. Instead we have developed review systems to evaluate courseware once archived in NEEDS.

Each *bibliographic* record describes the pertinent information about the courseware, in the same manner that traditional on-line public access catalogs provide information on books (i.e., title, author, publisher, subject heading, keywords, etc.). A user can search for courseware by entering terms into a WWW form — Title, Author, Subject Heading, Keywords, or Platform. NEEDS then performs a Wide Area Information Service (WAIS)-indexed full text search to provide a ranked list of courseware (the higher the ranking, the closer the courseware matches the requested query) [3, 9]. The user can then view the *bibliographic* record that describes the courseware and provides hyperlinks to download the courseware for different platform(s). NEEDS goes beyond the traditional on-line library catalog by providing recursive search capabilities and additional guiding and organization structures [82]. Hyperlinks on the courseware record provide access to related information indexed along multiple axes (i.e., author, publisher, subject heading, and courseware

² The Synthesis Coalition consists of: California Polytechnic State University, San Luis Obispo; Cornell University; Hampton University; Iowa State University; Southern University; Stanford University; Tuskegee University; University of California, Berkeley.

series). The capability to cross-index NEEDS courseware records provides a framework for extensibility. The hybrid capabilities in structured database queries (SQL) coupled with full-text search queries (WAIS) and our open architecture allows us to incorporate new research in controlled vocabularies and improved indexing and search algorithms. (See section C.4 for more details.)

Materials held in NEEDS are diverse — content ranges from single topics that can be covered in a few minutes to fully integrated, term-long courses. One of the most powerful concepts supported by NEEDS is courseware modularity, in some cases NEEDS catalogs courseware as well as the individual elements (e.g., images, videos, and text) that comprise the courseware. Courseware elements provide a vehicle for continued re-use of content material beyond the life-span of any particular courseware module. These elements can be used as is, or distilled from multiple sources and joined together to create new, customized courseware. Thus, the modularity supported within NEEDS is seen as a major enabling technology for fostering educational material adaptation and re-use.

C.2.1.2 Quality Review of Courseware

Courseware on NEEDS, as with any scholarly effort, requires review to assure quality and provide recognition [29]. The Quality Review of Courseware effort was developed to advance the field of technology-enhanced learning review as well as continually raise-the-bar for excellent courseware. We worked with numerous experts (including students, engineering educators, instructional designers, cognitive scientists, and learning theory experts) to develop a scalable evaluation system that balances the trade-offs between scope, completeness, and expertise of the peer review with the time required to assess improved learning through use of courseware [29, 70]. The result is a two level review process. *Endorsed* courseware relies upon a gestalt evaluation to determine: if the engineering content is error-free; if the package is complete with author descriptions of content and recommended pedagogy; if the courseware is aesthetically appealing; and if the courseware is potentially useful to instructors other than the author [28]. *Premier* courseware is subjected to an extensive evaluation by a panel of experts (e.g., engineering educators, instructional designers, and students) who bring their respective learning perspectives to the review process. The *Premier* review focuses on the courseware's capabilities and if it has demonstrated enhanced student learning. Judges use author supplied evidence of student learning; evaluation and assessment guides; instructor's guides and recommended pedagogical applications; and evidence of adoption and adaptation by others to evaluate these criteria. John Wiley & Sons sponsors the Premier Award for Excellence in Engineering Education Courseware, an annual national competition that identifies *Premier* Courseware.

C.2.2 NEEDS and the NSF Engineering Action Agenda Grant

NEEDS has recently been awarded a three year grant from the NSF Engineering Action Agenda program to provide services to the *engineering* education community through a proposal titled: "Expanding the National Engineering Education Delivery System as the Foundation for an On-line Engineering Education Community" [10]. From its inception NEEDS was conceived of and described as a digital library of courseware. However, based on our user studies and operating experience, NEEDS has progressed well beyond a manifestation of the traditional academic library in digital form, both in our target audience and in the services we provide.

Driven by notions of education and student learning, NEEDS also distinguishes itself from a commercial, Web-based search engine by providing focused, value-added services to our community. The success of NEEDS as a service depends not only on the development of a critical mass of content, but also on the development of a critical mass of viewership. The development of an on-line community — consisting of developers, adapters, adopters, interested parties and learners of the content made available through NEEDS — provides the means of sustaining NEEDS as a resource. The content continually draws the user back, and stimulates discussion among community members regarding adoption and adaptation of existing courseware, leading to new courseware development and courseware acquisitions. The community can address many of the concerns and challenges in

cataloging courseware (e.g., inadequate courseware description or lack of support material) by becoming a user-based support and evaluation system. Many of the new features we plan to add to NEEDS through the Engineering Action Agenda are focused at strengthening our present methods of review for all courseware within the system in order to help our user community evaluate whether to adopt or adapt a particular piece of courseware. (See pages C-14 and C-15 for a figure detailing the current and planned features of NEEDS.)

Using funds from the Action Agenda grant, we plan to add **Extended Usage Tracking** and **User Registration** to NEEDS. For the last three years we have relied on standard usage data generated by Web servers (e.g., browser-type and where the browser is located) to guide system development and features offered. However, Web usage logs do not allow us to easily couple information about what queries (searches) are performed with the results of that query, i.e., which courseware was presented, which courseware was downloaded, whether it was successfully downloaded, who downloaded it and why it was downloaded. To do this, we must institute a transaction-based system to track queries and their results. This system will allow us to provide authors with attempted download statistics and better understand our users' search patterns.

We also plan to institute a **User Registration** system for courseware downloads that allows us to map *who* uses courseware to *where* and *how* they are using it. This in turn facilitates longitudinal tracking and dissemination efforts for authors, and provides them with greater user feedback. We will track *successful* downloads with a follow-up survey to ascertain the adoption or adaptation of courseware; find similar or related courseware; and receive feedback for continuous system refinement. In addition, we will allow registered users to develop **User Profiles** through which we will proactively identify newly cataloged courseware of interest to the user. NEEDS thus becomes demand-driven by carefully targeting acquisition efforts toward identified content needs.



We plan to allow users to attach personalized **User Reviews** and supplementary **Support Materials** to the courseware bibliographic records. User Reviews will provide a wealth of community-based support for courseware. They may include information on a user's experience with the courseware and how a user employed the courseware — potentially expanding upon the author's original intent. A good example of User Reviews can be found at Amazon.com where book buyers can read reviews, written by other consumers, to better judge a book before making a purchase decision. Support Materials extend the catalog record by attaching user-provided links to related information.



We plan to continue to conduct **Endorsed Peer Reviews** and the **Premier Award**. As we do so, we expect to raise the expectation of what represents quality in courseware. In addition, we plan to develop **Feature Reviews**, similar to book reviews found in journals and newspapers.



We plan to add “off the shelf” threaded **Discussion** tools to further transform the static courseware record into a dynamic, living entity. These services extend the courseware record by providing a forum for users to discuss the courseware and its application.

C.3.0 Proposed Work

Action Agenda funding provides support for NEEDS to serve only the *engineering* education community using “off the shelf” software tools, it does not provide sufficient resources to examine a SMETE Digital Library. The proposed Digital Libraries Initiative – Phase 2 funding, however, will allow us to develop a test-bed Digital Library for Science, Mathematics, Engineering and Technology, perform user studies on this test-bed SMETE Digital Library and incorporate research from other digital library projects.

C.3.1 Develop a Test-Bed Digital Library for Science, Mathematics, Engineering, and Technology

We propose to use the NEEDS infrastructure as the foundation to support the development of a test-bed SMETE Digital Library. This infrastructure provides an existing system in which we can catalog, archive, and search for SMETE courseware. By expanding our scope to science and math, and its interface with engineering and technology, we break down the artificial barriers imposed by a strict disciplinary view of education. Because physics, chemistry and math are the pre-requisite lower division classes that can ultimately culminate in an engineering degree, it is a natural evolution of our work in engineering education to extend collection development into the sciences and mathematics by crossing the boundaries between physics, chemistry, math, and engineering.

As an initial step in developing the collection, we will work with our SMETE colleagues at Berkeley involved with a GE Foundation grant titled: “Integrating Calculus, Chemistry, Physics and Engineering Education through Technology Enhanced Visualization, Simulation and Design Cases and Outcomes Assessment” [30]. This grant builds upon existing curricular reform efforts supported by NSF, including the Synthesis Coalition, the Modular Chemistry Consortium, and a grant to “Improve the Gateway Courses in Chemistry, Mathematics, and Physics” [7, 58-64]. The GE grant has helped focus attention on the conceptual overlaps between these disciplines and has provided us the means to begin to understand and identify the different vocabulary and pedagogical approaches at the intersection between these disciplines.

In addition, we are working with the University of California System to identify and catalog materials developed system-wide in science, math, engineering and technology. As a result of an All University Conference on Teaching and Learning Technologies [71-73], the Office of the President is supporting our efforts to identify courseware and other educational technology developed within the nine campus University of California system for sharing and re-use. (See Section I for a letter of support from Dr. Carol Tomlinson-Keasey, Vice Provost-Academic Initiatives of the University of California, Office of the President.)

The materials developed through the GE grant, the Modular Chemistry Consortium and those identified in the UC System will form a strong, initial core of materials for our test-bed SMETE Digital Library. Over the course of this one year proposal, we will also perform web searches to estimate the quantity and scope of the materials available for cataloging in a full-scale SMETE Digital Library. We expect to be able to catalog additional courseware through our focus group sessions in math and science and from NSF program directors in target disciplines.

C.3.2 Initiate Development of a SMETE Digital Library User Community

C.3.2.1 Identify Potential Users

To identify potential users, we must accept a broad view of *who* our users may be. We must ultimately ensure a critical mass of viewership that will lead to increasing system usage. Our target user base, which is the SMETE community at large, can be described as a continuum of four learner/instructor user groups:

- *Developer* – designs courseware with defined learning objectives to meet a particular need, developing most if not all materials from scratch;
- *Adapter* – uses courseware developed by others as-is, with moderate modification and additional materials.
- *Adopter* – uses courseware developed by others as-is, with little or no modification or additional material; and
- *Interested Parties* – do not currently use courseware, but may be future developers, adapters or adopters.

While these four user groups by definition encompass learners (or students), it may still be useful to delineate the *Learner* as a special, fifth category. In doing so, we ensure our continued focus on learning. Our experience and on-going system evaluation have been instrumental in understanding how the system should operate for its intended user base [55].

We have identified several strategies to begin to build our SMETE user community [31, 45, 51, 53, 57]. We will begin with our collaborators in mathematics, physics, chemistry and biology at Berkeley on the GE Foundation grant. We will ask them to identify and recommend national participants in SMETE curricular reform. We will also identify appropriate grantees of previous DUE SMETE grants and select participants from previous SMETE curricular reform workshops [60-61]. Next we will search conference proceedings of appropriate professional society meeting(s), such as the annual meetings of the American Association for the Advancement of Science (AAAS), Educom, American Chemical Society (ACS), American Physical Society (APS), etc. in order to identify potential participants. As learners are a target end user, we will collaborate with partner schools through the chemistry consortia and engineering coalitions program to invite students nation-wide to become active within the community.

C.3.2.2 Perform a Needs Assessment

From this very broad definition of the SMETE user community, we will select a representative sample of users to participate in a needs assessment [80]. The most effective way to initiate this analysis is to utilize two sets of focus groups [46]. The first set will focus on identifying and clarifying user requirements and needs of the science and math components of our user community. The focus group topics will include:

- types of materials to be cataloged and topic/content areas users would find necessary or useful;
- types of standards and criteria for accepting materials;
- ease of use (e.g., types of tools and features, effectiveness of indexing, searching and downloading materials, etc.);
- perceptions regarding value of a SMETE Digital Library to learning, and possible uses; and
- features for encouraging development, adaptation and adoption of courseware.

From this first set of focus groups we will learn more about the SMETE community's views regarding the:

- potential value of a digital library for SMET education;
- level of probably use, as well as how community members envision using it; and
- type(s) of editorial oversight needed.

These results, will allow us to provide recommendations in direct response to questions raised from the National Research Council's Workshop "Developing a Digital National Library for Undergraduate Science, Mathematics, Engineering, and Technology Education" [60].

In the second set of focus groups we propose to initiate an evaluation of the test-bed SMETE Digital Library (developed in C.3.1 above) within our existing engineering education user community (e.g., developers and learners). We propose to address areas such as:

- what are the strengths and weaknesses of the existing service;
- how might the existing service be improved; and
- how to encourage the further development of our user community.

The SMETE developers, adapters, adopters, other interested parties and learners that we identify above will seed a general SMETE Digital Library user community and begin to form a critical mass of people and courseware in this area. Once identified, we propose to draw these community members into an on-going process of discussion and interaction. This proposal serves as the community

identification and formation component of a closely related effort proposed under the research side of the Digital Libraries Initiative – Phase 2, titled: “Research to Support a Community-Centered Digital Library for Science, Math, Engineering & Technology Education (SMETE)” [11]. (See section C.5 for more details on the interaction between these proposals.)

C.3.3 Evaluate the Test-Bed SMETE Digital Library.

The outcomes of our evaluation system will be:

- a system to regularly identify and prioritize enhancements to continuously improve Digital Library programs, services, structures and operations;
- a prototype for a process which regularly collects evaluation data that will be used to determine the success of the Digital Library’s services and goals; and
- new evaluation methods and protocols to further develop and assess a broader Digital Library to support the entire SMETE community.

C.3.3.1 System

Building on the results from the focus groups described above, telephone follow-up surveys will be administered to a small sample of focus group participants and some non-participants to ensure that the data collected during the focus groups accurately reflects the needs of the community. Together, the results of these two kinds of interviews will be used to establish an on-line user survey that will be incorporated into the initial user registration and cataloging processes. Embedding the collection of assessment data in this way allows us to capture both basic demographic information about the user (i.e., location, education, occupation, etc.), as well as more advanced data (i.e. *how* or *why* the community member expects to use the system to help him/her). Regular review of this data will be done for formative purposes in order to identify trends regarding the use of the system and potential areas for improvement and growth.

C.3.3.2 Prototype Evaluation Process

We propose to develop a prototype evaluation process for a full-scale SMETE Digital Library and test it by evaluating NEEDS [68, 77-78]. This prototyping process will allow us to test assessment tools, processes, and methods of analyzing data in order to examine their effectiveness. The NEEDS project provides us with an existing user community that, given the one year nature of this project, is readily accessible. Each of the methods described below will be the tools of the assessment process and will be tested on the community of engineering educators familiar with NEEDS. (Where possible, we will include a sampling of members of the science and math community. This data will help ensure that we are asking questions in a manner that is appropriate to each professional area.) The following section outlines the tools and processes that will be used and pilot tested in the evaluation of NEEDS.

The questions driving this evaluation are:

- What are the strengths of the services and programs provided by NEEDS?
- What areas of NEEDS should be improved or strengthened?
- How has the client’s use of the courseware been used to further engineering education? What has been the impact of this use on student learning, curriculum development, and faculty development?
- How has the engineering education community benefited from NEEDS?

C.3.3.3 Evaluation Methods and Protocols

Interviews/surveys: We will implement a telephone and on-line survey to a random sample of regular users of the system (NEEDS). The results will provide immediate feedback regarding the effectiveness of the service as it exists, the quality of the courseware encountered, and recommendations for how to improve. The survey itself will be a pilot for future on-line surveys described below.

On-line surveys: The development of the on-line user survey will be an important component for the prototype evaluation process. This survey will allow us to track information about the user that will assist us in profiling our users. Having accurate and in-depth user profiles will be an important step in strategically growing the system; they allows us to identify groups of users that we do not currently reach and develop programs or services to reach them. In addition to creating a profile, we will also be able to ask users about the effect of the courseware in their curriculum. For example, we will ask faculty to report on the impact it had on student learning; and ask students to report on the impact it had on their motivation to use the site as a resource or learning aid.

Cataloging: In the current cataloging process, we collect a variety of information from the courseware authors. The current cataloging protocol will be expanded to items that the focus groups and surveys have indicated should be available for each courseware record.

Discussion groups: Threaded discussion groups for individual courseware modules and concepts will provide unobtrusive means for evaluating the development of the SMETE Digital Library user community. Regular monitoring and content analysis of the discussions will provide insight into *who* is using the courseware, as well as *how* and *why*. Participants in the discussion groups will be informed of this process and only those conversations whose participants have agreed to be monitored will be included in the study. The amount and variety of participation in the discussion groups will be an important indicator of the level of faculty commitment to SMETE reforms and innovations. As a thorough content analysis would not be possible in a one year time frame, we propose to develop a set of metrics and criteria for use by longer-term projects, such as the one detailed in our companion proposal under the research side of the Digital Libraries Initiative – Phase 2: “Research to Support a Community-Centered Digital Library for Science, Math, Engineering & Technology Education (SMETE)” [11]. (See Section C.5 for more detail.)

User Reviews: The metrics and criteria developed above will also be tested on the User Reviews (see Section C.2.2), once they have been generated. User reviews are a good source of information regarding: the strengths and weaknesses of various courseware, pedagogical uses of the courseware, and adaptations or unintended outcomes of courseware that has been used. The number of reviews, in addition to their depth and breadth, will also indicate the level of engagement of users in the community discourse.

The evaluation process of the NEEDS project will lead to a better understanding of the evaluation requirements for a SMETE digital library. It will provide us the opportunity to test assessment tools and processes on a smaller scale, to examine the strengths and weaknesses in processes designed to collect data for formative purposes, i.e., information that leads to improving a program [56, 68], and to identify more specifically what the SMETE community values in a digital library.

C.4.0 Collaboration With Other Digital Library Researchers

The development of a SMETE Digital Library is an ambitious undertaking and should build upon existing efforts at collecting and indexing SMETE resources for learning. The Educational Object Economy (www.eoe.org) is a closely related resource that is focusing on a Web based community for learning tools in JAVA. Although narrower in scope than NEEDS, as its focus is on JAVA applets, it has a number of features which match and complement those that we propose. The EOE project is currently transitioning from Technology Reinvestment Program funding to a separate, independent foundation. Numerous other content specific resources for mathematics, physics and chemistry exist on the WWW. As part of this proposal we will use Internet “harvesting” to estimate the breadth and depth of science, math, engineering and technology education content available on the Web.

Two existing K-12 and education Web-based resources of note are the Eisenhower National Clearinghouse (www.enc.org) and the AskERIC service (www.askeric.org). The Eisenhower National Clearinghouse's (ENC) purpose is to provide K-12 teachers with a rich set of multimedia resources on mathematics and science curricula and to encourage the adoption and use of such materials in order to support national goals in mathematics and science. "The AskERIC Question Answering Service responds to questions on educational research, education issues, or the practice of education" but "does not have the resources to answer content specific questions" [12]. We have communicated with the staff of AskERIC in the past and will continue to do so to explore the intersections of undergraduate SMETE and K-12 education.

Due to our close involvement in digital library and database research we have been able to rapidly adopt evolving information technologies, as appropriate, over the five year period of NEEDS' operation [19-20, 41, 79]. Prof. Agogino has submitted a companion proposal, "Research to Support a Community-Centered Digital Library for Science, Math, Engineering & Technology Education (SMETE)," in order to address key open research questions. Research into these areas is not possible under current NEEDS operating funds nor are appropriate for the "Planning Test-beds and Applications for Undergraduate Education" section which this proposal targets. Tasks in this three-year research proposal are to: (1) develop a controlled vocabulary (CV) for representative fields in science, math, engineering and technology education (SMETE); (2) apply this CV as metadata for organizing, indexing and retrieving educational materials stored in the NEEDS digital library of courseware; (3) use digital library items combined with the CV to structure discussion and support virtual communities of practice for teachers, content developers and students, and (4) analyze the evolution of a contributory digital library with respect to on-line interaction and community knowledge structuring. If both proposals are awarded, Prof. Agogino will apply the research to the test-bed SMETE Digital Library proposed here and support its development after the first year of planning funding is completed.

C.5.0 Project Timeline and Milestones

October 1, 1998 – September 30, 1999

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|---|------------------------|
| • Identify members of a SMETE Digital Library user community. | Oct. – Dec. 1998 |
| • Identify and catalog science and math courseware into a test-bed SMETE Digital Library using the NEEDS infrastructure. | Oct. 1998 – March 1999 |
| • Collect evaluation data on NEEDS with engineering educators. | Oct. 1998 – June 1999 |
| • Collaborate with other digital library projects and specifically with other SMETE digital library projects. | Oct. 1998 – Sept. 1999 |
| • Perform a needs assessment for science and math. Perform focus groups at the annual meeting of the American Association for the Advancement of Science. (Note: we have already conducted and will continue to conduct focus groups at engineering conferences. This will be the first focus group at a math and/or science conference.) | Jan. – Feb. 1999 |
| • Evolve the NEEDS infrastructure into a test-bed SMETE Digital Library based on science and math focus group results. | March – April 1999 |
| • Develop SMETE Digital Library user community discussion groups as a component of the test-bed SMETE Digital Library. (Note: <i>engineering</i> discussion groups would have already been initiated as part of the Action Agenda funding for NEEDS.) | April – June 1999 |
| • Catalog additional courseware based upon materials identified by community members. | April – Sept. 1999 |
| • Develop and implement a prototype evaluation process for the full-scale SMETE Digital Library. | July – Aug. 1999 |

- Make final recommendations to NSF regarding the development of a full-scale SMETE Digital Library.

Sept. 1999

C.6.0 Evaluation and Dissemination

C.6.1 Evaluation

Evaluation is a critical component of this proposal. In order for the NEEDS model to be used as a foundation for building a SMETE Digital Library, we must have a clear understanding of the requirements of its client users from the SMETE community. In order to project the effectiveness of a SMETE Digital Library, we have the unique opportunity to find out how a community of users with similar educational goals views and uses NEEDS. To that end we will develop and prototype a system for collecting, in a systematic manner, on-going evaluation data and information regarding the effectiveness of the services and programs of NEEDS and our test-bed SMETE Digital Library.

C.6.2 Dissemination

The test-bed SMETE Digital Library, as built on NEEDS as its foundation, is at its core a dissemination system for courseware. For NEEDS and our proposed test-bed SMETE Digital Library, we strive for a model of dissemination that goes beyond the ability to search and download courseware. Rather, dissemination must also involve developing an awareness of the system through the formation of a SMETE user community. By forming the on-line user community, and watching it prosper and grow, we progress toward our goal of supporting new pedagogical models through Internet-mediated learning.

C.7.0 Summary and Conclusions

Prof. Agogino, the NEEDS professional staff and Dr. McMartin, an evaluation and assessment specialist, are ideally positioned to meet the goals of the NSF Digital Libraries Initiative Phase 2, category III “Planning Testbeds and Applications for Undergraduate Education.” We have over five years of experience in operating NEEDS, a state of the art digital library of undergraduate engineering education courseware. NEEDS, an acknowledged success of NSF’s Engineering Coalitions program, has evolved and expanded in response to numerous focus groups and evaluation sessions from within the engineering education user community. Due to our close involvement in digital library and database research we have been able to rapidly adopt evolving information technologies over this five year period. The NSF Digital Libraries Initiative – Phase 2 grant will allow us to leverage our existing base of engineering and technology courseware to include a math and science component. By building upon our existing foundation, we will be able to provide an operational test-bed SMETE Digital Library almost immediately. We hope to be able to work with other NSF grantees on this endeavor to compare notes and leverage each others’ resources. As NEEDS builds on national cataloging and information standards, our SMETE courseware catalog records will be portable to other systems and to the eventual full-scale SMETE Digital Library.

Combined with developing a test-bed SMETE Digital Library, we will develop a broad science, math and engineering user community that will provide the feedback necessary to improve and expand current user services by clarifying the requirements of a SMETE Digital Library. The results from focus groups, on-line surveys and follow-up telephone interviews with this community will help identify the different requirements of different user groups (i.e., adopter vs. developer, and novice courseware user vs. expert, large campus vs. small, etc.). In addition we will create a systematic means for collecting data regarding the effectiveness of the test-bed SMETE Digital Library’s programs and services and the development of its user community. A protocol will be developed for further analysis of user discussions to better understand the development of a sense of community among

participants. Based upon our needs assessment and test-bed evaluation, we will provide recommendations for continued development of a SMETE Digital Library.

C.8.0 Results of Prior NSF Research

Alice Agogino was PI and Director of the Synthesis Engineering Education Coalition funded under NSF Cooperative Agreement EEC-9625456 titled “Institutionalization, Evaluation, and Dissemination of Educational Innovations Developed Through the Synthesis Coalition.” The Synthesis Cooperative Agreement at UC Berkeley was for \$2,889,325 and began February 1, 1996 and ended January 31, 1998 [7]. A no-cost extension was granted to extend the NEEDS Database supplement until August 1, 1998. Synthesis was originally comprised of eight diverse educational institutions whose mission is to reform engineering education by developing new curricular and pedagogical models that integrate multi-disciplinary content, teamwork and communication, hands-on and laboratory experiences, open-ended problem formulation and solving, and examples of “best practices” from industry. Synthesis (www.synthesis.org) has published over 650 publications produced 9 NTU broadcasts, created or significantly reformed over 40,000 student credit units, sponsored 28 MS/Ph.D. theses and produced over 100 multimedia courseware modules. This courseware is archived and retrievable from NEEDS (National Engineering Education Delivery System — www.needs.org), an entirely new courseware development and distribution system developed by Synthesis that provides widespread Internet access to a growing multimedia courseware database. Northern Arizona University was added as a partner to Synthesis in 1995 to include Prof. Pamela A. Eibeck’s leadership in the Quality Review of Courseware project [29].

As an educational researcher and faculty participant in Synthesis, Prof. Agogino also co-authored many of the courseware modules used in Synthesis undergraduate curricula. Prof. Agogino worked on the Synthesis team developing Artifact Dissection and Multimedia Case Studies of Engineering Design [34-37, 66-67, 86]. Her research and development contributions target issues with cognition and learning and associated user interface design. Working with Prof. Marcia Linn in the UC Berkeley School of Education and faculty from Hampton, Iowa State and Stanford Universities, Prof. Agogino also initiated a program to improve the retention of engineering students — with a focus on female students — through scaffolding students in spatial reasoning in freshman/sophomore design courses [1, 5]. Saturday workshops and spatial reasoning courseware were developed and tested [1, 5, 33, 39]. On all of her educational projects, Prof. Agogino developed instructor’s guides and a range of assessment instruments, including pre and post tests, interview protocols, on-line skills self-testing, and student self-evaluations. Prof. Agogino graduated nine MS students [18, 23, 30, 33, 63, 65, 67, 86-87] and one Ph.D. student [40] from this work.

Working with doctoral student William H. Woods III and NEEDS professional staff (Brandon Muramatsu and George Toye), Prof. Agogino played a leading role in the development of NEEDS, building on her prior research in computer-aided design, digital design libraries and databases, and intelligent learning systems [2, 3, 9 82]. Prof. Agogino conducted digital design library and databases research under an NSF grant titled: “The Concept Database : A Design Information System for Concurrent Engineering with Application to Mechatronics Design” (NSF Grant No. DDM-9300025). The amount awarded was \$238,311 and the initial dates were July 1, 1993 - June 30, 1996. A no-cost extension was obtained to extend the grant until July 30, 1997. The Concept Database (Cdb) was a research project oriented towards developing a multi-media, networked, conceptual design support tool [4, 8]. The Cdb maintained a repository of design information resources accessible by a set of retrieval tools. These resources include analytical models, textual and pictorial design documentation as well as electronic product catalogs. Based on state of the designer’s knowledge of the current design problem, the Cdb applied appropriate deterministic or heuristic retrieval techniques, organized in a structured information filtering hierarchy, to navigate the designer through the information resources. Principal contributions from this research are: (1) “intelligent real time design” based on decision-analytic information value theory [6, 14-17], (2) new case-based machine learning and

natural language processing algorithms [25-28, 81, 83-85]; and (3) new neural architectures based upon the Adaptive Resonance Theory [74-75]. In addition, a customization framework and associated algorithms were developed to allow the redesign of existing components when they failed to meet specifications. The Cdb was applied to the mechatronic design domain, with particular reference to electric motors. The customization methodology was used to obtain optimal custom motor designs from the standard designs of a family of brushless DC permanent magnet motors [21-22]. The research was co-sponsored by Rockwell International Palo Alto Science Center, SUN Microsystems, Autodesk and Reliance Motors [16, 25]. Prof. Agogino graduated two MS students [13, 24] and five Ph.D. students from this work [17, 22, 27, 76, 83].

C.9.0 Background of Investigators

Professor Alice M. Agogino is the Principal Investigator for the proposed project. She is also Associate Dean in the College of Engineering at UC Berkeley in charge of the College's Center for Underrepresented Engineering Students (CUES) and Instructional Technology and Distance Learning Programs. She served as Director of Synthesis for the past three years. She conducts her research in the Berkeley Expert Systems Technology (BEST) lab and the C³AD (Concurrent, Collaborative, Computer-Aided Design) instructional lab.

Brandon Muramatsu will serve as the Project Manager for the test-bed SMETE Digital Library project and continues as the Project Manager of NEEDS. He is also a lecturer in multimedia at UC Berkeley, directs the Berkeley Instructional Technology Studio and is Chair of the San Francisco Section of the American Society of Mechanical Engineers.

Dr. Flora McMartin will serve as Director of Assessment for the proposed project. She has a doctorate in Education and Assessment and extensive experience in integrating assessment of student learning with faculty development and making organizational change [48-49]. Her past work includes serving as Director of Assessment of the Synthesis Coalition [50, 53, 55], evaluating the impact of assessment as a means for developing collaborative faculty workgroups [51-52], and directing studies on organizational change related to institutionalization of innovative academic departments and programs [43-44, 47, 54].

The Curriculum Vitae for Prof. Agogino, Mr. Brandon Muramatsu and Dr. McMartin are included in Section E.

C.10.0 Facilities

The development of a test-bed SMETE Digital Library will build upon the existing resources for the National Engineering Education Delivery System at UC Berkeley. The NEEDS infrastructure consists of redundant gateway Web servers, a catalog, search and archive Web server, and numerous development workstations. In addition NEEDS is participating in high-speed network research with the Berkeley Multimedia Research Center. This research program is investigating the development of guaranteed, high-speed networks for multimedia content delivery. The NEEDS technical staff and servers are housed in rooms 2111ABC Etcheverry Hall. Dr. Flora McMartin's office is part of the Engineering Systems Research Center in 3112 Etcheverry Hall and is equipped with equipment and software for performing statistical analyses, along with form scanning and evaluation. Prof. Agogino's multimedia and artificial intelligence research lab is located in 6102 Etcheverry Hall.

C.11.0 Budget

Funds of \$200,000 are requested for one year to support the development of a test-bed SMETE Digital Library based upon NEEDS. Personnel funds will support system development and courseware cataloging, as well as perform a needs assessment and system evaluation. Equipment upgrade funds of \$7,500 are requested to support the computing infrastructure and hard disk storage requirements for

new SMETE material in the NEEDS database. Domestic travel funds of \$8,400 per year are requested to support personnel travel to conferences and workshops to perform focus groups. Funds of \$1,500 are requested for participant support to host focus group meeting at professional society conferences and workshops (e.g., ACS, APS, AAAS, etc.). Funds of \$3,000 are requested to support survey costs.

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