Programs for Engineering Education in the National Science Foundation's Division of Undergraduate Education [*]

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Abstract

The programs of the Division of Undergraduate Education (DUE) serve as the focal point for the National Science Foundation's efforts in undergraduate education. These programs are directed at strengthening the vitality of undergraduate science, technology, engineering and mathematics (STEM) education for all students. DUE has a number of different programs, each with a scope and objectives that address specific issues in undergraduate education and some are particularly applicable to engineering education. The paper presents a brief summary of these programs and a reference to a complete description. One of these programs, the Course, Curriculum and Laboratory Improvement (CCLI) Program, which plays a prominent role in supporting research and development of engineering education, was revised this year and this paper discusses these changes.

Introduction

The Division of Undergraduate Education (DUE) serves as the focal point for the National Science Foundation's efforts in undergraduate education in science, technology, engineering, and mathematics (STEM). DUE programs are designed to strengthen the vitality of STEM education in a variety of ways with the Course, Curriculum and Laboratory Improvement (CCLI) Program playing a prominent role in supporting research and development of engineering education. Most of DUE's programs have been in place for a few years and the first part of this paper provides a brief summary of each. The CCLI program has undergone a major review this year so that the 2005 solicitation (NSF 05-559) is substantially different from last year's. [1] The second part of this paper discusses the rationale for and direction of these changes.

Overview of DUE's Programs

The following paragraphs, which have been adapted from various NSF documents, briefly describe all of our programs with the exception of the CCLI program – it is dealt with in the subsequent sections of the paper. Additional information about all DUE programs can be found on our website. [2]

[*] This paper represents the opinion of the author and not an official NSF policy.

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The *Advanced Technological Education (ATE) Program*, [3] which is jointly managed by DUE and the Division of Elementary, Secondary, and Informal Education (ESIE), provides grants to strengthen the education of technicians for careers in biotechnology, environmental technology, information technology, manufacturing, and many other science- and engineering-related fields that drive the U.S. economy. The program targets both the undergraduate and secondary school levels. Two-year colleges are expected to have a leadership role in all ATE projects. Collaborative efforts involving secondary schools, two-year colleges, four-year colleges and universities, businesses, nonprofit organizations, and government agencies are encouraged. The ATE program has two tracks. *Projects* adapt and implement exemplary educational programs and materials, develop new materials, provide professional development for college faculty and secondary teachers, provide technical experiences for students, or conduct research relating to the education of technicians. *Centers* provide comprehensive resources, serve as models for other projects, and act as regional or national clearinghouses for educational materials and methods.

The *National Science, Technology, Engineering, and Mathematics Education Digital Library (NSDL) Program* [3] aims to create, develop, and sustain a national digital library to serve as an online network of learning environments and resources for STEM education at all levels. Most projects focus on (1) establishing *pathways* that provide the means for users to connect with broad content domains that are appropriate to their learning needs or (2) the implementation of *services* that enhance not only the impact and value of the holdings, but also the effectiveness of the user interfaces that mediate information seeking behavior. Collaborative efforts that involve educational institutions, professional societies, the corporate and foundation sectors, and/or government organizations are encouraged.

The *Federal Cyber Service: Scholarship for Service (SFS) Program* [5] seeks to increase the number of qualified students entering the fields of information assurance and computer security and to increase the capacity of the U.S. higher education enterprise to continue to produce professionals in these fields. The SFS program is composed of two tracks. The *Scholarship Track* provides funding to colleges and universities to award scholarships to students in information assurance and computer security fields. Upon graduation, scholarship recipients will be required to work for the Federal government for two years in fulfillment of their Federal Cyber Service commitment. The *Capacity Building Track* provides funds to colleges and universities to improve the quality and increase the production of information assurance and computer security professionals through professional development of information assurance faculty and the development of academic programs.

The *Science, Technology, Engineering, and Mathematics Talent Expansion (STEP) P*rogram [6] seeks to increase the number of students (U.S. citizens or permanent residents) receiving associate or baccalaureate degrees in established or emerging fields within STEM. The goal of projects must be to increase the total number of students at the institution(s) receiving such degrees across all STEM fields.

The *Teacher Professional Continuum (TPC) Program*, [7] which is jointly managed by the Division of Elementary, Secondary, and Informal Education (ESIE) and DUE, addresses critical issues and needs regarding the recruitment, preparation, enhancement, and retention of STEM teachers for grades K-12. The program's goals are to improve the quality and coherence of the learning experiences that prepare and enhance STEM teachers; to develop innovative resources that prepare and support STEM teachers and school and district administrators; to research and develop models and systems that support the teacher professional continuum; and to disseminate this research as well as innovative models and resources to a national audience.

The *Robert Noyce Scholarship Program* [8] provides funds to institutions of higher education to support scholarships for juniors and seniors who are majoring in science, mathematics, or engineering and stipends for science, mathematics, or engineering professionals seeking to become teachers. Upon the completion of their programs of study, participating students are required to serve two years in a high-need school for each year of financial support received.

Rationale for the Revised CCLI Program

The vision of the revised CCLI program is excellent science, technology, engineering, and mathematics (STEM) education for all undergraduate students. Stimulating, disseminating, and institutionalizing innovative developments in STEM education through the production of knowledge and the improvement of practice are goals consistent with this vision. To achieve these goals, the CCLI program addresses challenges identified in several major reports. For example, the report, *Greater Expectations: A New Vision for Learning as a Nation Goes to College,* [9] recommends enabling students to become empowered, informed, and responsible learners ready to assume productive roles in society in both STEM and non-STEM related careers. Furthermore, the National Research Council's (NRC) report, *Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics,* [10] raises challenges that include improving the assessment of learning outcomes, teaching a broad range and large number of students, providing engaging laboratory and field experiences, and enhancing the faculty's knowledge of research on effective teaching.

In meeting such challenges, the CCLI program builds on a number of recent publications analyzing the current state and future needs in STEM education. The NRC volume, *How People Learn: Brain, Mind, Experience, and School*, [11] advocates that teachers draw out and work with students' preexisting knowledge, teach subject matter in depth and provide examples, help students develop self-monitoring and reflection skills, and integrate these practices into the curriculum in a variety of subjects. In addition, the NRC report, *Scientific Research in Education,* [12] recommends that educational research projects pose significant questions that can be investigated using direct empirical techniques, allow

replication and generalization across educational settings, and present results to encourage professional critique.

The program also acknowledges the need for STEM education research and development efforts to build on and contribute to the STEM education knowledge base. The Project Kaleidoscope report, *Recommendations for Action in Support of Undergraduate Science, Technology, Engineering, and Mathematics,* [13] calls for "collective action" to share ideas and materials so that projects build on, connect to, and enhance the work of others. It stresses that educational research and development efforts must move away from the practice in which an individual "owns" a new approach from conception to implementation. The planned CCLI program supports a collaborative model where investigators learn about and adapt the work of others and disseminate the results so that others can continue the investigation. The rationale and methods in CCLI projects will use the STEM education knowledge base, as reflected in the education research literature, the discipline-based education literature, and other appropriate sources that describe previous work by others. Also, all projects will contribute actively to this knowledge base and expand the experience base by sharing their findings.

In addition, the CCLI program recognizes that sustained improvement in STEM education requires that all participants engage in building a community of scholars. The National Academies Press report, *Improving Undergraduate Instruction in Science, Technology, Engineering and Mathematics,* [14] emphasizes the importance of expanding faculty and scholarly networks to promote effective instruction and to support rapid dissemination and adaptation of proven educational innovations. Furthermore, *Recommendations for Action in Support of Undergraduate Science, Technology, Engineering, and Mathematics* [13] concludes "we must find new ways to identify and bring new voices into the dialog." To help build this community of scholars, CCLI projects will seek ways to increase the participation of faculty in educational reform and innovation, particularly through activities such as implementation, assessment and dissemination

Details of the CCLI Program

The new CCLI program is based on a cyclic model of the relationship between knowledge production and improvement of practice in STEM education as shown in Figure 1. This model is adapted from a similar one in the report, *Mathematical Proficiency for All Students*. [15] In this model, research findings about learning and teaching challenge existing approaches, leading to new educational materials and teaching strategies. New material and teaching strategies that show promise lead to faculty development programs and methods that incorporate these materials. The most promising of these developments are first tested in limited environments and then implemented and adapted in diverse curricula and educational practices. These innovations are carefully evaluated by assessing their impact on teaching and learning. In turn, these implementations and assessments efforts generate new insights and research

questions, initiating a new cycle of innovation. As described in the solicitation, this leads to a program model containing five components:

- Conducting research on undergraduate stem teaching and learning,
- Creating learning materials and teaching strategies,
- Developing faculty expertise,
- Implementing educational innovations,
- Assessing learning and evaluating innovations.

A CCLI proposal may focus on one or more of these components. [1]

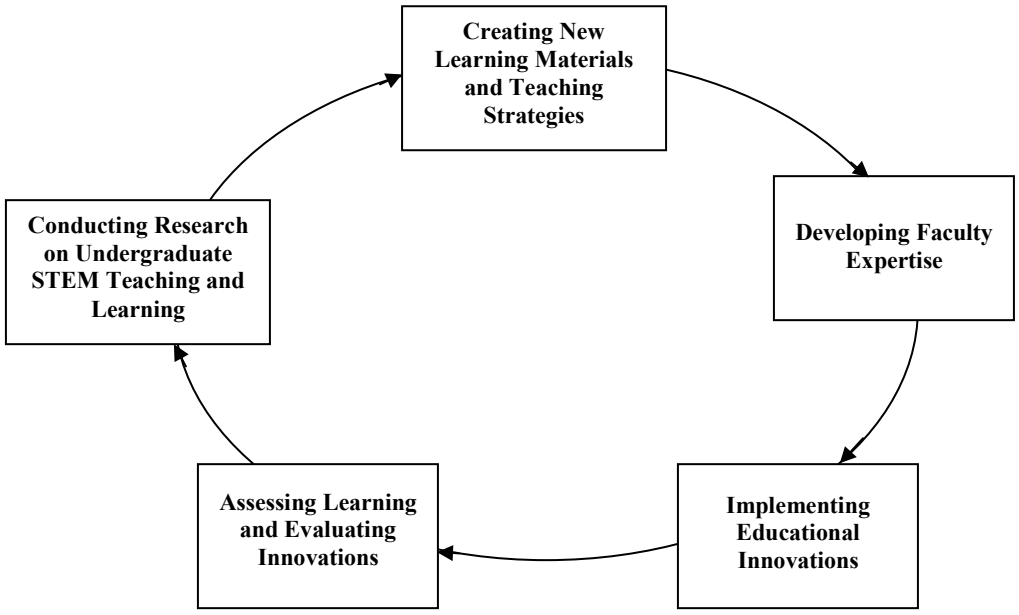

Figure 1. Cyclic model for knowledge production and improvement of practice in undergraduate STEM education

The CCLI program accepts three types of projects representing different phases of development. [1] These phases reflect the number of components of the cyclic model included in the project; the number of institutions, students and faculty members involved in the project; and the maturity of the proposed educational innovation. The three phases are outlined below:

- *Phase 1 -- Exploratory Projects* will have a maximum budget of $150,000 ($200,00 when four-year and two-year schools collaborate), last one to three years, focus on one of the components in the cyclic model, involve a small number of students, faculty members and institutions, and deal with new exploratory concepts. NSF anticipates funding 55 to 70 Phase 1 projects in response to this solicitation. The proposal deadline dates are May 17, 18, and 19,

2005 for organization in states starting with A through l, M and N, and O through Z, respectively.

- *Phase 2 -- Expansion Projects* will have a maximum budget of $500,000, last two to four years, focus on several of the components in the cyclic model, involve a intermediate number of students, faculty members and institutions, and deal with tested concepts. NSF anticipates funding 15 to 25 Phase 2 projects in response to this solicitation. The proposal deadline date is January 24, 2006.

- *Phase 3 -- Comprehensive Projects* will have a maximum budget of $2,000,000, last three to five years, focus on most of the components in the cyclic model, involve a large number of students, faculty members and institutions, and deal with established concepts. NSF anticipates funding 1 to 4 Phase 3 projects in response to this solicitation. The proposal deadline date is January 24, 2006.

Successful projects will share certain characteristics as outlined in the solicitation. [1] They will have a student focus with the potential for high quality and impact. Moreover, they will build on and contribute to the STEM education knowledge base and contribute to building an undergraduate STEM education community. Finally they will have a set of project-specific expected measurable outcomes that will be used in project evaluation, which will be an integral part of the project.

Submission and Review Process

CCLI proposal must be prepared in accordance with the NSF *Grant Proposal Guide* (*GPG*) which is available on the NSF website, [16] and submitted through the FastLane system. [17] As stated in the *GPG,* the proposal's *Project Summary* must separately and explicitly address the *intellectual merit* and *broader impacts* review criteria or else the proposal will be returned without review. Proposals that do not comply with the format requirements (e. g., page, font size, and margin limitations) specified in the *GPG* also will be returned without review. Applicants should allow sufficient time for their organization's approval process and for correcting any errors that occur in uploading their proposal -- they are strongly encouraged to check the uploaded version of the proposal for problems introduced in the uploading and conversion process. Applicants with questions about the preparation and submission of a proposal are encouraged to contact a project director (see the CCLI solicitation [1] for a list of CCLI project directors in each discipline) or the FastLane Help Desk at 1-800-673-6188 or fastlane@msf.gov. [17]

A panel of peers with expertise in the substantitive areas of the proposed project will review all proposals. In their evaluation, they will use the standard NSF review criteria on intellectual merit and broader impacts and the additional review criteria specified in the CCLI solicitation. [1] One set of these additional review criteria applies to all proposals while the others are appropriate for proposals in each of the three phases. Applicants are urged to study these criteria carefully and make sure that their proposals address all of the relevant ones.

Conclusion

DUE has an array of programs that support engineering education research and development. Individuals who are interested should review the web site to determine which program best matches their interests and ideas. The CCLI program, which plays a prominent role in engineering education research and development, has been revised and interested parties should review the new solicitation carefully before submitting a proposal.

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Biographical Information

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