

Undergraduate Research: Building a Road to Better Undergraduate Education

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Introduction

The past 20 years can be characterized as a period of awakening and growth for research involving undergraduates at primarily undergraduate institutions. From a quiet, often self-funded endeavor, it is now recognized as a key element of educational reform for all undergraduate programs, even adaptable to classroom exercises for non-science majors.

The Council on Undergraduate Research (CUR) was the first, and remains the leading, organization supporting undergraduate research in the sciences. From the first days of CUR's existence, more than 20 years ago, as a group of chemists from private, liberal arts colleges and universities engaged in significant research with undergraduates, to the present membership organization, CUR has supported, fostered and promoted all aspects of research related to undergraduates in a predominantly undergraduate institution (PUI) setting. Among CUR's members are also representatives of research universities and community colleges who seek to improve undergraduate education by engaging students in research with faculty. CUR now is an organization that has two major categories of membership: individual and institutional. CUR has grown to include 7 additional divisions besides the original Chemistry division: At-Large, Biology, Engineering, Geology, Mathematics and Computer Science, Physics and Astronomy, and Psychology.

CUR's members are absolutely convinced that the best way to teach science, mathematics and engineering is to engage students in research. To borrow the words of a CUR Councilor in Chemistry, Dr. Bert Holmes of UNC-Asheville, research is a 'way of knowing' that is applicable to all fields, not just science. Undergraduate researchers are introduced to the language of science, the theories (both past and current), the experimental approaches characteristic of their field, and the primary literature as they actively pursue the answer to a question. For undergraduates to participate in research, their faculty mentors must also be so engaged. CUR's primary focus is to support the faculty at PUIs by providing information on grants, by providing information on starting and continuing research, and by providing several forums for meeting other PUI faculty in similar circumstances.

A History of Progress

The main impetus leading to the founding of CUR was the perception by policy makers and others that research was only conducted at the research I universities, industrial and national laboratories. The thirteen founders of CUR knew that research of high quality could be found in the smaller, predominantly undergraduate institutions and that this

research involved undergraduates as well as faculty. The initial goal was to bring this knowledge to the funding agencies and to the scientific populace in general. The first task was to document the extent, nature and quality of the research at PUIs. Under Dr. Brian Andreen's leadership, CUR published the first edition of a *Directory of Research in Chemistry at Primarily Undergraduate Institutions*. With this, CUR began to be recognized as a voice speaking for PUI faculty and undergraduate research in national conferences and in discussions with funding agencies. Since then, CUR has published similar directories for the other CUR divisions and is nearly ready to take the seventh edition of the Chemistry directory to press.

Over the years, CUR's attention has shifted towards gaining support for research at PUIs. The focus has been largely targeted towards the federal funding agencies (NSF and NIH for example) but the private foundations have also been approached. The Council has been successful in these efforts. For example, NIH has implemented the Academic Research Enhancement Awards (AREA) and then modified the award in ways that benefit PUI faculty. The role that CUR played in both the establishment of AREA grants and in the subsequent changes is evidenced by the announcement of the new format at CUR's April Dialogue in 1997 by Dr. Ruth Kirschstein, Deputy Director of NIH. The Council also supported the REU and RUI grant programs at NSF. Currently, the leadership of CUR is working to increase federal funding opportunities at NASA, EPA and USDA. Each of these agencies recognizes that CUR speaks for research-active faculty at PUIs.

Among CUR's members, the most popular program is the Undergraduate Summer Research Fellowships. This program is unique in several ways. It is the only national, competitive program we are aware of that offers financial support for undergraduates to engage in research with a faculty member during the summer. The application is only four pages; the turn-around time between application and decision is short; and awards are made in each of the science divisions of CUR. CUR has succeeded in raising funding for these fellowships from four sources: federal agencies, private foundations, industry and endowment. These summer research fellowships have been invaluable for both PUI faculty and students. Faculty members have been able to obtain sufficient data to support one or more grant applications and they have been able to submit manuscripts based on the data collected. In some cases, they have been able to explore a new research area; in others, they have been able to establish a new laboratory. Students have presented their results at local, regional and national professional meetings, they have been co-authors on publications, they experienced the joy of discovery and learned to handle the frustration of failed experiments. We have anecdotal evidence that graduate faculties look for undergraduate research experiences in the students admitted to PhD programs. Thus, undergraduate research fellowships are a true win-win situation for PUI faculty, their undergraduates, graduate schools and the funding providers.

Even a casual scan of open academic positions at PUIs will reveal a nearly universal expectation of doing research with undergraduates along with excellence in teaching. No longer are teaching and research viewed as mutually exclusive activities of the professoriate. While CUR cannot claim sole responsibility for this integration of research

and education, we certainly have been among the early proponents of this view. Doing research is not only the best way to learn science, it is the most intensive way to teach science. One of CUR's, and PKAL's, tasks for the future is to convince state and federal legislatures of the truth of this assertion. The size of CUR's At-Large division, composed of deans, provosts and directors of undergraduate research programs, is further demonstration that many faculty and administrators at universities and colleges have accepted that research and education are ideally integrated.

CUR has steadily added new divisions (the most recent addition is Engineering) to reflect the broad spectrum of science, mathematics and engineering research that occurs in PUI institutions. As this is written, CUR's Strategic Planning Committee is considering the possible expansion of CUR beyond the traditional boundaries of science and engineering and beyond the borders of the United States to Canada and Mexico.

Collaborations with Sister Organizations

The Council's support of NCUR and PKAL reflect not only our mutual interest in undergraduate research and education but the increasing interest nation-wide in the relationship between faculty and student. NCUR and PKAL have a special partnership with CUR. Many of CUR's members are active in one or both of these organizations: CUR faculty routinely support their student presentations at NCUR's national festival of undergraduate research and CUR members and leaders have prominent roles in the advisory board of NCUR. As with NCUR, many of CUR members participate in the workshops offered by PKAL. PKAL and CUR have jointly offered some workshops related to the "Research Rich Environment" and "Mid Career Faculty". It is our hope that these enriching collaborations will continue to our mutual growth and benefit.

As CUR and PKAL look to the future, we find that each has made significant strides in preparing ourselves for the next century. PKAL has created and nurtured the Faculty for the 21st Century. These young scientists will form the core of the leadership in science research and education beyond 2000. PKAL's workshops are impacting the way science and engineering is taught; the effects will be increasingly apparent as time goes by. CUR has moved to Washington DC to enable its leadership to have more immediate access to our friends in collegial scientific and educational societies, primary funding agencies supporting PUI faculty, and science policy circles. We have initiated a move to electronic distribution of data – our contribution to the paperless society. CUR can point to invitations to submit White Papers to DOE, NSF, USDA, AAAS, SET (Science, Engineering and Technology) Work Group and the House Science Committee to name but a few in the past year or two. We fully expect to continue to work with these agencies in the future. One of the White Papers CUR presented merits additional comment because of the impact we perceive it will have on future science policy and funding decisions of the federal government.

The Future: Turning a Path into a Highway

“Unlocking Our Future: Toward a New National Science Policy” was presented to Congress by the House Committee on Science, chaired by Representative V. Ehlers, on the 24th of September 1998. The report is the first attempt at a cohesive science policy since Vannevar Bush’s germinal document “Science: The Endless Frontier”. The report gives careful consideration to the contributions of a wide range of institutions to the Nation’s science and technology enterprise, and of what the authors deem the proper role of the Federal government is with respect to each. The report covers research universities, national labs, industry, high schools, and elementary schools. It considers the spectrum from basic to applied research; it considers both “big” and “small” science; and it considers research done entirely on the soil of the United States and international collaborations. This very breadth makes it absolutely stunning that the report does not recognize the role of primarily undergraduate institutions, or the research that takes place at them. CUR will use “Unlocking the Future” to show that much remains to be done to convince legislatures of the need to address undergraduate education issues.

PUIs do play a broad role in our research/education enterprise. This role ranges from the training of K-12 teachers in science, to preparing scientifically literate citizens, to preparing undergraduates for graduate careers, to conducting high quality research at the (endless) frontiers of knowledge. The unique feature of undergraduate research at PUIs lies in the degree to which education and research meet in a well-executed undergraduate research experience. What are the benefits to our Nation’s goals in supporting such research?

The benefits can be divided into two broad categories: training of researchers and production of quality research.

The research potential of professors and students at PUIs is enormous. All college professors with the PhD are trained in research. The strong production of PhDs in SMET over the last 3 decades has resulted in an increase in talent at a wide range of PUIs and research universities. Maintenance and expansion of this research is strongly dependent on continued access to funds from the full range of state and federal agencies funding academic research. On page 11 of the Ehlers’ report, the authors say “....important discoveries often come from unexpected avenues.” This statement is just as applicable to research done at PUIs in collaboration with undergraduates.

However, a cursory examination of the productivity at PUIs and at typical research universities quickly shows that far more papers are published at the research universities. Why continue to fund this apparently less productive research? One point is a simple one - the more minds we have attacking significant problems the better we are using our resources. This is not the sole reason for continuing to support research at PUIs; the best reason is that the research is done by undergraduates in partnership with faculty.

The Ehlers' report states: "We must also ensure that the opportunities that promise to unfold for those with an education in science and engineering are available to all citizens. Today, women and some minorities are underrepresented in many scientific and engineering fields. This represents a tremendous under-utilization of our Nation's resources." Undergraduate research, especially in the close mentoring situations prevalent at PUIs, helps retain women and minorities in the pipeline. As an example, the male/female ratio in chemistry departments is much closer to 50% at PUIs than at the large research institutions. PUIs are located throughout the country. The research done there often has large impact on regional issues and economic development.

Students are more likely to go to graduate school if they have done undergraduate research. This is most true when undergraduate research is encouraged early in a student's career and where the research experience is not limited to honors students. Students who do undergraduate research, on average, become productive researchers in graduate school faster. An undergraduate research experience is the only opportunity before graduate school for a student to gain experience in wrestling with the ambiguity of interpretation that is the hallmark of true research.

The advantages of undergraduate research extend to future K-12 teachers as well. In discussing revisions of science and engineering curricula, the report quotes Bill Nye, the host of the television program *Bill Nye, the Science Guy* as saying "A teacher doing a demonstration is one thing, but a student doing it for her or himself is another. There is nothing more empowering." Engaging future K-12 teachers in research would allow them to experience - and better communicate - the excitement of scientific discovery. The lesson that discovery has a central place in engendering such excitement would help emphasize the central place that discovery should have in their own pedagogy.

Research collaborations strengthen the faculty involved. People active in research make better teachers. Research helps keep practitioners up to date. In addition, research gives a subtle understanding of the dominant issues that cannot be replaced simply by reading in the field. Experience gained by faculty in the administrative aspects of running a research program helps prepare them for administrative positions

What is required in the way of resources? The annual cost to support an undergraduate research assistant is comparatively small. The cost for a graduate student can be \$30,000 per year or more. The cost for an undergraduate is typically only \$4000, which supports full time summer research. A central theme of the Ehlers' report is: "The United States of America must maintain and improve its pre-eminent position in science and technology in order to advance human understanding of the universe and all it contains, and to improve the lives health and freedom of all peoples." Investment in research at PUIs is a critical and cost effective part of maintaining the health of the scientific enterprise. It makes effective use of the majority of our research trained scientists, improves the training of the next generation of scientists, and helps insure that they are drawn from every region and group in our Nation. The continued support of this segment of our research effort and the continued development of this effort must continue until we reap the full benefit of the capabilities of the professors and students at our PUIs.

Actions for the Future:

The objectives that CUR will achieve include, first and foremost, continued education of the public, and legislators in particular, of the benefits of fully integrating research and education for undergraduates. We will, working in collaboration with PKAL and NCUR, continue to encourage faculty to engage in research with undergraduates. We will continue to work with funding agencies to encourage and articulate the need for support for undergraduate research. We will continue to celebrate the success of our colleagues as they achieve their research and educational goals for themselves and their students.