ESSAY
Funding Undergraduate Neuroscience Education: CCLI Yesterday and Today

Nancy L. Pruitt[1,2], Jeanne R. Small[3,4], and Terry Woodin[4]
[1]*Department of Biology, Colgate University, Hamilton, NY 13346*
[2]*Former Program Director, Division of Undergraduate Education, National Science Foundation*
[3]*Department of Chemistry and Biochemistry, Eastern Washington University, Cheney, WA 99004*
[4]*Program Director, Division of Undergraduate Education, National Science Foundation, Arlington, VA 22230*

For over 20 years, the Division of Undergraduate Education (DUE) at the National Science Foundation (NSF) has been supporting undergraduate curricula in the sciences, including neuroscience. NSF's priorities in undergraduate education, however, have evolved during that period, and the competition for grants has increased. This history and overview of the current Course, Curriculum and Laboratory Improvement program (CCLI) illustrates the changing philosophy of DUE with regard to its curricular programs. It is hoped that understanding the current emphasis on assessing the outcomes of curricular changes and disseminating their results will help interested science faculty write better proposals and compete more effectively for funds.

Key words: CCLI, NSF, curricular change

In 1985, the Division of Undergraduate Education (DUE) launched the College Science Instrumentation Program (CSIP), the first National Science Foundation (NSF) program specifically aimed at improving undergraduate education. The CSIP program provided funds for up-to-date equipment to support laboratory instruction. CSIP quickly became NSF's largest and most visible program in the area of undergraduate science education. The current Course, Curriculum, and Laboratory Improvement program (CCLI), a programmatic descendent of CSIP, remains one of DUE's core programs and distributes over $30 million in awards each year to undergraduate science programs nationwide. As knowledge about effective science teaching and learning has evolved over the past 20 years, so has the philosophy and scope of CCLI. This essay reviews some of the changes in program priorities and award patterns in CCLI with the goal of helping proposal writers put current priorities in science education into perspective.

A BRIEF HISTORY OF CCLI

CSIP was initiated to address a perceived decline in the scientific workforce by attracting more students to majors in science, technology, engineering, and mathematics (STEM). CSIP was originally targeted to primarily undergraduate institutions (PUIs), which, as a result of the 1985 Oberlin report (Davis-Van Atta, 1985), were (and still are) largely viewed as one of the nation's important incubators for PhDs in the sciences. These grants, aimed at improving undergraduate laboratory instruction, enabled awardees to purchase modern, up-to-date equipment that they could not otherwise afford and that would enable them to enrich both the content of student laboratories and the way in which they were taught. CSIP's early annual budget of about $7 million supported small awards of $5,000 to $50,000, each requiring dollar-for-dollar matching from the submitting institution. In addition, NSF required that CSIP awards and matching funds be used solely for instructional equipment; no overhead or administrative costs could be included in proposal budgets or taken from grant funds. The combination of NSF funding and institutional matching went a long way toward modernizing the equipment used in teaching laboratories in PUIs.

In 1988, the range of CSIP-eligible institutions was expanded to include both two-year and doctoral-granting institutions, and the name of the program was changed to the Instrumentation and Laboratory Improvement (ILI) program. The objectives of ILI were similar to those of CSIP, namely to support improved laboratory experiences and thereby attract more students to majors in the sciences. However, ILI also emphasized the need to educate nonscience majors and preservice teachers, as well. In addition, the program put increased emphasis on projects that introduced laboratories that went beyond the traditional "cookbook" approach. With the advent of ILI, NSF was beginning to realize the potential for grants targeted to undergraduate education to influence the culture of more research-focused institutions. It was hoped that faculty members who were successful at landing educational grants could reap some of the same recognition from their institutions as those who regularly brought in research funds. As with CSIP, ILI required awardee institutions to match NSF funds dollar-for-dollar for equipment purchases; institutional overhead was prohibited. Despite these limitations, ILI consistently received about 2000 proposals and funded about 28 percent, or an average of 550 proposals, each year. By 1994, nearly 100 percent of doctoral granting institutions

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and 75 percent of four-year colleges had submitted at least one ILI proposal, and 87 percent of doctoral-granting and 55 percent of four-year schools had received one or more awards.

The Course and Curriculum Development (CCD) program was initiated in the same year that CSIP morphed into ILI and was limited in the first three years to curricular reform projects in engineering, calculus, and precalculus. But as well-equipped student laboratories in the bench sciences (funded with ILI grants) became more commonplace, creative faculty in all science disciplines began seeking support for curricular reform. The focus in undergraduate laboratory teaching was shifting from passive experiments with well-defined outcomes to more research-like exercises, in which students designed experiments, collected data, interpreted results, and communicated their findings in a variety of ways. In 1991, CCD was opened to all disciplines. CCD supported revisions in courses or entire curricula, implementation of nontraditional pedagogies, and development of materials to support new methods in both the classroom and the laboratory, with the more ambitious goal of catalyzing major changes in undergraduate science education at a national level.

An evaluation of CCD and ILI undertaken in 1996 (see www.nsf.gov/pubs/1998/nsf9833/ili-1.htm) concluded that these programs were succeeding in revitalizing education and re-energizing faculty at the local level—in the classrooms and departments of awardees—but fell short of the national impact the programs sought to realize. In addition, research in science education—how students learn and how we measure it—was maturing. Concerned faculty could now choose from tested methods to improve their classes, thus approaching science education as a science in and of itself. In 1999, CCD and ILI were folded into a new, four-track funding instrument, the Course, Curriculum, and Laboratory Improvement (CCLI) program. CCLI incorporated most of the features of both CCD and ILI, including the option to submit instrumentation or equipment proposals, but gave increased priority to testing the effectiveness of materials and practices in terms of gains in student learning. Adapting and implementing proven materials and classroom practices was incorporated into CCLI as a separate track, and what had been ILI became, in 1999, the Adaptation and Implementation (A & I) track of CCLI. A & I projects enabled science faculty to apply proven innovations or develop their own, as well as purchase the equipment required to implement them. CCD was folded into either the A & I track or the Educational Materials Development (EMD) track of the new CCLI, which supported innovative textbooks, software, course modules, laboratory exercises, and web-based teaching materials. Reflecting the need for better assessment of student learning and the desire to train the nation's faculty in tested educational approaches, two new initiatives were introduced, the Assessment of Student Achievement and National Dissemination tracks, respectively. CCLI budgets could include institutional overhead, although the A & I track still required that awardees provide matching funds to purchase instrumentation.

In 2000, the first year CCLI grants were awarded, four projects with neuroscience themes were funded. Three institutions, the University of Wisconsin - La Crosse, Regis University, and Gustavus Adolphus College, used funds from the A&I track to equip open-ended teaching laboratories that employ research-like pedagogies. In these revised courses, students ask research questions and propose the appropriate experimental methods to answer them. Students at Regis University have been authors on four abstracts submitted to professional research conferences, and the Principle Investigators report substantial gains in cognitive skills as a result of these laboratory reforms. The fourth project, developed at Rice University and funded from the EMD track, supported a web-based multimedia textbook in behavioral science (see psych.rice.edu/mmtbn/), which is freely available to all.

CCLI: THE CURRENT PROGRAM

Throughout its history and in all its various forms, the trend in CCLI has been toward a more holistic approach to STEM undergraduate education. The scope of the program has steadily expanded to include increased emphasis on evaluation of the effectiveness of educational reform and better dissemination of tested innovations, so as to broaden the impact of successful projects. Scientists and science educators are converging into a community of scholars sharing similar goals, methods, and expectations, so that projects concerned with undergraduate science education more closely resemble traditional science research projects in their attention to documenting results. In 2005 CCLI was substantially revised to reflect these changes. Using the model of disciplinary research proposals, the revised CCLI requires that the rationale for undertaking a project be built on prior work. To foster projects that are effective agents of change at the national level, proposers are encouraged not only to cite prior work by themselves and others, but also to describe how their project will be assessed and how the results of that assessment will contribute to the improvement of undergraduate STEM education. In the words of the program's solicitation (NSF 06-536; www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf06536), proposals must describe how the project will contribute to building a community of scholars.

The 2005 revisions to CCLI were, themselves, informed by the literature in education. The revised program employs a model for educational reform originally published to describe how mathematics education progresses (Ball, 2003). The model identifies five stages that form a cycle of advancement. Analysis of existing reform efforts (stage 1, research on teaching and learning) leads to creation of new learning materials and strategies (stage 2). New approaches require that faculty gain expertise (stage 3), so that they can implement tested educational innovations (stage 4). Finally, widely disseminated innovations must be assessed (stage 5, determination of resulting learning gains), which leads to information about teaching and learning that can be used to inform the next cycle of innovation (stage 1). Proposals to CCLI can address one or more elements of the cycle, depending on the size and scope of the project, but all must pay appropriate attention to assessment and dissemination. In place of separate tracks reflecting different kinds of program activities, (A&I, EMD, etc.), the revised CCLI is divided into three phases reflecting the size, scope, and maturity of the project being proposed. Indirect costs are permitted and no institutional matching is required for any of the phases.

This new emphasis in all phases of CCLI on evaluation and dissemination means that it is no longer adequate to assume (or hope that reviewers will assume) that simply implementing a reform in the classroom or laboratory will result in gains in student learning. Instead, proposers should state explicitly what they expect students to learn as a result of the project, how those learning gains will be measured and quantified, what outcomes constitute success, and how they will inform others of these outcomes. For many successful CCLI projects, this has meant engaging the aid of educational researchers (defined broadly, see below) to help define and assess outcomes. Inclusion of educational researchers also helps to determine how readily generalized successful teaching strategies are and how easily reforms can be implemented in different settings. Although it is not a requirement of the revised CCLI solicitation that proposals include outside evaluators, many include colleagues in education departments, sociologists or anthropologists interested in cultural change, or consultants external to the university. These collaborators can help conduct a thorough and unbiased evaluation of project outcomes, both during the course of the project and at its conclusion. Proposals for larger, more expensive projects (submitted as Phase two or three proposals, for example) are more likely to include the services of an outside evaluator.

While it is too soon to provide examples of neuroscience projects funded under the 2005 revised program solicitation (in 2005, only one neuroscience proposal was submitted under the new program), listed below are some highlights of ongoing projects that we believe illustrate current funding priorities. In addition DUE maintains a list of abstracts from recently funded projects on its Project Information Resource System (PIRS) website (www.ehr.nsf.gov/pirs_prs_web/search). Most Principle Investigators (PIs) are happy to share information about their projects when asked. Contact information for PIs can also be found on PIRS.

CREATING NEW LEARNING MATERIALS

The Neuron Connection: A Neuroscience Lab Manual for the 21st Century. Wellesley College, award number 0231019.

The PIs (Carol Ann Paul, Bruce Johnson, and Julio Ramirez), who are from three different types of institutions, are developing pedagogically sound, inexpensive, on-line laboratories for undergraduate neuroscience courses, called "The Neuron Connection." These digital-format laboratories include simulations, animations of "classical" experiments, and referrals to the primary literature in neuroscience. The digital labs are being assessed for the appropriateness and effectiveness of delivery in a wide range of college and university environments. Preliminary results were presented at the Society for Neuroscience annual meeting in San Diego in 2004 and in Washington, DC in 2005.

A Software Package for Teaching Neurobiology Through Interactive Laboratory Simulations. The University of Washington, award number 0127454.

Building on a previous NSF-funded project, the PI (William J. Moody) and collaborators have developed a neuron simulation software package that allows students to create a virtual electrophysiology recording set-up by placing amplifiers, stimulators, and other equipment into a virtual rack and wiring them together. Students can manipulate electrodes into virtual neurons and record changes in membrane voltage under various experimental conditions. Volunteer users were videotaped to identify areas of confusion, and appropriate changes were made to improve the product. Post-testing at intervals after using the software indicated that students' inquiry skills improved. Beta versions of the software were sent to more than 100 educators in over 20 countries, including many minority-serving institutions in the USA. Comments from beta testers were used to finalize the software.

IMPLEMENTING EDUCATIONAL INNOVATIONS

Computational Neuroscience Over the Access Grid Nodes. Carnegie Mellon University, award number 0231173.

PIs, David Deerfield, Eric Jakobsson, Barbara Kucera and Gregory Hood, are using the Access Grid group-to-group communication technology at the Pittsburgh Supercomputer Center to deliver a course in computational neuroscience, particularly aimed at students in EPSCoR states. The project's objective is to test whether courses originating at universities with supercomputing facilities can be effectively disseminated using synchronous interactions. Results indicated that students were comfortable with the Access Grid technology and would consider taking another Access Grid course if the topic were one not offered at their home institution. The PIs did identify one important hurdle to be overcome before cross-institutional courses can gain wide acceptance: Administrative issues concerning student credit and instructor compensation will need to be addressed at each participating institution. (This project was jointly funded by DUE and the Computer and Information Science and Engineering Directorate at NSF.)

Development of Laboratory Experiences in Neural Engineering. University of Illinois at Chicago, award number 0088823.

As expertise in the cellular and molecular interfaces between biological and artificial systems grows, a new generation of neural prostheses, devices that can interact with or emulate living nervous systems, is being developed. In response to these developments, the UIC Departments of Bioengineering and Biological Sciences have created a two-year, cross-college undergraduate curriculum in Neural Engineering, one of the first such programs in the country. PIs, John Hetling and Christopher Comer, used CCLI funds to equip a Neural Engineering Laboratory course that serves as the capstone experience in the new undergraduate curriculum. The novel curriculum, including the capstone laboratory course, was described in presentations to the ASEE (American Society for Engineering Education) annual meeting and the Whitaker Foundation Biomedical Engineering Summit. Some of the instrumentation was also used in a Bioengineering Summer Camp program for high school teachers.

REFERENCES

Davis-Van Atta D, Carrier SC, Frankfort F (1985) Educating America's scientists: The role of the research colleges. A report for the Conference on the Future of Science at Liberal Arts Colleges held at Oberlin College, Oberlin, OH. Oberlin College: Oberlin, OH.

Ball DL (2003) Mathematical proficiency for all students. Rand Education Science and Technology Institute, Santa Monica, CA

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Address correspondence to Nancy L. Pruitt, Department of Biology, Colgate University, Hamilton, NY 13346, (315) 228-7398 Email: npruitt@mail.colgate.edu.