Exploring the Concept of Undergraduate Research Centers

A Report on the NSF Workshop

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Executive Summary

The United States has long been envied for the strength of its postsecondary educational system in that it is simultaneously excellent and yet accessible. As we move into the 21st century, the burgeoning population and diversity of college-bound students has begun to place considerable stress on this system that is manifest in such disturbing statistics as increasing times to graduation and increasing attrition rates. These troubling outcomes have led to enhanced public scrutiny of the postsecondary system and calls for greater accountability in ensuring the success of the educational process. In response to these concerns, a national discussion has ensued about the very nature of the postsecondary educational process itself and how it might be improved to be both more engaging and inclusive, in recognition of the greater diversity of the student population, while at the same time, retaining appropriate rigor and depth. This discussion has made clear the fact that academic "business as usual" based on educational approaches that date back to the early 1900's is no longer sufficient to educate the student body of today.

Along with increased diversity in student population has come increased diversity in the possible modes of acquiring a college-level education. The mid-20th century model of an in-residence student attending one institution for an entire four-year undergraduate experience is no longer the norm. Tremendous growth in the number of two-year colleges, comprehensive universities, and even for-profit educational institutions attests to the expanding scope of the undergraduate educational landscape.

These changes in undergraduate education, the populations of students to whom it must be delivered, and the types of institutions within which it is delivered have led to a re-examination of the adequacy of the methods used in undergraduate education, and an enhanced appreciation for the value of pedagogies that actively engage students in the learning process. Participation in research and similar "active" modes of learning have been recognized as especially effective educational strategies, and undergraduate institutions are more frequently using these tools to enhance the undergraduate curriculum across all disciplines.

Nowhere is the utility of research as a learning tool more appreciated than in the sciences. However, despite a rich history of involving advanced undergraduate science students in research, the early science courses, those that are likely to be taken by a much broader range of students, are still largely based on the didactic model of curriculum delivery. At a time when student interest in most sciences is waning and the number of baccalaureate degrees awarded continues to decline (except in the life sciences), the use of these pedagogically stale approaches in introductory undergraduate science courses is detrimental, and has serious consequences for the future strength and vitality of the scientific workforce in this country.

The challenges before us in undergraduate science education are very clear: how can we provide active and engaging modes of learning such as research opportunities, with their inherent pedagogical value, to a larger number of students earlier in their undergraduate careers in a manner that will attract and retain them as majors in these disciplines? And, how can we successfully broaden utilization of these models beyond the current confines of research universities and the more elite four-year colleges to institutions with no history of research and to the growing population of students starting their undergraduate education at two-year colleges? This report contains the summary of a workshop convened to explore these challenges in the discipline of chemistry in the context of a model based on Undergraduate Research Centers (URCs). These Centers would provide research opportunities, perhaps focused around a single scientific theme, to undergraduates, particularly those in the early stages of their undergraduate experience, throughout a consortium of institutions of different size and type.

The workshop explored this concept through its focus on three specific tasks: examine the need for expanded opportunities for undergraduate research in chemistry, particularly in the early stages of a student's undergraduate experience; explore alternative models for providing undergraduate research opportunities that differ from the traditional single faculty mentor-junior/senior undergraduate student scenario; and formulate specific recommendations for a National Science Foundation program solicitation for URCs. The workshop brought together a cross-section of stakeholders in undergraduate chemistry education: faculty and administrators from a variety of educational institutions, including large research institutions, comprehensive universities, predominantly undergraduate institutions, community and tribal colleges, and K-12 schools; representatives of government laboratories, granting agencies, and industry; and an undergraduate student. Although largely based in chemistry, this group also contained representatives from related scientific disciplines. The workshop presenters introduced a similarly broad range of undergraduate research programs, from university-wide initiatives to research-based approaches in specific chemistry courses. This synergistic mix of perspectives and experience resulted in vigorous and expansive discussions that balanced enthusiasm for the concept of URCs with cautionary concern for barriers to successful implementation of such Centers. The process of the workshop—four plenary presentations, each one followed by breakout group discussions, which were in turn followed by reports from each breakout group and full group discussion—allowed consensus on a vision for URCs to emerge, with minimal direction or guidance from the Workshop Steering Committee. This combination of diversity among the participants and emergence in the workshop process were responsible for the success of the workshop in completing its three tasks. Specific recommendations of guidelines for a program solicitation for URCs are contained in the body of the report.

Within the consensus vision, several themes emerged that highlight the philosophical values embedded in the concept of URCs. One central theme was that of collaboration: participants agreed that URCs should bring institutions with divergent missions together to their mutual benefit. A second strong theme that emerged was that, as often as possible, students should be involved in real research and actively contribute to the production of new knowledge. The utility of community-based research experiences in attracting students to the sciences, particularly at urban and nonresidential institutions, was recognized in this context. While it was agreed that URCs should focus initially on expanding research opportunities for freshmen and sophomores, participants articulated an expansive vision in which URCs support research-based learning "from cradle to grave," from elementary school to civic involvement within the local community. Finally, the themes of institutionalization of the culture of research as the cornerstone of scientific literacy for *all* students and curricular reform necessary to successfully support such a vision of URCs were also emphasized. Despite its focus on a seemingly limited problem—improving research opportunities for undergraduates early in their academic experience—the concept of URCs clearly represents the kernel of a comprehensive vision for undergraduate education, one with the potential to transform it from an exclusive "ivory tower" into a vigorous and dynamic forum of inclusiveness and engagement for a larger group of students than we currently serve.

Introduction

Despite a track record of outstanding technical achievements in chemistry and related fields, there is growing concern that the number of U.S. students electing this career path is steadily declining. As shown by data taken from the National Science Foundation's *Science & Engineering Indicators 2002*[1], the total number of degrees awarded in the physical sciences has decreased almost 13% since 1980. Degrees awarded in chemistry, although slightly increasing during the early 1990's, also exhibit a significant downward trend since the late 1990's.

To sustain and diversify our outstanding technical workforce in these fields will require significant creativity and investment in educational infrastructure so that more students, particularly freshmen and sophomores, will be encouraged to select chemistry as a major. This goal requires that we deepen the pool of students we attempt to reach by involving them at an earlier stage of their academic careers, and that we expand the pool by including students at institutions with limited resources, such as community colleges and rural institutions.

Participation in research activities is now widely recognized as a key determinant in encouraging students to pursue careers in the sciences.[2-9] Anecdotal evidence supports a similar impact of research experiences on the career paths of students in chemistry.

Research at the undergraduate level is also known to be a powerful pedagogical tool that significantly enhances the quality of undergraduate science education insofar as research more effectively demonstrates the collective intellectual skills needed by practicing scientists than conventional methods of science education. Undergraduate research experiences are known to provide both tangible and intangible benefits including gains in relation to[2,5-9]:

- Skills
- Thinking and working like a scientist
- Clarification of educational and career goals
- Enhanced preparation for graduate school or career
- Self-confidence as a researcher taken seriously by others
- Socialization into the profession
- Sense of responsibility and independence as a researcher

There is little doubt that these benefits play a significant role in recruiting undergraduates to major in science and to pursue professions in these fields. The traditional model of undergraduate research, however, provides its benefits to a relatively narrow range of students, primarily upper-level students (i.e., juniors and seniors) at institutions with the resources to support research. Since these students are usually already science majors, the recruitment value of research is limited in this model. *The motivating premise that underlies this workshop is that the creation of communities of institutions that more broadly engage younger students* *(particularly freshmen and sophomores) in research experiences will attract a larger and more diverse student body to chemistry and related disciplines.* Research projects conducted within these communities could be more broadly defined than the traditional mentor-student apprenticeship model in order to be better "titrated" to the skills of such students as well as to be consistent with available facilities and instrumentation. Appropriate activities for such a model might include traditional faculty-initiated research projects in addition to carefully designed discovery-based laboratory exercises, or basic research projects that support classroom or laboratory curriculum development, among others.

To gain deeper insight into the feasibility of this concept, a workshop was held at the National Science Foundation (NSF) in Arlington, Virginia from March 30 through April 2, 2003. The goals of this workshop were to assess the interest in and merits and feasibility of creating such Undergraduate Research Centers (URCs) in chemistry. The Steering Committee for this activity (Appendix 1) identified a group of individuals (Appendix 2) representing a broad array of stakeholders from research universities, predominantly undergraduate institutions, comprehensive universities, community colleges, high schools, government laboratories, industry, funding agencies, and foundations to help achieve these goals. The workshop featured seven plenary talks to present existing models for novel undergraduate research programs and small group discussions to facilitate the exploration of issues pertaining to the development of URCs. Participants considered the value of research for undergraduate students and explored alternative models for delivering research opportunities to a wider audience than is currently served by the traditional model of undergraduate research, including students earlier in their undergraduate careers, students at community colleges, and students at institutions in rural locations. Thus, the primary hypotheses of the workshop were that:

1. Research experiences enhance the quality of undergraduate science education and the resulting motivation of students to pursue careers in the physical sciences;
2. Undergraduate research experiences need to be more widely and equitably accessible to students at all levels of the curriculum and at all types of post-secondary institutions; and
3. Exposing students to research at an earlier stage in their undergraduate careers (or even at the secondary level) is beneficial both in terms of improving the quality of education and recruiting students to careers in science.

This report details the outcomes of this workshop in the form of summaries of the plenary talks and the highlights of discussions that took place during small group breakout sessions. A compendium of undergraduate research program descriptions that embody one or more of the central principles of the URC concept is also included. It is hoped that this information will be a useful resource of ideas for the community as it seeks to weave research experiences into the fabric of undergraduate education in chemistry at all levels of the curriculum. This report also contains the consensus recommendations for the development of URCs resulting from workshop discussions that are respectfully submitted to the National Science Foundation for their consideration.

Objectives of the Workshop

The objectives of the workshop were to:

1. Define and refine the problem of enhancing and expanding the opportunities for undergraduate research, particularly at lower levels of the curriculum;
2. Consider alternative models of undergraduate research through presentations of model programs; and
3. Formulate specific recommendations for a National Science Foundation program solicitation for URCs.

Structure of the Workshop

The Workshop consisted of four sessions, each with a plenary presentation by one or two speakers followed by breakout discussion groups and concluding with a large group discussion of reports from the breakout groups.

Session 1: **Broadening the Scope of Undergraduate Research**

Plenary Speaker: *Karen Morse, President, Western Washington University*
"Broadening the Scope of Undergraduate Research"

This session considered the role of research activities, broadly defined, in contributing to the intellectual development of undergraduate students, increasing the number of undergraduates that pursue careers in science, technology, engineering and mathematics, and the development of the scientific workforce. The populations of students that are or could be affected by participation in research activities were considered, as were the needs of these respective populations and how their education could be enhanced through participation in research. Finally, barriers to achieving this enhancement were considered.

Sessions 2 & 3: **Mechanisms and Opportunities for Increasing the Participation of Freshmen, Sophomores, Women, Under-represented Minorities, and Persons with Disabilities in Undergraduate Research**

The first of these two sessions considered the traditional model of undergraduate research that is done predominantly with upper-class students (i.e., juniors and seniors), the strengths and weaknesses of this model, and barriers that have made this traditional model largely inaccessible to significant segments of the undergraduate population. The second session followed with consideration of mechanisms for broadly increasing participation in research activities and strategies for interfacing with other communities who could benefit from access to or enhanced undergraduate research activities. (Vignettes describing innovative programs that broaden participation in research to the target populations or that successfully interface with other communities such as community colleges, high schools, industry or government labs were solicited from participants and others for inclusion in the program to facilitate discussion of strategies for increasing participation in research.)

Session 2: **Traditional Models of Undergraduate Research: Strengths and Weaknesses**

Plenary Speakers: *Mike Doyle, University of Arizona*
"Research with Undergraduates: How to Win Friends and Influence Students"

Elaine Seymour, University of Colorado-Boulder
"Establishing the Benefits of Research Experiences for Science Undergraduates: First Findings from a Pilot Study"

Session 3: **Increasing the Pool**

Plenary Speakers: *Pam Mills, CUNY-Hunter College*
"Do Only Our Best Students Deserve a Research Experience? Authentic Research Experiences in the General Chemistry Laboratory"

Ray Turner, Roxbury Community College, Boston
"The ATOMS Project: An Inner-city Model for Undergraduate Research Centers"

Session 4: **Structure, Resource Needs, Assessment, and Sustainability of Undergraduate Research Programs**

Plenary Speakers: *Carlos Gutierrez, Cal State-Los Angeles*
"Structure, Resource Needs, Sustainability, and Assessment of an Undergraduate Research Program at a Minority Urban Comprehensive University"

Sandra Gregerman, University of Michigan
"Improving the Academic Success and Retention of Diverse Students through Undergraduate Research"

This session considered the "nuts and bolts" aspects of establishing, operating, assessing, and sustaining broadly-based undergraduate research programs. Critical barriers and pressure points that inhibit implementation of such programs, and essential resources that would allow these barriers to be surmounted were explored.

Criteria that define the success of such programs were articulated, and strategies for assessing this success were considered. Mechanisms for resource identification to allow these programs to become self-sustaining were discussed.

The workshop concluded with the articulation of consensus recommendations to advise the development of a program solicitation for proposals for URCs.

Recommendations

A set of recommendations for URCs emerged with a broad base of support from participants:

1. ***Increasing student involvement in real research***. URCs should identify and guide students into real research opportunities (as opposed to laboratory exercises) appropriate for their age and skill level.
2. ***Focus on first and second year students***. While URCs will ideally embrace a research community extending from K-12 through postgraduate, the initial focus is on expanding and enhancing research opportunities for students in their first and second years of college.
3. ***Multi-institutional participation***. URCs should bring several institutions together in collaborations and partnerships of mutual benefit. “Institution” is broadly defined to include traditional educational institutions (undergraduate colleges, research universities, community and tribal colleges, high schools or K-12), as well as industry, government agencies and research laboratories, and local communities. Proposals should provide a detailed management plan specifying how inter-institutional relationships will be negotiated and coordinated.
4. ***Impact on capacity***. URCs should increase the number of students served by both existing and new research programs.
5. ***Amount of funding and duration***. URCs should be funded in amounts ranging from $100,000 to $500,000 per year for a duration of three to five years. Five years is preferred to allow time to assess the impact of early research experiences on students throughout the course of their undergraduate career.
6. ***Program administration.*** URCs should provide independent administrative staff and resources for coordinating existing programs, implementing new ones, and providing assessment.
7. ***Student, faculty, and institutional development***. URCs should facilitate continuous development of students throughout their academic career (K-12 through postgraduate, or, in the broadest vision, from “cradle to grave”), ongoing development for faculty through workshops and teaching resources, and institutional development through the education of administration about the value of undergraduate research.
8. ***Curricular integration of research***. URCs should support curricular reform and innovation to integrate research experiences as a key component of education for all students and to foster an institutional culture of research. Programs that foster interdisciplinary approaches to research are encouraged.

9. ***Program assessment***. URCs should provide staff and resources for effective, ongoing program assessment according to contextually meaningful measures.
10. ***Sustainability***. URC proposals should include plans for institutionalizing long-term sustainability.
11. ***Planning grants***. A planning grant competition should be provided prior to solicitation of final proposals to enable institutions to explore opportunities for Undergraduate Research Centers in their region and to develop a competitive URC proposal. This is particularly important for geographically-isolated institutions, those with few research resources, or those with little history of research.

Workshop participants stressed that these guidelines should be interpreted permissively rather than restrictively in evaluating proposals. The intent is to solicit creative and innovative proposals that result in redefining and expanding the research community, beginning with the inclusion of undergraduate students in their first and second years of college.

Summaries of Workshop Presentations

Broadening the Scope of Undergraduate Research

Plenary Speaker: *Karen Morse, President, Western Washington University*
"Broadening the Scope of Undergraduate Research"

Dr. Morse addressed the intellectual development of undergraduates, increasing the number of undergraduates who pursue careers in science, and development of the scientific workforce. Her vision of scientific education is broad and integrative: she described her institution as a place where undergraduates frequently work alongside graduate students and postdoctoral researchers, as well as high school students. Her goal for this talk was to sketch some possible issues for discussion with respect to URCs. The first issue is how to define a URC: as a strong undergraduate research program? As a coordinated, inter-institutional program? As a consortium? As partnerships with community colleges, high schools, or industry? As faculty development, curriculum reform, minority programs? Other key questions are: who are we dealing with? What are the problems? What do we want to accomplish? Science is learning by doing, and our goal should be a "seamless education" in research in which learning is intertwined with the experience of discovery and the building of problem-solving skills. Faculty can lead students into a research frame of mind by intertwining and integrating them into their own research missions. Specific recommendations for doing so included:

- Keep the undergraduate research experience small-scale so that it's manageable and so that students realize satisfying results.
- Provide individual attention and intellectual stimulation; build relationships.

- Respect the nature of undergraduates: they are different from graduate students.

Dr. Morse emphasized the need to consider the undergraduate psyche when conceptualizing URCs: undergraduates have a strong need for guidance, support, direction, and encouragement to help them develop understanding. Personal interaction and mentorship are extremely important in building strong student-faculty relationships. The need to target specific populations (honors students, female and minority students, high school students, community college students, and especially students who will go on to become science teachers) is balanced by the need to expose all students to engaging scientific discovery and to identify potential scientists at an early age. One function of URCs could be to make faculty aware of the specific needs of underserved populations; e.g., of the role of communication in helping women to feel comfortable in science. Dr. Morse noted the success of the Shannon Point Marine Center at Western Washington University[10] in increasing the participation of minorities, women, and disabled students. This program emphasizes mentor relationships that begin in the academic realm and extend into the professional environment upon completion of the program. Successful targeted programs:

- Stress the importance of understanding the student psyche;
- Exploit a high-quality niche by leveraging existing institutional strengths or community opportunities;
- Attract the targeted group;
- Draw funding; and
- Develop a sense of apprenticeship in students.

Several barriers to developing these programs exist: restrictions on faculty time for mentorship and for program and curriculum development; restrictions of laboratory space and equipment; curricular constraints on the time needed to prepare students to undertake research; insufficient rewards for faculty participation in undergraduate research; and a research culture that is discouraging to potential young scientists. URCs could help overcome these barriers in the following ways:

- Providing workshops on basic research, communication, and collaboration skills;
- Providing faculty development workshops;
- Valuing innovative pedagogy;
- Sharing and disseminating the information and the results of student research;
- Providing administrative support and assessment;
- Communicating priorities with administrations;
- Transmitting studies on undergraduate research;
- Detailing the undergraduate psyche;
- Providing funds for undergraduate stipends and conference participation;
- Developing research cohorts;
- Providing speakers;

- Providing programs and online resources for undergraduates; and
- Building students' imaginations and their sense of discovery.

Above all, URCs can help to create a university culture that values student learning and student contributions to the creation of new knowledge. Funding alone will not solve the pipeline problem. URCs can help to build an ethos of undergraduate research by rewarding student research and creative endeavors, not just in science, but in all disciplines.

Traditional Models of Undergraduate Research: Strengths and Weaknesses

***Plenary Speaker**:* *Mike Doyle, University of Arizona*
*"**Research with Undergraduates: How to Win Friends and Influence Students"***

Undergraduate research is a capstone experience for students. Advantages for students and faculty include the mentor relationship, the opportunity to develop problem-solving skills and to perform experiments, the opportunity to explore and clarify career choice, the opportunity to contribute (or even author) publications and to take part in presentations, and an important link to the profession. The advantages for students and faculty tend to mirror each other, creating a satisfying experience for both participants. The Oberlin Reports of 1985[11] and 1987[12] noted the significance of undergraduate research and its importance in attracting students to careers in the sciences. Students who perform research as undergraduates tend to enter graduate school in science and pursue science as a profession. There are impediments to undergraduate research, however: time and space, salaries, stipends, and other funding tend to be in short supply. An additional impediment is ensuring that undergraduates have sufficient skills and self-confidence to carry out research effectively.

Several years ago, a number of foundations collaborated to fund a study on the environment for research at predominantly undergraduate institutions and produced *Academic Excellence: The Sourcebook*,[13] that provided data on the extent of research activities at these institutions. During the past fifteen years, there has been a significant increase in the number of students pursuing biology and biology-related sciences, but the number of students entering chemistry has remained fairly constant. From 1991 to 2000, the number of summer research students in the natural sciences has gone from 20 per institution to 33 per institution, showing strong support for undergraduate research. The government is providing most of the support for this research ($500 million compared to less than $150 million from all other sources in the past ten years). Peer-reviewed proposals submitted by faculty at predominantly undergraduate institutions to the NSF RUI program, the NIH AREA program, Research Corporation's CCSA program, and the ACS-PRF Type B program for research have remained level from 1986-2000, with about 1200 proposals received per year and 400 awards given per year. In terms of disciplinary distribution, 2200 of 5529 grants went to chemistry during the years from 1986-2000. These awards were distributed among 675 institutions, with 40 percent of these receiving only one or two awards between 1986 and 2000. The NSF RUI program for undergraduate research in chemistry at predominantly undergraduate institutions within the context of their resources is now receiving 50 proposals per year and funding 20 per year, or roughly 40 percent, a relatively high proportion. The NSF Instrumentation and Laboratory Improvement (ILI) program has seen proposals decrease from 2000 per year to approximately 1300 per year, although the level of funding has remained constant at approximately 500 awards per year. The NSF Major Research Instrumentation (MRI) Program has also funded predominantly undergraduate institutions at a very high "success" rate. External funding to faculty in chemistry at predominantly undergraduate institutions between the years of 1990 and 2000 averaged as follows: female faculty: \$13,947 per year (or 0.31 grants); male faculty: \$12,707 per year (or 0.30 grants). This amount is lower per faculty member than any other of the natural science departments. Publications by chemistry faculty in peer-reviewed journals during these years averaged as follows: female: 0.48 per year; male: 0.63 per year, with a composite of 0.60, a rate that compares favorably with those in other natural sciences at predominantly undergraduate institutions. (For comparison, the numbers of publications are 1.3 per faculty at M.S. institutions and 3.7 per faculty at Ph.D. institutions.)

Characteristics of faculty at predominantly undergraduate institutions (rated as high-average-low) include:

a. Number of teaching contact hours: 16 – 12 – 8
b. Grant support per year: \$30K - \$13K - \$5K
c. Number of publications per year: 0.75 - 0.60 - 0.25
d. Number of publications produced with undergraduates: 40% - 26% - 10%

The average cost for acquisition and maintenance of chemistry research equipment at predominantly undergraduate institutions is approximately \$50,000 per year, which is realizable by most institutions. The cost of undergraduate research at a predominantly undergraduate institution with an existing laboratory (including stipend, supplies, faculty salary, and travel) totals between \$14,000 and \$21,000 per year.

From a research productivity point of view, graduate students are relatively unproductive during their first two years, as are undergraduate students in their first two years. The third and fourth years for both graduate and undergraduate students tend to be productive. The question is: can we profitably expect students in their first two years to be productive, and who should pay for this experience? A proposed undergraduate curriculum would be an introduction to the techniques and methods of research during the first two years, with the third and fourth years devoted to investigative research. The success of this experience could be measured in terms of publications, preparation for graduate or professional school, presentations, resume-building, and experience and motivation. An ongoing problem is the role assigned to research in the definition of academic excellence at different institutions. It seems, however, that the same constraints often apply to both those who pursue research and those who do not. The difference is the passion for research.

During the group discussion of Dr. Doyle's presentation, the fact that URCs could benefit undergraduate research at predominantly undergraduate institutions by providing infrastructure and helping to alleviate time problems was noted. The point was made that although it's not terribly difficult to find funding to support students, it is often much more difficult to find funding to develop and support the infrastructure needed for undergraduate research.

***Plenary Speaker**:* *Elaine Seymour, University of Colorado-Boulder*
"Establishing the Benefits of Research Experiences for Science Undergraduates: First Findings from a Pilot Study"

Dr. Seymour presented highlights of first findings from her research group's five-year study of undergraduate research at four liberal arts colleges (Grinnell, Harvey Mudd, Hope, and Wellesley) with a long history of undergraduate research programs.[9] The study is both qualitative and quantitative. The qualitative study focuses on the contributions made by undergraduate research to education, career choices, and personal/professional development, as well as the processes and conditions under which these outcomes are realized. The study also considers what (if anything) is lost when students do not participate in undergraduate research.

The study sample comprises all senior students (N = 79) and their faculty mentors working in summer research at the four sample institutions in the disciplines of biology, chemistry, physics, mathematics, computer science, engineering and psychology. First year interviews were conducted with the 79 undergraduate research participants, their faculty mentors (N = 55), and 9 undergraduate research program administrators. In the second year, 69 of the original student cohort were interviewed very close to their graduation, along with a comparison student group of graduating seniors who: chose not to do undergraduate research, chose not to do so until their senior year (e.g., for a thesis), chose alternative experiences, or applied for undergraduate research but were not selected. A comparison group of faculty were those who never or rarely mentored undergraduate researchers, or were taking time out from this summer work.

Interviews with participants were transcribed *verbatim*, hand-coded and the data entered into 'The Ethnograph', a set of computer software programs that aids in the analysis of large qualitative data sets that allows searches for coded segments across the data set or sub-sets of it, and the generation of code word frequencies. Codes and their thematic groupings are stored in an electronic codebook that is augmented and edited as the analysis progresses.

From the research group's analysis of the first round of student participant interviews, Dr. Seymour presented an overview of students' perceptions of the benefits of their undergraduate research experiences as summer research apprentices:

I. 28% noted personal and professional gains, including:
   A. Increased confidence (40%)
      1. 29% In ability to do research
      2. 11% In contributing real knowledge to science
   B. Increased confidence in "feeling like a scientist" (27%)
   C. Increased confidence in presenting, prospects of publishing a scholarly article, and in writing skills (7%)
   D. Establishing a mentoring relationship with a faculty member (16%)
   E. Peer/professional collegiality: with faculty, with other students (9%)

II. 28% noted intellectual development in thinking and working like a scientist, including:
   A. Gains in the ability to *apply* knowledge and skills (57%):
      1. 43%: Critical thinking and problem-solving skills, including analyzing data, understanding theoretical/conceptual frameworks
      2. 13%: More advanced/mature understanding of the nature of science, how scientific knowledge is built
   B. Gains in knowledge and understanding (43%)
      1. 15%: greater knowledge, understanding in greater depth, making connections within and between science
      2. 13%: Consolidating and deepening knowledge through presentation, teaching
      3. 10%: Increased relevance of coursework
      4. 6%: Understanding the process of research: tolerance for frustration, setbacks and "failure"

III. 19% noted improvement of skills, specifically:
   A. Gains in communication skills (43%)
      1. 22%: Presentation and oral argument (from the student's point of view, this is very important)
      2. 14%: Communication skills, generally
      3. 7%: Writing skills
   B. Other gains in skills (57%)
      1. 22%: Lab skills
      2. 11%: Work organization skills
      3. 9%: Computer skills
      4. 8%: Reading comprehension skills
      5. 5%: Ability to work with others
      6. 2%: Ability to retrieve information

IV. 12% benefited from clarification of future career goals, including:
   A. The experience of hands-on research clarified, reinforced student's interest in the field (30%)
   B. Clarified, reinforced student's interest in going to graduate school (25%)
   C. Increased probability of student's continuing on to graduate school (14%)
   D. Increased interest/enthusiasm for student's field of study (12%)
   E. Stimulated interest in a research career (6%)
   F. Clarification that research is *not* good temperamental fit for student (5%)

V. 9% benefited by enhanced career/graduate school preparation, including:
   A. Undergraduate research provided "real world" work experience (36%)
   B. Undergraduate research offered opportunity to network with faculty, peers other scientists (28%)
   C. Undergraduate research enhance student's resume (18%)
   D. Other areas of increased job/graduate school preparation (19%)

VI. 4% benefited from changed in attitudes toward learning and working as a researcher, including:
   A. Gains in learning and working independently (86%)
   B. Gains in intrinsic interest in learning (14%)

Interestingly, the decision to attend graduate school (which is a benefit of undergraduate research viewed from the perspective of institutions who offer undergraduate research programs) is not necessarily seen as such by students. Moreover, the researchers found that, among their rising senior sample, few students reported that their research experience had led to a decision to enter graduate school, although many used the opportunity to clarify and refine their existing plans. A handful decided not to continue in academic science on the basis of their research experiences. The researchers will use their third and final interviews with the whole student sample (participants and the comparison groups) in part to establish when these young people formed their career plans and what were the salient influences in their decisions.

Students appeared to be less motivated to apply for a summer undergraduate research position because of its value as a resume item in their applications for higher education or employment than by the intrinsic value and interest of the research itself. Indeed, students stressed that many of the benefits of undergraduate research are transferable to a wide array of educational and professional situations. However, many gains reported by students reference aspects of professional socialization that are essential for those who are considering an academic research career. These include learning the patience and creativity to deal with the normal risks of research work, with its setbacks, errors, uncertainties, and ambiguities, and learning to give and receive professional critique.

An interesting gender difference in student responses was noted: female students reported that they were closely watching both male and female faculty, especially those with families, to see whether and how a balanced life (that included work, family, personal, and social activities) could be achieved in academic science. How more senior colleagues were observed to respond to younger family with children was also carefully observed by women students. This finding may contribute to our understanding of ongoing national difficulties in attracting and retaining women in the sciences.

The next phase of the research will include comparison of faculty perceptions with those of their student of the benefits of undergraduate research, considerations of the costs and benefits to faculty of engagement in undergraduate research programs, clarification of the longer-term benefits of undergraduate research (including its role in shaping career decisions), and distillation of the processes and mediating factors whereby good outcomes are achieved. Core components of these processes are predicted to include: departmental and institutional roles in establishing a structure and climate that supports undergraduate research programs; the many facets of faculty mentoring; the role of the peer research group; and the reflective engagement of participants in their own growth processes.

Increasing the Pool

***Plenary Speaker**:* *Pam Mills, CUNY-Hunter College*
"Do Only Our Best Students Deserve a Research Experience? Authentic Research Experiences in the General Chemistry Laboratory"

Dr. Mills opened her presentation with the story of "Ray," a former undergraduate chemistry student. Ray was an average student, with a GPA of less than 3.0, extremely pleasant and respectful, and interested in freshman chemistry ("because it's challenging") and in English ("because I'm a good writer"). As an upper class student, Ray considered undergraduate research, but faculty felt he was not sufficiently motivated, and no one would accept him into a research laboratory. The question that often arises in such cases is whether Ray should be provided with a research experience? Are there any benefits to bringing Ray into research? Dr. Mills proposed that instead of focusing on the question of increasing the numbers of majors and graduate students, the role of research as a valuable component of liberal education should be considered. She suggested that redefining the meaning of research for undergraduates is a crucial part of creating meaningful models of undergraduate research.

The goals of a liberal education include the development of critical thinking skills, understanding multiple modes of inquiry, and the application of critical thinking skills to "real world" issues and problems. These goals are identical to the goals of science education. A 1997 report from the National Academy of Sciences[14] entitled *Science Teaching Reconsidered* recommends the use of research as a teaching and learning model and suggests that "the activity of finding out can be as important as knowing the answer." Presently, there are two primary models of undergraduate research: the graduate model, in which the construction of new knowledge is the primary objective, and the student-centered model, that emphasizes process over outcome and whose primary objective is to provide experiences that are new to the student. Is the classroom-based, student-centered research model a viable alternative to the traditional model of undergraduate research? How important is it to the student (not to faculty) that their research produces knowledge that is new to the scientific community? How would a student-centered, classroom-based research model contribute to the liberal education of students? Benefits would include the development of communication and critical thinking skills (learning to think and act like a scientist), the opportunity to see real-world applications of their learning, and increased confidence to conduct scientific research.

Dr. Mills described the research cycle as consisting of five stages: preparation (studying and possibly repeating what is already known), formulation of a "What if . . . ?" question (forming a hypothesis and designing a study or possibly extending an existing study), the collection and analysis of data (repeating the experiment, if necessary), reporting the results (in an oral or poster format or in a journal article), and peer review of the results (in which knowledge is constructed by the scientific community; this step is often excluded from the undergraduate research model). Existing models of student-centered research include only part of this research cycle, are directed primarily to upper-class students, and are usually based on a faculty member's existing research program. Can this model be successfully applied in the education of freshmen chemistry students?

Dr. Mills presented the model currently in use at Hunter College, a large (enrollment of 20,000) urban public institution (part of the CUNY system). The class enrolls 100 students, primarily freshmen, and consists of a three-semester course, the third semester of which is a two-credit, non-laboratory course on chemical bonding taken concurrently with organic chemistry. Lecture and laboratory are integrated, with four hours of lecture, three hours of laboratory, and two hours of workshop. The research cycle of the course takes the following form:

1. Semester 1 (first semester, freshman year): The theme is learning how to communicate data, with some inquiry and experimental design in the labs.
2. Semester 2 (for 5 of 14 weeks): Students propose and conduct an experiment. At the end of the semester, students submit the results as a paper in journal format. Most students do a straightforward extension of a laboratory exercise that they've already performed. Grading is binary, either 0 or 100 points: either they do it or they don't.
3. Semester 3: Students elect a peer review board and conduct the peer review process on papers from the previous semester, selecting papers for publication on the web. Examples of published papers include:

    - "How will different barriers affect the voltage of a galvanic cell?" by Michael Breen
    - "Investigation of the non-linear portion of an absorbance vs. concentration plot," by Jaroslav Usenko and Jophn Sfakianos
    - "Thermodynamics of water vaporization," by Christine Jones and Yunyan Shen

What happened to Ray? Ray was elected to the peer review board, on which he served with great distinction. His journal article was, as expected, mediocre and was not selected for publication. Interestingly, Ray was one of the most insightful and critical editors ever to serve on the board, and it is puzzling that he never seemed able to exercise his insight and critical abilities in relation to his own work. Nonetheless, Ray went on to become a high school chemistry teacher in New York, where he has just finished his first year and is reportedly very happy with his new profession. In short, Ray is a positive outcome of the undergraduate research experience.

Dr. Mills concluded by reiterating some key questions related to undergraduate research and introducing some new ones:

a. How important is it to students that their discoveries be new to the scientific community?
b. How would such a student-centered research model contribute to the liberal education of students?
c. Is a student-centered research experience viable?
d. Can we further attract new students by a radical transformation at the freshman chemistry level?

A discrepancy exists in the structure of introductory courses across the disciplines: the social sciences and humanities provide one track for introducing students to their areas of study, while the sciences have multiple tracks. What would happen if the sciences developed a single, integrated introductory curriculum for all students? Suppose that the freshman year was unified around the process of *doing* science for all students: is this possible? Would it benefit our majors? Would it empower more students?

During the full-group discussion after Dr. Mills' presentation, participants noted other examples of this type of student-centered model, including one example described by Professor Steve Regen at Lehigh University in which an entire class performed an aggregate experiment and produced an article that was published in the journal *Materials Chemistry*. In response to a question about the "all-or-nothing" grading scheme that is used for the conceptualization and execution phase of the research cycle in the Hunter College freshmen chemistry experience, Dr. Mills stated that it was to reinforce the communally-constructed nature of knowledge by stressing the peer review process over instructor grades.

***Plenary Speaker**:* *Ray Turner, Roxbury Community College, Boston*
"The ATOMS Project: An Inner-city Model for Undergraduate Research Centers"

Dr. Turner began by identifying a problem: the MCAS (Massachusetts Comprehensive Assessment System), a standardized examination required of all graduating high school seniors, reflects considerable underachievement in certain regional sectors. Test results demonstrate a lack of math and science preparation among students entering Roxbury Community College (RCC). Dr. Turner took two approaches to address this problem: the development of several strategies designed to boost students' skill levels in math and science, as well as upgrading the college's technology infrastructure to allow for 24 hours a day, 7 days a week interactive web-based teaching and learning modules; and the development of a new program to involve students in community-based, culturally-relevant research. The infrastructure for these approaches also supports pre-college students involved in many of the college's K-12 programs. Once students are proficient in math and science, the college's honors science program screens students and places qualified students at prestigious research universities in Boston. ATOMS (Advance Training Opportunities for Minorities in Science) is a Bridges to the Future grant funded by the NIH National Institute of General Medical Sciences. While the college is successful at placing qualified community college students in internships at major research institutions, it has recently put a different spin on ATOMS by expanding it in order to harness human potential energy for science through a new collaborative project called FUSION (Facilitating Urban Science Initiatives by Organizational Networking). This approach recognizes the importance of environmental health and health disparity issues prevalent in minority communities and the likelihood that science exploration may be made more attractive when framed in a "culturally relevant" context. The high density of public and private agencies and research institutions surrounding RCC provides a unique opportunity to strengthen existing partnerships through e-networking and e-collaboration.

Culturally relevant and community-based science projects could serve as "magic bullets" to recruit more minorities to the sciences at every level. A "Smart Lab" at Roxbury Community College equipped with advanced broadcast media technology and an advanced television studio will play a significant role in supporting the virtual scientific learning community. The Urban Gardening Project is exploring the concept of "farms in the city" and offering many students an opportunity to engage in hands-on research in soil chemistry, while the Air Quality experiments conducted in Roxbury neighborhoods, in cooperation with Harvard University School of Public Health, involve the analyses of airborne sub-micron particles and polynuclear aromatic hydrocarbons. These projects, conducted by RCC students in collaboration with over 30 community-based agencies, and the results of these experiences are shared through use of technology. Dr. Turner's presentation included a wealth of examples of RCC students actively involved in research (many as collaborative groups), thus demonstrating both the feasibility and the success of implementing undergraduate research within the community college environment and emphasizing the importance of local, community-based research for attracting and involving minority students.

During the group discussion after Dr. Turner's presentation, the link between community-based research and service learning, a connection with potential for work with high school students and an opportunity to empower students as community builders, was noted.

Structure, Resource Needs, Assessment, and Sustainability of Undergraduate Research Programs

Plenary Speaker: *Carlos Gutierrez, Cal State-Los Angeles*
"Structure, Resource Needs, Sustainability, and Assessment of an Undergraduate Research Program at a Minority Urban Comprehensive University"

Dr. Gutierrez began by summarizing the history of California State University - Los Angeles (CS-LA), which was founded in 1946 as one of 23 institutions in the California State system. CS-LA currently enrolls 20,765 students and is the most ethnically and racially diverse four-year institution in the United States. CS-LA students have the lowest per capita income level of any of the California State institutions and come primarily from within a 25-mile radius of CS-LA (so are largely commuters). Students are largely self-supporting, working an average of 18 to 40 hours a week.

In 1957, the chemistry department chair decided to focus the department on serving the needs of the teachers' college. Three faculty members, however, had a different agenda: they wanted to incorporate research into the undergraduate curriculum. For a model, they looked to predominantly undergraduate institutions such as Carleton, Oberlin, Grinnell, Hope, Bates, and Furman: small liberal arts colleges where undergraduate research was already proving to be successful at preparing students for graduate school. Despite the obvious differences between CS-LA and these small liberal arts institutions, they all provide many opportunities for students to work closely with faculty in undergraduate research. The Minority Opportunities in Research (MORE) program is designed to assist students in developing their own abilities (as distinct from faculty developing students' abilities) and making their talents available to the research enterprise. MORE serves as an umbrella program housing numerous programs that focus on students from funding agencies such as the National Institutes of Health (NIH), NSF, the American Chemical Society, etc. A key to the success of MORE is the creation of staff positions dedicated to administration of the program. In addition, participation by faculty and staff is widespread.

MORE provides an "idealized" four-year plan for students that integrates research, workshops, seminars, writing support and orientation into academics. Although students ideally enter the plan as freshmen and continue for all four years, students in fact enter at various points, up until the beginning of their senior year. Retention of MORE students to graduation in their major is 95 percent. (University-wide, retention of majors who do not participate is 30 percent). CS-LA students in the NIH Research Initiative for Scientific Enhancement (RISE) program have co-authored 557 journal articles and more than 3,000 presentations at local, national, and international meetings. Dozens of MORE students are currently enrolled in doctoral programs; CS-LA supplies more graduate students to UCLA than any other institution. Eleven MORE graduates are now faculty members.

Dr. Gutierrez quoted Anthony Andreoli: "We are developers of talent, not its creators. Talent is widely distributed." Having an entity on campus that worries specifically about the development of student talent makes an enormous difference. The goal of MORE is not to convert every student into a scientist, but to identify the students who are motivated to become scientists.

Dr. Gutierrez advanced his argument for supporting minority participation in research through a series of quotations, beginning, interestingly, with a quotation attributed to Pablo Picasso: "Art is the lie that lets us see the truth." Likewise, "Chemistry is the lie that lets us see the truth: molecular truth." Chemists are model builders, and it is important to remember that we study models. In contrast, a quotation from a student indicates that his attraction to science is related to its freedom from bias or prejudice: "What matters is what you know and what you can do with it." Another quotation states that distance learning is preferable because the Internet masks race, ethnicity, and gender. Both of these statements betray a false belief that it is possible to discard the factors that "model" each of us (race, gender, ethnicity) and engage directly with truth. Dr. Gutierrez offered another perspective through a student whose passion for chemistry is unabashedly flavored by his identity as Chicano: "I do Chicano chemistry," he says of his study of chiles. "These molecules are hot. They burn me up. [. . .] If I don't study the chemistry of chiles, who will?" This student embodies a kind of "holistic" science, and Dr. Gutierrez considers him the best of his student scientists. As David Bohm and David Peat write in *Science, Order and Creativity*, "Different kinds of thought and different kinds of abstraction may together give a better reflection of reality. Each is limited in its own way, but together they extend our grasp of reality further than is possible with one way alone."[15] This is the most compelling intellectual justification for working to increase the participation of minorities in science: the greater the diversity of our talent, the richer, more complex, and more complete will be the science that results.

The NIH RISE program provides annual salaries for students as follows: $6,200 for freshmen, $7,200 for sophomores, $8,400 for juniors, and $9,400 for seniors. Undergraduate research at CS-LA is a year-round activity, usually embarked upon in the second year, although students can begin as freshmen. Requirements to enter the program are motivation and a better-than-2.5 GPA but who are capable of growing to a 3.0 GPA by graduation. (Ability and talent do not necessarily correlate directly with GPA.) NIH RISE is not for chemistry only, but includes ample opportunities in chemistry. At least one summer is spent in off-campus research at various locations. Because 55 percent of CS-LA students transfer from community colleges, particular attention is paid to these students through programs such NIH Bridges to the Future.

While research training is the heart of the MORE program, it also consists of other important components: attention to academics, travel to meetings, academic and career advisement, seminars, and workshops. Career advisement is particularly important, since faculty generally tend to advise in academic directions. On Friday 30 times each year, the Biomedical Science Seminar meets to broaden students' scientific awareness, provide opportunities for them to present their research, and improve their awareness of graduate school and career opportunities. Speakers are invited from academia and industry. Workshops offer training in laboratory safety, techniques, and instrument use, as well as GRE preparation and applying to graduate school. Writing support in science is provided by two graduate students throughout the four-year program; students are encouraged to "write with the precision of a poet."

The program was slow to develop assessment and evaluation, but has profited from its findings. It is important to plan for evaluation from the beginning and to work with someone with expertise in evaluation. Evaluate for the right reasons: to learn and to improve the program, not simply to satisfy the requirements of the funding agency. Ongoing evaluation is provided by the Program Evaluation and Research Collaborative (PERC). Turning evaluation into research helps to make evaluation interesting.

Among the resources that are required are a plan (what are the institutional goals for undergraduate research?), people (a core of talented, research-oriented faculty who care about undergraduates, supportive administration, and talented staff), infrastructure (adequate facilities and instrumentation), and funding. NIH, NSF, the Arnold & Mabel Beckman Foundation, and the Dreyfus Foundation have all been supportive. Sustainability is required for each of these components.

It's important to remember that most of the work takes place under the direction of the individual faculty member; the MORE program is simply an umbrella structure to support this work. "My research students and I do chemistry because we're good at it, we like it, and it is our pleasure."

In the discussion following Dr. Gutierrez' presentation, it was noted that occasionally, students will give short shrift to their academics in order to spend more time in the laboratory, but the answer has been to monitor their academics and to limit their lab time accordingly. Recruitment is largely by word of mouth, though letters are sent to all entering students. Students respond enthusiastically to being approached about research opportunities.

***Plenary Speaker**:* *Sandra Gregerman, University of Michigan*
"Improving the Academic Success and Retention of Diverse Students through Undergraduate Research"

Dr. Gregerman began by noting the significance of the current date, when the University of Michigan affirmative action case was due to be heard by the Supreme Court. The fate of programs such as the one she was presenting is uncertain. The Michigan Mandate was a call to increase diversity in the university system. The current University of Michigan profile is: enrollment of 25,000, of which 23 percent are students of color (9 percent African American, 4 percent Latino/a, and 10 percent Asian American). The University is a large public research university, 40 minutes from Detroit and 60 minutes from Lansing.

While recruitment of minorities was proceeding well prior to implementation of the University Research Opportunities Program (UROP), retention rates were poor. Explanations for this problem include poor high school preparation, a lack of identification with the culture and goals of college and lack of close contact with faculty, and external pressures (financial, cultural, or familial). The solutions identified were to integrate these students into research through "living learning", to encourage peer-to-peer interaction (study groups and seminars), mentoring (both student-to-student and student-to-faculty or -staff, and the UROP, or student-faculty partnerships through undergraduate research. (Although UROP does emphasize diversity, all first and second year students are invited to participate in the program.) The rationale behind UROP is that many students of color do not identify with the academic mission and do not feel welcome; consequently, close contact of these students with faculty is a key determinant for minority retention. Invitations to students to participate in research lets them know that they belong in the academic environment and are welcome to participate in its mission. Developing research skills also develops transferable critical thinking skills.

Working closely with students from diverse backgrounds also educates faculty about the barriers faced by minority students and about the value of diversity in an academic setting.

Features of UROP include its focus on first and second year students, a program that extends throughout the academic year, involvement of all the university schools and colleges, peer advising and community building, an emphasis on the multicultural aspects of research, faculty participation in a campus-wide retention effort, biweekly seminars, evaluation activities (including longitudinal assessment since the program began), and research peer groups and research symposia. Students spend 6 to 12 hours a week engaged in research activities and meet monthly with peer advisors to follow the progress of their research and to talk about their academic studies. Research peer groups meet twice each month to share information about research, hear research presentations, discuss research ethics, and participate in skill-building workshops. Several research symposia each year provide an opportunity for students to share the results of their research.

Faculty recruitment takes place through targeted mailings, presentations at faculty meetings, recommendations and referrals, word of mouth, student recruitment, and articles in departmental and campus newspapers. Student recruitment takes place through mailings, presentations at high schools, campus presentations, targeting of diverse students to ask them to participate, and counselor referrals. Students are paid through work-study funding; UROP is the second largest work-study employer on campus. Students also receive academic credit for their participation.

The Fall term begins with enrollment workshops and sessions on getting started in research, research ethics and case studies, academic advising, research fieldtrips, and listening to other students talk about their research. The Winter term begins with the Martin Luther King, Jr. Research Symposium that focuses on community-based research across the curriculum, and continues with research in the discipline (the cutting edge of research), race and gender issues in research, a panel to discuss graduate school issues, and a panel to discuss professional career options. The Winter term includes sessions on working in academe versus working in industry, resume and CV writing workshops, alternative and nontraditional careers in the sciences, professional oral presentation and poster skills, and concludes with a research symposium.

The skill-building workshops allow faculty to focus more time on actual research activities. These workshops include resume writing and interview skills (students interview for the research projects that interest them; some faculty complain that they can no longer tell the good students from the bad students based on their self-presentation), library and web research, web page design, PowerPoint presentations, and computer workshops (HTML, programming, etc.) Special workshops can be arranged at faculty request (e.g., laboratory safety workshops, etc.)

Since UROP is a campus-wide initiative, examples of research projects are diverse: gene therapy development using transgenic mouse models; investigating the sources, chemistry, transport, and deposition of mercury in the Great Lakes; and test methods for characterization of asphatene precipitation. Chemistry students frequently are involved in research in other departments. Research activities include library research, book development, course development, laboratory research, community-based intervention research, survey research, technology transfer, and performance art.

Learning outcomes of undergraduate research are various: academic course work becomes more relevant to students; students develop critical thinking and problem-solving skills and communication skills; students are socialized into their disciplines; they gain computer skills and skills in library and internet research, as well as statistical understanding; students learn to work independently; and they grow in multicultural understanding. Often, students find the academic setting discouraging, but find their abilities recognized and affirmed in the research setting.

The Engineering Pipeline model (initially funded by General Electric) is exemplary for chemistry in its focus on guiding students into graduate school. The program identifies underrepresented students and recruits them during the spring and summer before they enroll. First year fellowships are offered to provide a book stipend and to involve students in research right away with faculty. Students participate in biweekly seminars and attend monthly academic advising. Summer fellowships provide continuity of the research experience. One third of these students continue their studies at the masters and doctoral levels after graduation.

Among the lessons learned from UROP are that early identification of students is critical, along with early faculty mentorship. Opportunities to attend professional meetings and social interactions with other students and graduate students are vital to the socialization of students. Dedicated staff who can provide personalized academic advising are also essential to the program.

A significant number of program graduates have continued onto graduate school (for may students with less than stellar academic records, their research experiences compensated and allowed them to attend graduate school, nonetheless). For many students, research mentorship reinforced their skill and intellectual ability in ways not reflected by their performance in gateway courses.

The UROP in Residence (UIR) program allows 130 diverse students with a shared interest in research to live together in a single residence hall, where they enroll in a special seminar (Introduction to Research) in the fall. UIR students also have access to special sections of various courses.

The keys to a successful undergraduate research program are institutional and administrative support, good public relations, faculty support, staff resources, flexibility (the ability to adapt programs to student needs), and communication among all participants. Above all, the program must fit well with the institution’s overall mission and goals.

Funding for UROP initially was internal (Vice Presidents for Student Services and for Research); the first external grant came from the State of Michigan Office of

Equity. Subsequent funding has been both governmental and from private foundations, as well as from the Provost. UROP received an NSF Recognition Award for Integration of Research and Teaching.

Assessment is important for formative evaluation, to document program impacts to determine efficacy, for acquiring external support, to obtain local validation for the program, and to influence future policy and funding decisions. Assessment also serves a significant research role in exploring the question: to what degree does UROP enhance student retention, academic success, integration, and the pursuit of graduate education among all participants? A multi-method approach to assessment has been implemented, including quantitative research (surveys and retention studies), qualitative research (focus groups and individual interviews), and an experiential sampling study. The original retention study matched experimental and control groups by comparing UROP participants with UROP applicants matched according to entering GPA, test scores, high school profile, race, and gender. Both pre- and post-surveys were blind for the participants (i.e., they did not know the purpose of the surveys). The sample size was 1,280 students. Findings indicated that UROP participation increases retention rates for some students; retention rates were most improved for African-American males and during the sophomore year. African-American students whose performance was below the median for their racial/ethnic group benefited the most. UROP participation also seems to increase degree completion rates for African-American males.

During the focus group survey, students in UROP, not in UROP, and in another campus retention program discussed their research experiences. The purpose of the focus groups was to determine why UROP was having a positive impact on students. Student responses were categorized as either proactive, reactive, or inactive. UROP students tended to talk about their education much more proactively, representing 58% of all proactive comments. UROP students are more likely to anticipate future events, such as graduation, graduate school, or career choices. UROP students are also more likely to initiate activity with others and to see faculty and staff as positive influences. In the alumni study, experimental and control groups consisted, respectively, of UROP students and two to four non-UROP students matched according to age, test scores, high school GPA, intended major, and race and gender. The sample size consisted of 291 alumni. The return rate for the survey was 58.55%. Findings indicate that students who participate in UROP or another research program are significantly more likely to pursue graduate study than control students. UROP students are significantly more likely to pursue professional degrees, such as the MD or the PhD. UROP students are more likely to request letters of recommendation from faculty than non-UROP students. There are no differences or interactions according to race or ethnicity indicating that UROP equalizes the pursuit of graduate study.

In the experiential sampling study, UROP and non-UROP students (matched as in other studies) wore beepers and wrote down whatever they were doing whenever they were beeped. UROP students proved to spend more time talking with professors, participating in class discussion, working, and studying than non-UROP students, who appeared to have significantly more free time than UROP students and who spend more time socializing and attending to personal maintenance.

African-American UROP students and white non-UROP students spent more time in class than white UROP students and non-UROP African-American students. Several publications have resulted from these research efforts.

During the group discussion of Dr. Gregerman's presentation, some additional features of UROP were mentioned: annual funding from the Provost is $900,000; and nonscientific research makes up approximately 25% of UROP research projects. A campus-wide program (rather than a departmentally-focused one) is very important when addressing issues of diversity, for which it is better to focus on student development than on disciplines. Research bridges to community colleges have increased the transfer rate, but the numbers are still small. Faculty have helped to shape the program to some extent by providing feedback on workshops, but in general have not provided much direct participation. A faculty advisory board has recently been formed to address this problem.

The Value of Research in Undergraduate Chemistry Education

During the first two breakout sessions, participants engaged in discussions of the value of research in the undergraduate chemistry experience, and the strengths and weaknesses of the traditional model of undergraduate research in which an undergraduate, typically during their junior or senior year, engages in research under the direction of a single faculty mentor. A summary of the relevant points made during these discussions and conveyed during the reporting sessions is contained below.

Undergraduate research has been a cornerstone of the undergraduate major in chemistry for decades. Its value as an educational component in the undergraduate experience was enhanced by the Undergraduate Research Participation program established by the National Science Foundation in the early 1960's. Since that time, the chemistry community has willingly embraced the traditional single faculty mentor-student apprentice model of undergraduate research for advanced undergraduates, and anecdotal information suggests that many students choose to pursue graduate work in chemistry or related disciplines as a result of such undergraduate research experiences. From the 1960's to the mid 1990's, the number of undergraduate chemistry degree recipients steadily rose, suggesting the health of the undergraduate structure. However, since the mid 1990's, the number of degree recipients in chemistry has begun to decline. Although some argue that if all biochemists, chemical biologists, and environmental discipline degree recipients are included in the count of baccalaureate chemistry degrees, the numbers do not support a decline, the number of traditionally-trained chemistry degree recipients (i.e. those largely educated in chemistry programs) does appear to be decreasing due to increasing specialization of the field and proliferation of more interdisciplinary areas. The consensus is that the decline in majors is attributable to multiple factors. Less chemistry is required in other majors such as engineering or nursing today compared to a decade ago. Chemistry-related disciplines such as biochemistry and environmental science are siphoning off a fraction of the top students, since students tend to view the chemistry major as “too hard” or less relevant than these other areas. Finally, the perceived “staleness” of the chemistry curriculum undoubtedly contributes to this loss as well.

Other educational and societal factors also contribute to this decline in chemistry majors. These include education problems in science at the K-12 level such as poorly trained teachers and teaching to standardized tests, and as documented by Seymour and Hewitt in *Talking About Leaving*,[16] the lack of student knowledge of career opportunities in chemistry, poor teaching in undergraduate chemistry at the general chemistry level, and the fact that students entering college no longer perceive the physical sciences such as chemistry to be either desirable or achievable as career aspirations.[1] This latter factor is particularly problematic for attracting women and minority students into careers in the sciences.

Of this list of contributing factors, changes in the undergraduate degree program in chemistry would seem to be the most straightforward to address. The general perception that undergraduate research experiences play a pivotal role in students choosing to pursue careers in the sciences is commonly held. Indeed, a small but growing body of research supports this perception,[3,6-9] although this hypothesis has not yet been proven on a large scale. Nonetheless, if one assumes that undergraduate research is a significant factor in student career choice, a logical extension of this assumption is that increasing the availability and accessibility of undergraduate research opportunities for students has the potential to not only improve the educational experience for all students taking chemistry courses, but also increase the number of undergraduate chemistry majors.

Research creates knowledge, communicates discovery, and provides a significant opportunity for the mentorship of students. Research additionally increases the confidence of students, stimulates their curiosity, improves their communication skills, and enhances their critical thinking and problem-solving skills.[9] Research can generate sustained and persistent enthusiasm that contributes to the retention of a student either in a specific discipline or even in their undergraduate studies. Research mentoring can lead to the efficient integration of students into research communities in a way that clearly establishes their career paths.[3] The age of students involved in research is not nearly so important a factor as their ability to relate well to a mentor. Alumni of undergraduate research programs indicate that the research experience itself was a central factor in their perceptions of their undergraduate experience, regardless of whether this experience lasted 6 weeks or 4 years.[3,6-9] Not enough is known about why research has such an impact on undergraduates, so further investigation in this area might be encouraged as part of the development of URCs.

One difficulty in increasing undergraduate research experiences for undergraduates according to the single faculty mentor-student apprentice model is the limited number of undergraduates that this model can accommodate within the existing faculty capacity. Although the number of students who can be involved successfully in research under the direction of a given faculty member depends on that faculty member's capacity for mentorship, the notion of significantly broadening participation in undergraduate research to include freshmen and sophomores will require new paradigms for providing such research experiences within the existing faculty capacity. The possibility of soliciting mentors from sources other than the regular faculty ranks (e.g., postdoctoral researchers, graduate students, advanced undergraduates, national laboratory or industry scientists) was discussed, as was the possibility of designing "science semesters abroad," similar to the traditional semester abroad to expand undergraduate research opportunities. The content of research should be distinguished from the experience value of research in relation to the level of student involved: a significant research experience for a high school student would most likely not be a significant experience for a postdoctoral student.

As has been shown by recent studies,[3,5-9] mentorship is the critical component of any undergraduate research experience and increasing the system's capacity for such mentorship requires, at the very least, support at the institutional level in the form of recognition of research mentoring activities and curricular reform. Given its value as an educational experience, there is a developing movement nationwide to require undergraduate research or other significant independent creative work as part of all curricula.

To achieve this end, research must become part of an institution's fabric as an inherent value that supports and strengthens the education of students. Institutionalizing research will automatically involve more students, but will also require institutional change both in terms of curriculum reform and the faculty reward structure. Continued curriculum reform to better integrate research activities is needed. Engaging students as scientists early in their educational experience in active, discovery-based labs can provide a logical developmental pathway for their later successful involvement in research. An additional approach that might be helpful in developing some of the appropriate skills needed for research early in the undergraduate career of students is the model of the Research Methods course frequently used in the social sciences.

In order to implement such curricular change, the limitation of faculty time must be acknowledged and addressed. Faculty time for mentoring undergraduate research and/or curricular reform is limited and expensive, but critical for successful education in chemistry. Institutions must be encouraged to find adequate resources in terms of faculty release time for the curriculum development necessary to support an institutional culture of research. In addition, since good undergraduate research mentoring requires considerable faculty time, faculty must be provided with release time or teaching credit for mentoring activities. Faculty participants of this workshop almost uniformly cite faculty time as a critical limitation to further broadening undergraduate participation in research.

Further limitations to the traditional model of undergraduate research involving the single faculty mentor-student apprentice include those directly related to the students. Student course and work schedules often do not allow adequate time for engaging in time-intensive research activities. This problem can be exacerbated by insufficient stipends for students who must work to support themselves, a scenario of increasing frequency especially in environments such as community colleges or urban campuses. Moreover, students are often unaware of research opportunities, especially in large, impersonal institutions such as many research universities, urban institutions, or community colleges.

Many research opportunities have historically been given to those perceived to be the “best” students, those students already committed to the discipline, or those students already possessing a particular skill set. This selectivity has often led to diminished opportunities for women and minority students, and neglects potential “diamonds in the rough” among student populations other than those who have historically pursued chemistry as a career. Such selectivity for research experiences is unfortunate, however, since among populations of students who are not necessarily predisposed to science, successful research experiences can often lead to attracting these students to pursue a science degree.

Student research experiences can also be variable in quality depending on the mechanism used to establish faculty mentor-student relationships and depending on faculty expectations of undergraduate researchers. In some programs, random assignment of faculty mentors can lead to unsatisfying research experiences for a portion of undergraduate participants. Unrealistic faculty expectations for research productivity of undergraduates can also lead to a negative student perception of the experience. Therefore, it is of the utmost importance that mentor relationships be allowed to develop spontaneously whenever possible and that adequate attention be paid to appropriate choice of research project for a given undergraduate, taking into consideration the background, skills, and interests of the student.

Initiating and sustaining undergraduate research at predominantly undergraduate institutions and community colleges can be particularly challenging. At predominantly undergraduate institutions, one difficulty is the relatively rapid turnover of student researchers, especially if they don’t begin their research until late in their undergraduate careers. Because they have fewer peers for interaction, faculty at smaller institutions often find the generation of research ideas that are relevant and interesting more difficult. Faculty at smaller institutions also tend to have heavier teaching loads than faculty at larger, research-oriented institutions and so have less time available for supervising student research. Lack of institutional support is also problematic in many cases both in terms of financial support for the necessary research infrastructure and also in terms of administrative buy-in that research is a central component of the undergraduate educational portfolio. This latter problem is particularly acute at community colleges, an environment in which “teaching” is viewed as the primary mission with the implicit model of classroom lecturing as the expected manifestation. Technical assistance for the maintenance of departmental instrumentation and for student training on that instrumentation is frequently lacking at smaller institutions and community colleges.

Regardless of institution size, institutional buy-in at all levels must be promoted with sensitivity to the nature and history of the individual institution. Such buy-in can be promoted by means of both downward and upward pressure: downward by administration in terms of recognition of teaching credit for mentoring undergraduate research, and upward by faculty in terms of structuring tenure and promotion documents to emphasize contributions in the mentoring of undergraduate research as significant educational contributions. Participants did note, however, that while institutional buy-in involves promotion of research across the curriculum, different disciplines have different definitions of what constitutes research and the resources that are required to support it (e.g., research in English is very different from chemistry research). It is clear that "one size does not fit all" when it comes to undergraduate research programs. Needs are very diverse, so flexibility is needed in defining undergraduate research programs. Any model adopted by a particular institution should be "win/win," offering students the best possible educational experience and recognizing, rewarding, and supporting faculty efforts to mentor students.

Broadening Participation in Undergraduate Research: The Case for Undergraduate Research Centers

During the final two breakout sessions, participants considered possible solutions to the limitations of the traditional model of undergraduate research, including the possible role of Undergraduate Research Centers as vehicles for broadening the participation of undergraduates in research in chemistry. Underlying these discussions was the near-universal acceptance among the participants that research has inherent pedagogical value in undergraduate education in chemistry, and that broadening the scope of undergraduate research to encompass students earlier in their undergraduate careers could have substantial positive benefits including an improvement in their education, greater retention of undergraduate majors in chemistry, or attraction to chemistry of students who might have pursued other majors. A comprehensive vision for what URCs could be as agents of systemic educational reform emerged during these breakout sessions. A summary of the relevant points made during these discussions and conveyed during the reporting sessions is contained below.

Participants generally agreed that in order to broaden participation in research in a manner that is not constrained by the limitations of the traditional model of research, innovative, "out-of-the-box," and potentially controversial new paradigms must be explored as experimental endeavors. The concept of Undergraduate Research Centers was viewed as having considerable merit as a new paradigm for broadening undergraduate research participation. As this concept was discussed further, a far-reaching vision of URCs that would have impact beyond simply broadening research participation was formulated. This vision encompassed impact and systemic change in education at the disciplinary level as well as at the institutional level.

At the disciplinary level, the first and most obvious impact of URCs would be the creation of many more research opportunities for undergraduates. Such opportunities would be distinctly different from those already existing in the extensive NSF Research Experiences for Undergraduates (REU) program in which many students leave their home institution to undertake research, typically in the summer. Thus, in contrast to the REU model of "bringing students to the research," URCs ideally would function to "bring research to the students" by providing research opportunities at the students' home institutions.

Beyond the number of research opportunities, however, participants valued the potential impact of URCs in enhancing the overall quality of the undergraduate educational experience by providing students, preferably early in their undergraduate careers, with role models and mentors as well as first-hand insight into how new knowledge is created in science. Indeed, many participants thought this impact to be the most important of those articulated. Furthermore, strong sentiment was expressed that this impact be realized for *all* undergraduate students, not just those planning to pursue science degrees. By so doing, these Centers would help to shape the undergraduate experience in a way that promotes the education of more scientifically literate citizens.

The value of having students learn science by *doing* science has been well-recognized since the 1983 National Commission on Excellence in Education report from the Department of Education entitled *A Nation at Risk,*[17] but its full-scale implementation in a meaningful way at the undergraduate level has been slow to develop due to many of the same barriers that were described above in the context of the traditional model of undergraduate research. Significant advances in the use of discovery-based or problem-based learning in undergraduate science education have been made, but often, these exercises stop well short of a *bona fide* research experience based on the investigation of unknown phenomena. Thus, the provision of opportunities for undergraduates to become engaged in the very business of science through the generation of new knowledge should lead to an enhanced understanding of the scientific process along with its limitations in providing answers to challenging and complex problems.

The unique problems faced by community college students in terms of limited access to research are noteworthy here. According to data reported in the NSF report *Shaping the Future*,[18] enrollments in science, math, engineering, and technology courses in two-year colleges account for approximately one-third of the total enrollment in these courses at all types of institutions nationwide. Despite these large numbers, however, research opportunities are generally quite rare at community colleges. In many such institutions, a mindset exists which almost exclusively emphasizes the classroom lecture as the only appropriate model for undergraduate education. (Research opportunities, while rare, are not altogether absent, however, as demonstrated by the program described by one of the plenary speakers at this workshop, Dr. Raymond Turner of Roxbury Community College in Boston. For another example of research programs at community colleges, see the brief description of research activities at Oakton Community College in Chicago in the section "A Compendium of Undergraduate Research Programs" at the end of this report.) Poor access to research is further exacerbated for many community college students attending institutions focused on educating underrepresented minority students. These institutions are often geographically situated in socio-economically depressed urban areas or extremely rural areas (e.g., tribal colleges) that might be well removed from the influence of or access to neighboring undergraduate institutions that do support research. Moreover, a substantial fraction of students attending community colleges often have work or family obligations that make it virtually impossible for them to pursue additional educational opportunities, such as undergraduate research, at a remote site, regardless of their educational value. In order to broadly influence the education of freshmen and sophomore chemistry students in this country, URCs will have to not only find ways of successfully engaging community colleges in partnerships, but also find mechanisms for successfully accommodating the individual circumstances of many of today's community college students.

Recent research demonstrates the critical role that effective mentors play in student retention and satisfaction with science majors at the undergraduate level.[3,6-9] Participants recognized that mentors do not necessarily have to be faculty members to be effective, but could include postdoctoral researchers, graduate students, industrial or government lab scientists, or even upperclass undergraduates who have the knowledge and perspective to provide appropriate guidance to the student and a window into the workings of the profession. This hierarchical "deputy" model would greatly expand the capacity of the undergraduate system to provide research opportunities to large numbers of students.

Workshop participants also recognized URCs as entities that would advance the knowledge base in chemistry through new research. Although the rate at which new knowledge would be created with undergraduates would be expected to be much below that with graduate students and/or postdoctoral researchers, participants were consistent in their belief that URCs should support real research involving undergraduates and not simply discovery-based laboratory exercises. The value of discovery-based exercises very early in the undergraduate experience as an appropriate vehicle for preparing undergraduates for participation in research was noted, however.

URCs were also viewed as potential drivers of curricular reform in chemistry. Participants felt it important to distinguish between the simple replacement of existing segments of the curriculum and the infusion of research as a pedagogical tool into all segments of the curriculum. In some cases, this may take the form of discovery-based laboratory exercises, and in other cases, it may take the form of conventional research projects involving the investigation of complex phenomena in a manner that addresses questions for which answers to significant questions are not yet known.

The URC concept was noted to be especially suited to facilitating research and education in multi-disciplinary areas given its focus on establishing partnerships and research communities among different groups. Finally, participants recognized the potential for URCs to support more traditional curriculum development activities through the involvement of undergraduates in the research necessary to support such development. As an example of how research could be used to support curriculum development, a research project might encompass experiments to develop and optimize a suitable undergraduate laboratory experiment based on a new research result published in the recent literature or the development of a workable classroom demonstration.

URCs could also offer experiences that involve community-based research projects. Undergraduates often see community-based projects as more relevant than fundamental research projects; furthermore, community-based activities can be particularly effective in attracting minority students to science. In addition to the community-based research projects described in Dr. Turner's plenary talk, another example of a community-based project that was successful in attracting Native American undergraduates to chemistry was described by Dr. Jani Ingram at Northern Arizona University. Dr. Ingram received a grant to support undergraduate research to determine the speciation of uranium in groundwater from abandoned mines on Native American Indian reservations where the incidence of cancer among the population has been disproportionately high. Participation in this project by Native American students has been overwhelming in response to the immediate environmental and familial impact of this issue for this particular group of students.

One additional impact of URCs would be to stimulate and increase the capacity for research in chemistry, or to increase access to existing research capacity in chemistry. URCs might help provide and sustain the infrastructure at an institution necessary for modern chemistry research in terms of instrumentation, technical staff support, and technology. Improving faculty capacity to initiate and sustain undergraduate research might be an additional outcome of URCs, especially if institutions at which a culture of research has not traditionally existed are partnered with institutions, such as research universities, government labs or industry, that have a long tradition of research.

The potential impact of URCs on the education and training of educators at all levels of the K-16 continuum was cited as a significant benefit. URCs could provide research opportunities for in-service secondary school teachers to help them maintain their current state of knowledge and skills, and to help them sustain the enthusiasm for science that led them into careers as science teachers. Ideally, the engagement of high school chemistry teachers in the process of modern research would lead to more and better educated students with interests in science entering college, and enhance the overall vertical integration of the educational process. Research opportunities were also recognized to be significant mechanisms for high school chemistry teachers who were not trained in chemistry to broaden and enhance their knowledge and skills, thereby contributing more effectively to this vertical integration. Undergraduate students who are pre-service K-12 science teachers would also benefit from the increased opportunities for research that URCs would provide. For faculty at college-level institutions that have not had a significant history of undergraduate research, URCs could provide opportunities for training in research-related activities such as the design of appropriate projects for undergraduate students at different levels, effective mentoring of undergraduate researchers, and grantsmanship.

Finally, URCs provide the opportunity for additional assessment of the outcomes and benefits of undergraduate research. Although some work on the impact of research on the educational experiences and career paths of students has been undertaken, evaluation of this impact has not yet been conducted on a scale large enough to draw compelling conclusions. The experimental nature of URCs will make them appropriate places to develop new assessment vehicles by which success can be defined across a range of contexts. Participants noted the utility of the concept of a "meta-URC" devoted solely to the assessment of research that might also serve to coordinate assessment and evaluation activities across all URCs.

Beyond the discipline-specific impacts of URCs described above, participants also recognized the potential value of URCs in promoting systemic institutional change. Of perhaps greatest importance could be the role of URCs in facilitating the institutionalization of research as a valuable pedagogical tool for undergraduate education. The need for undergraduate institutions of all types to embrace research or similar independent creative activities as a cornerstone of undergraduate education has been a hallmark of several recent comprehensive reports including those from the Boyer Commission on Educating Undergraduates in the Research University, *Reinventing Undergraduate Education: A Blueprint for America's Research Universities,*[19] and the American Association of Colleges and Universities Greater Expectations National Panel, *Greater Expectations: A New Vision for Learning as a Nation Goes to College*.[20] Indeed, evidence that there is a national movement in support of a culture of research in undergraduate education is seen by the fact that *U.S. News & World Report* now uses undergraduate research as a category of programs that enhance learning in their evaluation of undergraduate programs.

The vision of URCs presented here has as one of its core components the need for establishing partnerships between institutions of different types. Partners might come from among research universities, predominantly undergraduate institutions, comprehensive universities, community colleges, industrial concerns, national laboratories, and even various segments of the K-12 educational system. Thus, URCs have the potential to facilitate horizontal integration across the many stakeholders in undergraduate education in a way not previously achieved and to achieve better vertical integration in the education of students through a more closely correlated set of activities at each educational level. In this way, URCs could actually become *undergraduate research communities* that would provide access to research opportunities for students who previously had not had this access, and undergraduate education at each of the participating institutions would hopefully be enriched and diversified by the existence of the partnership in a way that could not be achieved by each institution acting alone. The goal for URCs is that their whole be greater than the sum of their parts. While this most certainly would be achieved for specific disciplines around which a URC were focused, there would hopefully be additional institutional value gained in a culture of partnering with divergent institutions that could be institutionalized at some level.

The final institutional impact envisioned for participants in URCs is enhanced prestige that might be realized on either a local, regional, or national scale that often accompanies large-scale funded activities such as program grants and center grants. Such prestige is deemed necessary for institutional buy-in and support for the concept motivating URCs.

The Ideal Undergraduate Research Center

Through expansive and reflective discussions over two days, workshop participants arrived at a consensus vision of the model URC. In this model, URCs could be flexibly and innovatively designed in a way that met the needs of the partner institutions. Partners would be expected to come from across the spectrum of stakeholder institutions in undergraduate education and would minimally involve more than one institution. "Institution" in this context is broadly defined to include traditional educational entities anywhere within the K-16 continuum (undergraduate colleges, research universities, comprehensive universities, community and tribal colleges, high schools or other K-12 schools) as well as industry, government agencies and research laboratories, and local communities. Although extensive flexibility in the definition of URCs is recommended, proposals should be required to contain a detailed management plan specifying how inter-institutional relationships will be negotiated and coordinated to the betterment of undergraduate education at *all* partner institutions.

URCs would ideally be focused on undergraduate students at the freshmen and sophomore levels, with the additional involvement of advanced undergraduates, high school teachers, high school students, etc. as appropriate. In contrast to REU programs, URCs would bring research to the undergraduates instead of bringing the undergraduates to the research. Proposals for URCs would clearly articulate how vertical continuity in chemistry education would be facilitated by the Center through coupling experiences in the URC with other educational opportunities for students prior to and after their involvement in URC activities. Widespread involvement of faculty at participating institutions was viewed as necessary for success of URCs.

URCs would be expected to demonstrate how their presence will influence curricular reform at one or more of the participating institutions, and how this reform will be sustained in the long term. Finally, URCs would be expected to undertake assessment of the benefits and outcomes of the undergraduate research experiences that they provide, and the impact of these experiences on the career paths of the specific target populations of the URC.

Funding for URCs was recommended at a level between approximately $100,000 and $500,000 per year for a duration of between three and five years. Some level of institutional commitment from all partner institutions should be required to ensure success as well as indicate administrative buy-in to the URC concept and mission. Appropriate requests for financial support for student stipends are expected as part of the award as is support for administrative oversight of the Center. Faculty stipends might be appropriate in certain circumstances as necessary incentives for faculty participation.

Despite the compelling vision of URCs described here, participants also articulated the considerable obstacles to successful implementation of the URC concept. First, given the rather stochastic occurrence of existing partnerships of the nature envisioned, mobilization of the undergraduate education community to respond to a call for proposals for such a program may be sluggish at best. The National Science Foundation may wish to include a cycle of planning grants for this program to better enable undergraduate institutions to establish the appropriate partnerships and adequately prepare a competitive and well-conceived proposal. Participants also voiced concern over the feasibility of developing convincing plans for sustaining URCs beyond the duration of the NSF award itself.

Finally, concern over the development of equitable partnerships between institutions of such different size and culture was also expressed, since multi-institutional activities often suffer from "top-down" dynamics that contaminate relationships between large and small institutions. Flexibility in the definition of the lead institution in a Center was encouraged; any institution should be allowed to lead a consortium as long as they demonstrate the ability to provide effective leadership. Another strategy suggested to NSF for mitigating potential problems in equitability between partners within a given consortium was to distribute funds directly to each institution instead of distributing all funds centrally to a single lead institution.

A Compendium of Undergraduate Research Programs

Examples of undergraduate research programs that embody the central principles of URCs already exist. Workshop participants were asked to provide short vignettes describing innovative undergraduate research programs. Those programs that exemplified the guiding principles of multi-institutional, unique partnering with industry or government laboratories, outreach to K-12 teachers and/or students, targeting freshmen or sophomore students, or using unique modes of mentoring undergraduate research were chosen for inclusion here. Although there are undoubtedly many more research programs across the nation built on the core principles of URCs of which we are unaware, it is hoped that collectively, this sampling of programs will provide a useful compendium of creative ways to effectively engage undergraduate students in research at institutions representing the spectrum of those involved in undergraduate education. These vignettes are arranged in alphabetical order by lead institution.

In the summer of 1996, two members of the **Berea College** Mathematics and Computer Science Department began an undergraduate research program that applies mathematical and computer modeling to various issues of local concern. Over the years, these summer research experiences have involved fourteen students with majors in mathematics, physics, and chemistry, three faculty members, two non-profit agencies, and several departments on campus. The problems addressed have covered a broad range of categories including risk assessment of the incineration of toxic materials, modeling sustainable forestry, estimating floodplain growth due to community development, and predicting the spread of the flu due to delays in vaccination. The students involved have frequently gone on to graduate school in fields related to their research and have won awards for presentations of the research.

Undergraduate research in mathematics tends to be complicated by the desire to have students involved in more than surface roles regarding real problems to which faculty themselves do not know the answers. Due to the nature of theoretical mathematical research, unsolved problems tend to be well beyond the knowledge base of even graduating seniors, and in addition, the use of such research often is beyond the understanding of the students. In response to this reality, the Berea College Mathematics and Computer Science Department has attempted to design a program where the more applied research is always designed to require significant student input in a problem whose relevance is obvious to all. This program allows the students to use the mathematics and computer science they already know, teach themselves some of the basics of the field of application (e.g. physical hydrogeology), and then discover the excitement and frustration of real research on a problem they can clearly understand.

As one example, in the summer of 1996, the research problem was to calculate the dispersion of dioxins that would result if a stockpile of nerve gas were to be incinerated (as was planned at the time) at an army depot that is located less than 15 miles from Berea College. The work was generated by the request of a local non-profit agency, the **Kentucky Environmental Foundation** (KEF), and clearly had the advantage of being important to the students involved. Moreover, the topic required them to master a computer model simulating dispersion, the chemistry of dioxins, the relevant biological food chain, and the mathematics that would help address all these problems. The students stayed in close contact with the members of KEF, opened dialogs with the EPA, and sought the advice of the designers of the computer modeling program. The results turned out to be revealing mathematically and surprising in terms of the actual impact.

Bridgewater State College provides support for undergraduate/faculty research opportunities through the Adrian Tinsley Program for Undergraduate Research ("Tinsley Program"), http://www.bridgew.edu/ATP/. These opportunities include summer stipends, semester grants, travel grants, and a campus-wide undergraduate research symposium. Students in the natural sciences have been supported through the Tinsley Program, and a variety of external grants through their mentors. Since 1999, science students have actively participated in a Chemistry OutReach Program involving chemical demonstrations conducted at regional elementary and middle schools. The goal of this program is to excite the school children about chemistry, provide a resource of classroom demonstrations for the classroom teacher, and provide a service-learning opportunity for all BSC science students. In 2002, the OutReach Program was expanded by having groups of research students present their work at regional high schools. The goals are to encourage high school science students to seek out and participate in research activities at the college level, and to provide BSC research students with an unusual forum for presenting their research at a level where justification of their research projects (to "constituents") is as important as how their data justifies their conclusions. BSC student presenters must prepare lecture material with visual aids, a collaborative group work activity based on the lecture, and a "fun" activity in the form of a game. For example, in 2002 a group of BSC students discussed their Green Chemistry research projects and following the group work activity acted as the hosts of a Green Chemistry "Jeopardy" game. The BSC presenters are also required to prepare evaluation forms for the students and classroom teacher to complete.

The research component of the BSC OutReach program has only been in existence for one year; thus, assessment is difficult at this time. It is notable that all juniors who participated in spring 2002 have volunteered to participate again in 2003. We hope to expand this program to regional community colleges in 2003-04. We see this program as an opportunity to bring in high school juniors and seniors, and community college students and faculty to participate in research projects with BSC students and faculty.

Cameron University, a primarily undergraduate regional institution in Lawton, Oklahoma, has developed several collaborative programs with comprehensive institutions and companies in an effort to provide students with exceptional research opportunities that will enhance their undergraduate education.

As one example, Dr. Ann Nalley, a professor of Physical Sciences at Cameron University, has worked for the past 20 years with local industries to provide enrichment programs for her students by forming industrial partnerships to support internships. These collaborations have been formalized through a grant from the Oklahoma Center for the Advancement of Science and Technology (OCAST) that provides funding on a matching basis to support industrial R&D internships for both students and faculty in Oklahoma. The purpose of this OCAST R&D Faculty and Student Intern Partnership (FSIP) program is to improve Oklahoma's R&D base by supporting student and faculty internships in Oklahoma R&D facilities and to encourage greater numbers of students to prepare for careers at scientific and technical firms. Students are employed as interns in industry to perform R&D research in chemistry either in the summer or during the regular academic semester. Recent activities in this project include partnerships with **Cosmetic Specialties Laboratory, Inc.**, a Lawton based Cosmetic Manufacturing laboratory. Dr. Nalley and her students have been involved in developing analytical methods for analyzing cosmetics, which assist in maintaining quality control and in new product development. In addition, a partnership with **Halliburton Energy Services** Duncan Technology Center located in Duncan, Oklahoma has resulted in numerous projects including: software engineering, where student and faculty interns have worked with software companies to develop software packages; assisting in problem solving strategies related to oil field production; the analytical measuring of Log POW values; and the modification of natural polymers used in oil production to make them environmentally friendly. More than 20 students have had an opportunity to participate in the program. Contact: Dr. Ann Nalley, Department of Chemistry, Cameron University.

COSEN: CAROLINAS AND OHIO SCIENCE EDUCATION NETWORK: Mentoring, Peer-Support, and Research Experiences for Women and African-American Undergraduate Science and Mathematics Students. To encourage students to major in mathematics and the sciences and to consider research and teaching careers, a comprehensive program was initiated in 1989 and completed in 1999 by eight higher education institutions. **Davidson College, Denison University, Duke University, Furman University, Kenyon College, Oberlin College, Ohio Wesleyan University, and The College of Wooster** formed COSEN with funding from the Pew Charitable Trusts. The consortium was committed to supporting individuals underrepresented in science and mathematics, particularly women and African Americans.

COSEN was envisioned as an experimental program. The underlying rationale for COSEN was that intervention, in the form of enriching experiences within a supportive environment, must be provided at a variety of levels throughout the formative college years. COSEN programs gave students a critical mass of affiliates, contact with professionals who were mentors and role models, and hands-on research experiences.

The COSEN program annually sponsored mentoring and peer-group activities for students on each campus, led by women and African-American faculty; a one-week, hands-on research experience conference for 64 first-year students; three-week field research workshops in geology, marine biology, and tropical biology for 40 students; ten-week research collaborations, matching 25 students with faculty from different institutions, which concluded with a two-day research conference. Each year, these activities provided nearly 300 students with enriching science experiences within a supportive environment.

Through COSEN, the academic community was strengthened. Faculty and administrators became aware of the issues facing those underrepresented in science. Cooperation between students and faculty on each campus and among campuses increased. Campus student groups became independent organizations, promoting leadership and academic excellence. COSEN conferences and research experiences gave students an understanding of the scientific process and the confidence to pursue scientific careers. An evaluation survey indicated that a majority of participants were considering attending graduate or professional school in science. By providing programs throughout the college years, COSEN offered a comprehensive approach, enhancing students' education, experience, and expertise.

A key element of COSEN success was the participation of faculty and administrators with vision and ability. It was also important to have a stable organizational structure and generous funding. The interrelationship between consortial and campus programs strengthened both, with COSEN events often motivating students to become campus leaders. Yearly participant (faculty and student) surveys provided valuable information for monitoring progress in meeting goals. The local mentoring/study groups, the first-year student conference, and the field and laboratory research opportunities offered students positive experiences and a network of support. The combination of these factors resulted in a cohesive and effective program. Contact: Susan Palmer, Executive Director, The Five Colleges of Ohio, Kenyon College.

The Chemistry REU Consortium: Juniata College, Macalester College, Northern Kentucky University, Saint Michael's College, Trinity College (CT), and Trinity University (TX) constitute the first Chemistry REU Consortium. Instead of a collection of 10-12 undergraduates attracted to the same location, we attract them to similar projects at dispersed locations. The unifying feature is that all the students are working on related projects involving the synthesis of Theoretically Interesting Molecules. The entire group meets together two to three times during the summer, having an expanded group meeting where faculty and students hear about what everyone else is doing and engage in intellectual discussion of the design and execution of the research. The hope (which was realized) is that these sessions will lead to significant cross-fertilization of ideas among the groups. Further, one major researcher in this field joins these meetings each summer, describing his or her own research and commenting on the research of the consortium. One of these group meetings coincides with one of the major national organic chemistry meetings, so students hear many of the major researchers across the discipline describe their chemistry and the ensuing discussions. Students present 15-minute seminars on their projects at the end of the summer and also create posters of their research for the Consortium Web Site. Contact: David Reingold, Department of Chemistry, Juniata College. Further information:
http://www.trincoll.edu/depts/chem/toms/REUsite/frames/frameindex.html

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In 1948, **The College of Wooster** initiated a radical overhaul in its curriculum that was based on combining the acquisition of knowledge with the understanding of method. This change was based on the belief that a student's drive to learn is best developed by undertaking a major independent research project that leads to self-discovery through three semesters of college work. Today, 50 years of the Independent Study program has created a culture shared by all at Wooster. Independent Study is not an honors program; the Wooster faculty believes that *all* students should be challenged to achieve their best efforts of independent and creative thought. The effectiveness of the Independent Study program at Wooster stems from the collaboration of students and faculty, learning by doing, and the challenge that it provides for all students.

Although the emphasis of the Independent Study program is on the last two years of a student's education, the foundation for critical thinking is laid much earlier in the College curriculum. The Wooster curriculum is designed to introduce students to the challenges they will meet as juniors and seniors, through required freshman seminars, writing-intensive courses and inquiry-based teaching across the curriculum. Although no formal link to Independent Study is established, the College designed the Sophomore Research Program in 1987 to provide a transition for students between First-Year Seminar and Junior Independent Study. The Sophomore Research Program provides opportunities for students to work as paid research apprentices to Wooster faculty members. Through this program, students become true partners with faculty in the research process and acquire an understanding of the process involved in conducting research.

Formal Independent Study begins in the junior year, with one course of that year devoted to independent investigation. During the senior year, one course each semester is tagged for independent study credit, representing 25% of the coursework during the senior year. For many science students, the senior project is initiated during the summer between the junior and senior years by working in a lab or out in the field with a Wooster faculty member or taking an internship at another institution or laboratory. Students identify their topics, design an approach to answering their questions and test their hypotheses, collect the necessary data, learn how to separate evidence from conjecture, and present their work in a thesis during the spring semester. Many departments encourage oral presentation of the student's work. Upon submission of the student's thesis, two faculty readers evaluate the finished project and administer an oral examination, allowing the student a chance to discuss his or her work at a higher level with at least two individuals who have some knowledge of the project. Contact: http://www.wooster.edu/programs/

K-16 Science at **Edgewood College.** A unique opportunity to teach and learn science exists at Edgewood through the Sonderegger Science Center, the center of science instruction for the three institutions comprising Edgewood Inc., which encompasses students from kindergarten through graduate school. Every effort is made to have students and faculty from different grade levels work together whenever appropriate. One example of this is with the Introduction to Natural Sciences course (Nat Sci). Nat Sci was developed to meet the needs of pre-service teachers. The subject matter is broad in scope and the lessons delivered in a way that models current best practices in K-12 science instruction. In addition, all elementary education majors must take their elementary science methods concurrent with Nat Sci. The methods course is team taught by science educators who are faculty in the Natural Sciences Department. Instructors of the two classes meet regularly to integrate the student's experiences to the highest degree possible.

One of the major activities in the Nat Sci course is a scientific research project where students, working in small teams, participate in ongoing scientific inquiry around major themes dealing with the natural environment surrounding Edgewood College. (Edgewood is located on a large parcel of land containing woods, prairie, and grassland, and is adjacent to a lake, the University of Wisconsin Arboretum, and several city parks.). At various times during these projects, college students are teamed with "little buddies" from Edgewood Campus School (K-8). The "little buddies" study similar topics in their science classes with the assistance of University of Wisconsin graduate students as part of a KTI (kindergarten through infinity) program.

As an addition to a forty year plus history of successful undergraduate research at **Harvey Mudd College** involving required senior research theses and an intensive summer research program, a Sophomore Spring Semester Introduction to Research course was initiated seven years ago in which sophomores are offered the opportunity to work with chemistry faculty to learn methods of research by doing research. Through an application process, interested students are matched with faculty in whose research they have expressed interest. All nine faculty in the department typically take a student enrolled in this course. The students are paid a stipend typically based on an afternoon per week of effort but do not earn credit. Stipend funds are provided by the department from a Henry Dreyfus research grant. Accepted students appreciate the opportunity to begin meaningful science. While primarily targeting sophomores, freshmen have been placed in the program. Students are introduced to the chemical literature, the techniques necessary to pursue the project, and general methods of conducting research.

Hope College first involved undergraduate chemistry students in research in the 1940's and now annually involves over 50 chemistry and biochemistry students in undergraduate research. The goals behind Hope College's research program are to create new scientific knowledge and to train students to become scientists. Over the last decade, Hope College has been expanding the participants in undergraduate research projects beyond the traditional population of junior and senior science majors.

- Hope College emphasizes early entry to research by encouraging first and second year students to become involved in research. This results in more students being involved at any given time, raises student expectations that they should become involved in research as part of their education, and allows for more substantive work due to spending longer time on a project.
- The Chemistry Department actively contacts other schools that do not have substantive research programs in order to offer summer research opportunities to their students. Whenever possible, offers are made to under-represented minorities in order to increase the diversity of the research student cadre.
- Under-represented minority students from local high schools have been invited to participate in a 6-week summer research program, which also includes enrichment activities and science career awareness programs. Some of these students have matriculated at Hope College, majored in a natural science, and continued on to graduate school.
- The Chemistry Department runs non-residential summer science camps for K-6 students. The Chemistry Camp "counselors" are undergraduate students who are typically considering careers as K-12 science teachers. While their experience is not a traditional research experience, these students achieve many of the learning gains associated with undergraduate research, e.g., independent decision making in a laboratory setting, as well as become enthusiastic science teachers.

Hope College's strong undergraduate research program stems in large part from the faculty's focus on the success of the student research experience in developing scientific skills and producing new scientific results. Research students at Hope College know that the faculty take a personal interest in their learning, are eager to help them develop to their full potential, and are dedicated to their future success. Contact: Will Polik, Department of Chemistry, Hope College.

Although there are several PhD. programs at **Idaho State University**, the Chemistry Department is consistent with any at predominantly undergraduate institutions except for the existence of a BS/MS program. Recently, this program has been combined with an NSF REU program to provide regional students, particularly two-year college students, with the opportunity to participate in research and continue their studies to receive a graduate degree.

The BS/MS program is a three-year program to which students are admitted after their second year in college, provided they have completed the core requirements. This program provides an excellent opportunity to recruit 2-year college students within the region who have not been traditional graduate school prospects. Students admitted into the program are awarded a stipend and tuition waivers. They are required to perform research on a part-time basis during the academic year and full time during 10-week sessions during their first and second summers of the program. Their academic program requires them to take graduate courses as early as their junior year. Due to limited funding, only three students are funded per year for a total of nine students. This matches the number of departmental faculty active in research and allows greater mentor-to-student contact.

A recently awarded (2000) NSF REU grant has as its mission to provide undergraduate research opportunities to regional 2-year college students, opportunities which are non-existent at their campuses. While REU participants are encouraged to continue their education and research efforts at an institution of their choice, some students have proceeded to matriculate in the BS/MS program at ISU. Research opportunities for participants span the traditional fields within chemistry and also involve atmospheric, environmental, and labeled biological substrate chemistry.

Science In Motion: A Basic Education/Higher Education Science and Technology Partnership. "Science in Motion" was created at **Juniata College** to meet the needs of local high school chemistry teachers in teaching "hands-on science." The program was launched following a year of discussion between basic education and higher education faculty about how to update science curricula to include the use of modern instrumentation and technology. The basic education/higher education partnership program was formed based on the following six guiding principles. 1) More can be accomplished in science at the high school level, but those in the best position to know what is needed are the teachers themselves. 2) The excitement of science, for students <u>and</u> teachers, is best transmitted through hands-on work—that is "learning science by doing science." 3) There is science equipment that is both powerful enough to solve real problems and also suitable for high school students. 4) Higher education faculty are in a position to help basic education through the sharing of both knowledge (providing professional development) and resources (providing access to state-of-the-art equipment and fully prepared laboratory supplies and materials). 5) A program such as "Science in Motion" should not add to the burden of high school teachers, but rather must supplement and enhance classroom learning. 6) The same group of teachers should be involved over a period of several years so that a systemic change can take place.

The National Science Foundation initially provided two five-year grants to fund a program that supported chemistry and biology teachers. The concept of Science In Motion subsequently spread to other disciplines and other locations. The **Commonwealth of Pennsylvania** now funds a total of eleven basic education / higher education science and technology partnerships. State-wide programs modeled after the Juniata experience are in operation in Alabama and Delaware, and smaller regional programs exist in California (Occidental College), Illinois (Chicago Science Alliance), North Carolina (North Carolina State University), Indiana (Purdue), and New York (Marist College).

In summary, the success of the program has shown that teachers are not the major barrier to good science teaching in our schools; the major barrier is a systemic lack of time, resources and support for science education in public education. The specific challenges are: 1) access to adequate resources, 2) access to good professional development opportunities for science teachers, and 3) the development and support of inquiry-based science curricula. This partnership helps educators to address these challenges. As a result, high school students with interests in these sciences become more likely to pursue careers in science because they have had exposure to the stimulating practice of hands-on science. Subsequently, these students are in a much better positions to begin early undergraduate research careers**.** Undergraduate students employed by the program also benefit from the experiences gained in developing, teaching, and supporting high school laboratory exercises – an ongoing need to keep science education up-to-date. Contact: David Reingold, Department of Chemistry, Juniata College.

Keck Geology Consortium. The Keck Geology Consortium is a group of twelve, small geoscience faculties (**Amherst College, Beloit College, Carleton College, Colorado College, Franklin & Marshall College, Pomona College, Smith College, Trinity University, Washington and Lee University, Whitman College, Williams College, The College of Wooster**) who work together to improve undergraduate geoscience education through research. Since it's founding in 1987, the Keck Geology Consortium has sponsored 103 research projects for undergraduate students, supporting 800 undergraduate students from over 80 schools across the nation and overseas. Project faculty representing 43 organizations have worked with the Consortium. Consortium alumni are a diverse group: 48% are women, and since 1991, when the Consortium began collecting data on racial and ethnic identification, 21% are from groups under-represented in the geosciences. Alumni span the distance along career path from graduate school to mid-career, work in geoscience-related business and industry, are K-12 and tertiary educators, work for non-profit organizations, and a occupy a variety of professions outside the sciences.

The Consortium offers research projects at two levels: introductory projects for rising juniors and advanced projects for rising seniors. These projects are designed for large groups, nine to ten students and three faculty, in order to combine the intellectual excitement of working in a research group with opportunities to work independently on scientific research. Students working on advanced projects make a yearlong commitment to the program, and the nature of their experience varies markedly throughout the year. In the summer, students spend four-weeks at the study site, learning the geology, identifying a project, and gathering data. Field time is an intense experience during which students and faculty form connections that will characterize the group for the next academic year. Following the fieldwork, students return to their home campus and work under the guidance of an on-campus faculty sponsor. Introductory projects give beginning students a taste of geoscience research, as well as sense of the challenge and enjoyment that comes from solving Earth Science problems. In these projects, students work in small teams to complete a project in five weeks. These are intense weeks for students as they learn not only the research problem but also the dynamics of their particular group. Students improve their communication and cooperation skills as they gather and interpret data, and produce a paper in a relatively short period of time. During the academic year, students work, via e-mail and the post, to produce an extended abstract and poster for presentation at the annual symposium.

The program year culminates for all students with presentation of results at an annual symposium the following spring. Students are required to submit four-page extended abstracts for publication in the symposium volume. At the symposium, students present their work in both poster and oral presentations. Students are also required to complete independent study or senior thesis based on their Consortium project. Many also present results at regional and national conferences. More detailed information about the Consortium program and structure can be found at http://keck.carleton.edu.

Undergraduate Research En Masse at **Lehigh University.** For the past five years, Professor Steve Regen has incorporated original research projects as part of a second-semester organic chemistry laboratory. The goal has been to provide a research experience in the chemical sciences to as large and as broad a student body as possible. This past year's experiment is illustrative:

In the fall of 2001, students worked on idea of combining ion exchange chemistry with micellar chemistry to create a new class of materials ("hydrophobic sponges") that could remove organics from water. In the first few weeks of the spring 2002 semester, fundamentals of polymer and ion exchange chemistry were presented to the students during pre-lab briefings, along with how soaps work. Then, the basis of the research idea was presented to the class. Students were told that two of Professor Regen's coworkers (Dr. Vaclav Janout and Mr. Xun Yan) were preparing resin-bound surfactants and that they were trying to develop an analytical method that could be used to measure the absorption of organics. The students' task in this project would then be to do structure-activity studies.

A detailed procedure was given to the class, and they then obtained the key data during one long (double-laboratory) period; experimental methods included micropipeting, GC calibrations using an internal standard, and quantitative GC analysis were employed. Students submitted signed and dated data sheets, which included their raw data plus calculated absorption values. The data were compiled by Mr. Yan and returned to the class in the form of Tables and Figures, along with copies of their data sheets. With the exception of five students, the quality of the data generated was very good—smooth curves were obtained with minimal scatter. The five students were given an opportunity to repeat their experiment on a Saturday; four chose to do so and obtained data that "hit the curves" produced by their colleagues. The results were discussed in class and a reasonable interpretation of the data formulated. The students were kept fully engaged, intellectually, throughout the project. After obtaining written permission from the students to include them as coauthors, a manuscript was prepared based on their findings and submitted to *Macromolecules*. Prior to submission, the process of scientific publication was discussed. All correspondence with the Editor (including the reviews) were shared with the students. The paper was published [*Macromolecules*, 2002, *35*, 8243] using a special coauthor format designed by the ACS, where the names of the students were listed at the bottom of the first page. We had a "paper signing party" at a local ice cream parlor in September of 2003 to celebrate their achievement.

In February of 2003, emails were sent to this class (79 students) requesting feedback on the research part of the course; 25 responses were received, all of which were strongly positive. For other similar projects, see: *Chem. Mater*., 1998, *10*, 855; *Macromolecules*, 1998, *31*, 5542; *Org. Lett*., 2000, *2*, 2157. Contact: Steve Regen, Department of Chemistry, Lehigh University.

Preparation for Undergraduate Research at **Lewis-Clark State College**. At Lewis-Clark State College (LCSC) all chemistry majors are strongly encouraged to complete a research project before graduation. While many individual faculty strive to develop research projects that are beneficial for undergraduate students, the Lewis-Clark State College Division of Natural Science has developed a sequence of research preparation courses that have proven to be quite beneficial. Past experience demonstrated that substantive research projects require significant preparation, particularly in the area of literature review and project design and planning. In order to enhance student preparation for, and exposure to research, all Natural Science majors at LCSC are required to take NS 380 (Natural Science Seminar – one credit). In this course students spend four weeks developing extensive literature-searching skills that utilize multiple on-line search engines and databases. Since this course is taken by science majors from multiple disciplines and because of the interdisciplinary nature of much current research, students are exposed to research skills in multiple disciplines including chemistry, biology, earth science, computer science and math. As the semester progresses, students use primary literature found during these searches to prepare abstracts of scientific articles. They learn about scientific writing styles and how to use citation software. Additionally, students are exposed to many on-campus resources that are useful in doing research or preparing presentations or manuscripts. Some examples include the media center, computer services, etc. The course culminates in individual student presentations on an area of research that is of interest to the student.

After completing this course, students who elect to conduct a research project take a second course, NS 398 (senior proposal – two credits). In this course students select a faculty mentor with whom they will work to develop a formal research proposal for a project to be conducted in subsequent semesters. Using the skills developed in NS 380, students conduct a primary literature review, design a detailed proposal outline and write a formal proposal modeled after the National Science Foundation proposal format. The proposal contains a project summary, project description, citations, timeline for completion, resource requirements (budget, facilities, equipment), methods of dissemination and letters of support from any collaborators in other departments, institutions, industry or government agencies. When completed, the proposals undergo review by a faculty panel and are either accepted, accepted with revisions or rejected. Projects that are approved usually result in research projects that last at least one year. The culmination of the research projects is a presentation to the college faculty which is evaluated on both content and presentation quality.

This formal preparation for conducting research has had significant positive benefits. Projects are better planned; students are much more familiar with the literature in their research area and thus take a more active role in designing their projects. One student proposal was only slightly modified and submitted to a company that resulted in donation of a Raman spectrometer to LCSC. The end result of this process is an increase in student presentations at scientific meetings, numerous award-winning student posters and an increase in student co-authors. Contact: Christine Pharr, Department of Chemistry, Lewis-Clark State College.

The MERCURY Undergraduate Research Consortium. Computational chemistry faculty from seven undergraduate institutions have formed a consortium known as the Molecular Education and Research Consortium in Undergraduate computational chemistRY (MERCURY). The consortium allows faculty and students from **Colgate University, Connecticut College, Hamilton College, Hobart & William Smith Colleges, College of the Holy Cross, Mount Holyoke College and St. Lawrence University** access to state-of-the art computational power and numerous opportunities for student and faculty collaboration, mentoring and cross-fertilization. The objective in forming the MERCURY consortium was to help undergraduate research programs flourish, and this has indeed occurred as evidenced by the number of proposals and papers submitted by members either collectively or individually. The consortium has recently received $780K from the National Science Foundation's Major Research Instrumentation program to purchase computational resources. MERCURY institutions provided $615K in matching funds, and with these funds, an excellent collection of computers that provide heavily-used computing cycles for faculty and undergraduate students has been assembled. Another measure of consortia success is that in the two years since the consortium was first established, its collective publication rate has almost doubled, the number of external grant awards has more than tripled (submittal rates are even higher) and more than four million dollars has been raised to support computational chemistry research involving undergraduate students. The faculty involved in the MERCURY consortium have mentored over 250 undergraduates, of whom 1/3 to 1/2 have gone on to graduate school, and a disproportionate number of these students have been women and minorities.

The MERCURY Consortium annually organizes a national meeting focusing on undergraduate computational chemistry. Students and faculty benefit intellectually and socially from engaging in detailed scientific discussions with others. The ability to discuss science with others passionately engaged in the same subfield is a rare opportunity for an undergraduate and these exchanges further students' education and continue to encourage students' interest in pursuing graduate studies in chemistry. Contact: Susan Parish, Department of Chemistry, Hobart & William Smith Colleges. For more detailed information please see mars.chem.hamilton.edu.

The Murdock Trust has supported and, more recently, administered a program that provides two summers of full-time research experience for in-service high school science teachers. This **"Partners in Science"** program was initiated by Research Corporation, with offices in Tucson, and was administered nationally by them for about ten years, with the Murdock Trust providing funding and auxiliary services in the Pacific Northwest. Since the year 2000, the Trust has assumed full administration of the program in the Pacific Northwest as well as sponsoring the annual national conference for teachers in that program. The Camille & Henry Dreyfus Foundation has also funded this program for several years in the New York City area.

This program is addressed to in-service high school science teachers who teach biology, chemistry, astronomy, geology, or physics. Its purpose is to provide teachers with an experience and a perspective on science that most have never received: that of science as an organic and open-ended activity. Grants in this program are made to the host research institution (mostly colleges and universities), and include summer stipends for the teachers as well as some minimal travel, research, and incidental support. After completing the two-year research experience, teachers may apply for Supplementary Awards, limited to $6,000 each, to go directly to their high schools to implement the hands-on approaches to teaching that they have learned in the research laboratory.

To date, about 620 teachers have participated nationally (about 245 of these in the Pacific Northwest), impacting about 500,000 high school students in their classes. In a recent evaluation of the program, many teachers commented that, as a result of the experience, they feel more confident in their teaching, they have new excitement and feel greater professional dignity, and are connected better with the community of scientists. Many noted increased enrollments in their science courses, greater numbers of science majors, and more student motivation and interest. As a direct result of their research experience, teachers indicated that they introduced (per teacher-participant) 0.49 new regular courses (mostly emphasizing hands-on work), 0.90 new laboratory courses, and 0.42 new units into their curricula. Over a third of the teachers were successful in approaching other sources, either local or national, for additional funding for their school science programs, totaling over $1.3 million. Contact: John Van Zytveld, Murdock Foundation.

National Environmental Modeling and Analysis Center (NEMAC). The National Environmental Modeling and Analysis Center (NEMAC) is part of a major proposed collaboration in the Asheville, North Carolina area, bringing together three very different cultures – the academic community, the government, and private enterprise – for addressing the region's economic well being. The Center will be located on the campus of the **University of North Carolina at Asheville** (UNCA) and will work in collaboration with other academic institutions, governmental agencies, non-profit companies, and commercial companies. NEMAC will support many elements of the western Carolinas economy and will build on the infrastructure created through public funding already in place.

Others that are a part of this collaboration include the **Education and Research Consortium of the Western Carolinas** (founded by Congressman Charles H. Taylor of the 11th Congressional District), the **National Climatic Data Center** (NCDC), and **Barons Services Advance Meteorological Systems** (BARONS). These organizations will initially supply the academic, governmental, and commercial expertise necessary for the collaboration. UNCA will provide the direction and administration of the Center. Previous thriving collaborations have shown that participation by all three sectors is vital to success. The Center will add to the intellectual base of UNCA and will provide the institution with a means to be pro-active in the region in a way that is consistent with the goals and mission of the University. NCDC will gain increased use and relevance of the data in its archive, and BAMS will gain incubation resources to allow it to begin the commercialization of NCDC data.

The participation of the commercial sector is key to the success of the NEMAC, since the initial funding from the Library of Congress is seed money with the expectations that NEMAC will become self-sustaining from both commercial products and regional and national funding sources.

It is envisioned that NEMAC will provide UNCA faculty and undergraduates research opportunities during both the academic year and the summer. Very important is the additional intellectual capital for UNCA coming from both the collaborations and those scientists who will be employed by the center. Contact: John Stevens, Chief Research Officer, University of North Carolina-Asheville.

North Carolina State University provides diverse REU opportunities for national and international undergraduate students, including those from predominately Black and Native American universities, to participate in faculty-mentored summer undergraduate research. REUs in Chemistry and related fields are cited below, as are programs to stimulate interest in science for K-12 students and to prepare middle and high school science teachers for modern approaches in science education. NC State is a member of the **University of North Carolina Undergraduate Research Consortium**, a system-wide network of 16 universities with a common goal of promoting undergraduate research experiences across these and other universities. It forms an ideal, well-organized model for developing a NSF Undergraduate Research Center.

North Carolina State REUs are as follows:
REU Department of Chemistry: www.ncsu.edu/chemistry/chemreu/. Students from 10 national universities participated in 2002 as mentored researchers at North Carolina State and with corporate partners.
REU in Fungal Genomics: www.fungalgenomics.ncsu.edu. In 2002, nine faculty collaborators at six institutions mentored outstanding students in state-of-the-art facilities using cutting edge techniques with the mission to discover and analyze the function of genes from economically important fungi.
NSF Green Processing REU: www.che.ncsu.edu/reu. In 2002, students from 14 universities in 13 states participated in environmentally-responsible processing research in Chemical Engineering, Civil Engineering, Textiles Engineering, Chemistry and Science, and Wood and Paper Science.
NSF Minority Graduate Education Summer Research Experience:
www.fis.ncsu.edu/grad_fellows/mge/sre.htm. A faculty-mentored research experience with workshops, seminars and presentation of research; for outstanding undergraduates who are considering a Ph.D.

REU Physics Program: www.physics.ncsu.edu/reu. Faculty-mentored research in condensed matter and materials physics, nanoscience and technology, atomic and nuclear physics, optics, astrophysics, and physics education.
NSF Science & Technology Center for Environmentally Responsible Solvents & Processes (CERSP): www.nsfstc.unc.edu. Involves five participating institutions with the mission to support multi-disciplinary, fundamental research to identify and enable sustainable processes and products using CO_2-related technology. Programs are weighted strongly towards historically underrepresented segments of society.
NSF-VIGRE Traineeship Program: www.stat.ncsu.edu/admin/vigre02.htm. A program in the Department of Statistics for training statisticians who make interdisciplinary applied research and problem-solving activities central to the learning process.
Sustainable Agriculture at the Center for Environmental Farming Systems: www.cefs.ncsu.edu/. Hands-on research in modern farming practices that promote agricultural sustainability and resource management.
NSF Triangle Universities Nuclear Laboratory REU:
www.tunl.duke.edu/Undergrad/REU/reu.shtml. Faculty from North Carolina State University, Duke University, and the University of North Carolina, Chapel Hill enable students to become directly involved in low-energy nuclear physics research.
Howard Hughes Medical Institute Student Research Exploration and Precollege Outreach Program: www.science-house.org/student/hhmi/sri.html and
www.ncsu.edu/project/bio-outreach/:

- **Summer Research Interns:** For 9 rising college sophomores through seniors majoring in science, math, science education, and technology. Must attend one of nine colleges/universities in North Carolina. Students are placed in North Carolina State campus laboratories or in government or corporate laboratories of the Research Triangle Park, NC.
- **Reaching Incoming Student Enrichment (RISE) Program:** Provides summer research experience for 32 incoming NCSU freshmen in the department of their declared major.
- **Learning Through Research Seminars:** Provides a series of Learning Through Research Seminars by leading scientists for undergraduate students on the NCSU campus and each of the other institutions in the consortium to stimulate student interest in research and to aid in recruiting student interns.
- **Bennett's Millpond Project:** Provides support for a year round, faculty-mentored research program for teams of high school teachers and students in investigating the environment of the old millpond in northeastern North Carolina.
- **Science of Sports:** Research experience for high school juniors/seniors; involves physiology and physics of sports.
- **Environtech:** Two-week guided research experience for high school sophomores/juniors in environmental technology.

Contact: George Barthalmus, Interim Director, University Honors Program, North Carolina State University.

Interdisciplinary Undergraduate Research at **Oakton Community College**. At Oakton Community College, in Des Plaines, Illinois, we are in the third semester of an embedded and interdisciplinary undergraduate research program for community college students. This experience is offered as a course during the academic year. For each of three semesters, Spring 2002, Fall 2002, and Spring 2003, there have been an average of 8 students enrolled in the class. The course is taught by 5 faculty from chemistry (1), biology (3), and medical laboratory technology (1). All faculty members are present during course time and meet outside of class to plan each week.

Students participate in three interdisciplinary research projects. The first, in collaboration with **Northwestern University**, studies biofilms that develop during cystic fibrosis. The second, in collaboration with the **Chicago Botanical Gardens** studies the fungi that connect the roots of oak trees. The third, in collaboration with the Advanced Photon Source (high energy synchrotron) at **Argonne National Laboratory**, **Brookfield Zoo**, and the **Field Museum of Natural History** studies molecular evolution through the x-ray crystal structures of lysozyme from the egg whites of different species.

The interdisciplinary nature of the experience is exciting for both the students and the teachers. The students learn science by doing science in an environment where they observe their teachers thinking about a scientific question from different disciplines. Oakton Community College is hoping to become a model for other community colleges. Over half of the nation's enrolled undergraduates attend community colleges and over 75% of future K-12 teachers receive their only science education at a community college. If community college students can be given exciting, discovery-based research experiences, community colleges are in a powerful position to change the way the nation thinks about science and the way future teachers teach science. Contact: Mark Walter, Division of Science and Health Careers, Oakton Community College.
http://www.oakton.edu/~mwalter/ure

Undergraduate research at **Pacific Lutheran University** (PLU, Tacoma, WA) has been ongoing for more than 40 years. The program began in 1958 when the first grant was awarded to PLU by the Research Corporation, followed by the first NSF undergraduate research grant in 1962. Since then, a variety of sources have supported undergraduate research programs, including grants from the Research Corporation, NSF, and private foundations such as the M. J. Murdock Charitable Trust.

Students are involved in research as early as possible. Some students who begin research early in their academic career, e.g., before their sophomore or junior year, continue their research at PLU in subsequent summers, and their continued participation strengthens the program. As veteran researchers they are able to accomplish more in the second (or third) summer, and they can serve as peer mentors for beginning research students. Some students, after completing one or two years at PLU, move on to NSF REU sites or other summer research programs in larger settings. Collaborations between PLU faculty and colleagues at research universities also open the door for PLU undergraduates to conduct research at the collaborator’s institution.

Faculty at PLU have built bridges with non-PLU researchers in the community through the Partners in Science program (described above). One faculty member has recently authored an RUI renewal grant that proposes to include involvement of local MESA (Math, Science, and Engineering Achievement) Program high school students in his research lab. Other faculty have mentored students engaged in the high school International Baccalaureate program, and students from nearby high schools who simply wanted to gain experience in a chemistry lab.

PLU faculty have also maintained and developed connections with some of the national laboratories. PLU students have also gone to several national laboratories for summer-long research experiences. Contact: Craig Fryhle, Department of Chemistry, Pacific Lutheran University.

A partnership between **San Jose State University** and the **IBM Almaden Research Center** supports a unique summer internship program in which undergraduates and teachers do publishable research at the leading edge of technology in an industrial research environment. The program, started in 1994 and extended in 2001 for three more years, is supported by a Grant Opportunities for Academic Liaison with Industry (GOALI) grant from the National Science Foundation. The program encompasses projects in the areas of chemistry, engineering, and physics of materials with special relevance to the microelectronics, semiconductor, and computer industries.

The goals of the program are manifold: to do research that would not be possible without complementary resources (people, equipment, stipends); to expose participants to academic/industrial environments; to enhance scientific education; to increase the participation of underrepresented groups in science and engineering; to provide information for enlightened career decisions.

Summer projects are at the IBM Almaden Research Center and draw about 20 undergraduates and 4 teachers from across the United States. Year round collaborative research for SJSU students at both institutions is also supported by this program. Participants are individually mentored and become part of their mentor's research group. Career Day, a weekly technical seminar on IBM research frontiers, and a concluding poster technical meeting enrich the internship experience, while networking with interns from this and other programs and interacting with an international group of graduate students and postdoctoral fellows broaden it.

The interns form a diverse group, coming from large universities, from primarily undergraduate institutions, and from community colleges across the United States. Typically 50% of the participants are women and 13% are members of groups underrepresented in science and technology. Non-local undergraduate participants are housed together in the SJSU dorms as part of their award, fostering a sense of cohesiveness within each group of interns.

Recruiting is done via post, e-mail and Internet postings to summer internship sites; word of mouth is one of the most effective methods of reaching potential interns. IBM scientists distribute information about this program and other internship opportunities when they speak at college campuses. Additionally, the grant provides some support to interns to present their work at regional and national scientific meetings, another avenue to prospective participants.

In developing this program, many issues have had to be addressed. For example, academic and industrial institutional goals sometimes differ, and timetables and milestones may be out of phase. Intellectual property and confidentiality issues have to be considered and resolved. A personal champion at each institution has been a must. Our experience has been a win-win-win situation-- the industrial partner gains research, enhanced academic ties and an injection of youthful enthusiasm; the academic partner gains research, student and faculty industrial awareness and can leverage other funding; and the interns gain unique insider experience in an industrial research environment. Contacts: Charles Wade, Dolores Miller, IBM Almaden Research Center, and Joseph Pesek, Maureen Scharberg, Department of Chemistry, San Jose State University, San Jose, CA.

The Summer Program for Research Interns (SPRI) at **The South Carolina Governor's School for Science and Mathematics** is a program for rising high school seniors in public and private schools in South Carolina. The goal of SPRI is to motivate bright, academically talented students to pursue careers in science, mathematics, or technology.

Participants in the program include rising seniors at GSSM plus a number of students from other state high schools who are chosen from a pool of applicants. The participating students are paired with researchers in a field in which the student has indicated an interest. The student works in the researcher's lab for an average of six weeks during the summer on a project that can usually be completed within that six-week period. At the conclusion of the research, the student writes a summary of the project in the form of a scholarly paper. The students also present the results of their research at the Governor's School Annual Research Colloquium.

The research project can take a number of forms.

- One example of a project that involved real-world problem solving is a project that Michael McTaggart, a GSSM student, completed for the Exercise Science Department of the University of South Carolina in the summer of 1995. The department needed a dynamic force platform to expand their ability to complete studies on falls of individuals. The cost of $40,000 for a commercial dynamic force platform was prohibitive. Working with the Civil Engineering Department of the University, Michael designed, programmed, and tested a working prototype of a device that cost under $100.
- In the summer of 1997 Lindsay Sims, another GSSM student, helped to make the conversion of a Sigma 115 gas chromatograph to an Autosystem gas chromatograph for the Du Pont plant in Florence, South Carolina.
- Marshall Shuler, a student at South Florence High School, worked with the United States Department of Agriculture at the Coastal Plains Soil, Water, and Plant Research Center in Florence, South Carolina. Marshall's project was to determine if wastewater from swine operations could be treated effectively with media filters.

As students work on the projects, they not only gain a considerable amount of information on the subject, they develop skills inherent to the field in which they work. Students usually begin the research by studying the background of the subject with the direction of the research mentors. Once the students have a background in the area of research, they begin to work in the laboratory or in the field. By the completion of the project the students often become proficient in their specialized fields of study.

Many students continue in their summer research field through college. For example, Rosa Bailey worked with Dr. William Pennington at the Clemson University x-ray crystallography lab in the summer of 1991. Rosa recently completed her Ph.D. in x-ray crystallography at Clemson. She worked with Dr. Pennington throughout her college career in that same lab in which she did her summer research. Another student who completed her research in the summer of 2002 in a University of South Carolina biology lab said, "My research experience helped me decide on my major for college. It was truly an exciting and educational experience."

Participating institutions include the three major research institution in South Carolina, **Clemson University, the Medical University of South Carolina, and the University of South Carolina**. Additional institutions include other state colleges and universities, industries, and private and governmental institutions. A few students serve their internships in institutions in other states or foreign countries. Since the program began in the summer of 1990, thousands of student interns have participated at more than 80 institutions. Contact: Robert Trowell, South Carolina Governor's School for Science and Mathematics.

SURE/SEED: A Chemistry Collaboration at Stonehill College. In 1996, Stonehill College created a formal, campus-wide, summer undergraduate research program – the Stonehill Undergraduate Research Experience (SURE). Open to students in all disciplines, the SURE Program funds up to 15 professors and 15 students each summer for intensive work on a research topic. Either a student or a member of the faculty may initiate the partnership. The faculty/student teams collaboratively shape a proposal for the project that outlines the goals, the methods, and the anticipated outcomes for the research.

During the Summer 2002, the Department of Chemistry expanded the SURE program to include economically disadvantaged high school students from southeastern Massachusetts (**Apponequet Regional High School, Brockton High School, Newton Country Day School, Quincy High School and Rockland High School**). Academically gifted, economically disadvantaged high school juniors and seniors worked in Stonehill's chemistry and biochemistry laboratories for eight weeks as part of the American Chemical Society's Project SEED (Summer Educational Experience for the Disadvantaged). The SEED program was jointly sponsored by the American Chemical Society and the Verizon Foundation's EdLink program. The program's aim is to increase the number of students from under-represented groups that choose to go to college to study science, particularly chemistry or biochemistry.

Each high school student was jointly mentored by a faculty member and a SURE college student. The SURE students started working in the laboratories three weeks before the high school students arrived and thus were comfortable working in the laboratory, but still remembered clearly the many questions they had when they first started three weeks prior.

A unique feature of the Project at Stonehill is the coupling of the SEED student with a SURE scholar. The high school students benefit from the extra chemistry knowledge and experience that the undergraduates have while obtaining a first hand account of college life. The Stonehill students benefit from teaching, which reinforces their knowledge of the principles and applications of chemistry. The need to describe the research to the high school students makes the SURE students have a better understanding of it.

Timberline High School, Boise, ID. High school chemistry programs have recently been initiated with **Boise State University** (BSU), the **Idaho Department of Environmental Quality** (IDEQ), memory-chip maker **Micron Technology**, and local non-profits for service-learning activities in the city of Boise. The underlying strategy of these programs has been to place students with university researchers, and to build programs that have an emphasis on student engagement in chemistry. The latter are "light" in their research aspects.

Program descriptions:

1) **Partnership with IDEQ**. An air quality monitoring station has been set up at Timberline High School. Starting in the Fall, Timberline chemistry students will be taking weekly PM10, CO, NO_x, and SO_x measurements. Using these collected data and an understanding of atmospheric pollution chemistry, these students will be part of DEQ's community outreach program that will help to educate the public about our local air quality problems and solutions for improvement.

2) **Partnership with BSU**. In collaboration with Dr. Paul Dawson, Timberline chemistry students will study the oppressive inversion layers that occur in Boise every winter. Students will measure the inversion's optical thickness daily and compare these results with Dr. Dawson's sonar-modeled data. One student will do an internship with Dr. Dawson during the summer and continue independent research at Timberline for one period

a day during the school year. The research will mainly consist of local air pollution data collection and GIS modeling.

3) **Micron Technology**. To better understand the chemistry of technology, field-trips to Micron are planned and Micron scientists lead hands-on activities in Timberline classrooms related to microelectronics fabrication. This has resulted in placing students in job shadows at Micron.

4) **Service Learning (SL)**. Starting next Fall, Timberline students will have the option of adding a 0.5 credit SL-Chemistry class. Approximately 30 students will do this per semester; they will be placed in different non-profit or government agencies. An example project is student testing of residential homes for lead-containing paints. SL students will do 20+ non-school hours of service per semester and then submit a project that links their service work to the chemistry curriculum. This activity is hands-on and allows students to participate in and contribute to the real work done by chemists. Contact: Neil Greeley, Timberline High School, Boise, ID.

The **Maryland Educators Summer Research Program** (MESRP), headquartered in the Center for Science and Mathematics Education at **Towson University**, provides opportunities for motivated in-service and preservice teachers to experience cutting-edge science and technology through authentic research experiences. This hands-on approach promotes inquiry-based learning and gives teachers the credibility and experience needed to incorporate current content and authentic data into science and mathematics curriculum.

MESRP operates on a yearly cycle, beginning in early spring, when eligible inservice and preservice teachers are invited to apply for participation in the program. A selection committee, appointed by MESRP, reviews and ranks all applications and makes recommendations for placement according to each candidate's suitability for specific sites. Site Representatives interview candidates recommended for placement at their sites to determine final approval for intern placement.

During the summer, interns team with mentor scientists for a six- to twelve-week internship to participate in research at government, university, and private laboratories throughout Maryland. As both learner and contributor in the research environment, interns gain a wealth of knowledge that will impact how they view teaching and learning. Whenever possible, in-service and preservice teachers are paired at research sites, enabling experienced teachers to serve as mentors who can provide valuable insights on both classrooms and workplaces to preservice teachers. Likewise, preservice teachers are able to contribute fresh perspectives from their teacher preparation program.

The commitment to learning does not end with the research experience. During the school year following their internship experiences, interns participate in outreach and professional development activities designed to build bridges between laboratories and classrooms, while providing resources and further learning opportunities for themselves and other educators. These activities, which include a Classroom Implementation Project, a Speaking Event, and a Collaborative Activity, facilitate the transfer of attitudes and beliefs about science and mathematics education into classroom practices that engage students in active, investigative learning that will ultimately improve their attitudes, perceptions, and performance in science and mathematics.

As the program concludes its third year, it is evident by the existing evaluations that the design and implementation of MESRP has far-reaching potential to significantly impact the future of science and mathematics education. The continued support of the research laboratories and various funding agencies speaks to the validity of the program and a mutual interest in the enhancement of the teaching and learning of science and mathematics in the state of Maryland.

The Department of Chemistry at **Trinity University** believes that undergraduate research is the cornerstone of effective undergraduate chemistry education. Part of the vitality in such a program comes from a critical mass of student researchers. With funding from the National Science Foundation, ACS-PRF, Research Corporation, the Camille and Henry Dreyfus Foundation, and the Welch Foundation, between 19 and 45 undergraduate researchers have been supported every summer for the past decade. The average number of summer research students has been 33.

While the size of the program is significant, hidden in the numbers is the program's novel approach. Great emphasis is placed on involving students in research early in their academic careers. For that reason, heavy recruiting is done in first and second year chemistry classes among students who have not yet declared a major. The rationale for this approach is based on the belief that the experience in a research lab is fundamentally different from that in a teaching lab, no matter how much aspects of discovery are incorporated into the curriculum. If this is indeed the case, a student considering science or medicine as a career benefits most from early involvement in research. Such an experience clarifies for a student that a scientific career is an appropriate choice, or helps them decide to make other plans. Last summer, the department supported 34 students on summer research projects; 22 of the students had completed no more than two years of college chemistry. This philosophy extends to include high school students in the research lab. On average, two high school students per summer have participated in research with the support of the Dow Chemical Company Foundation. Many of the high school students involved in the program subsequently enroll at Trinity University. By recruiting research students early, many of chemistry majors leave Trinity University with two, three, or even four years of research experience. Consequently, they are highly recruited by graduate institutions.

Student research efforts also continue during the academic year, with 33 students enrolled in research for credit last year and about 15 more students doing research on a volunteer basis. Volunteering in research allows students who are concerned about their ability to sustain research activity during a tough academic semester to continue their excitement about research by maintaining a research presence, attending research group meetings, and benefiting from many of the activities associated with research. The emphasis on the involvement of young students in research was underscored by the creation of an independent study course targeted to students in their first two years at Trinity University.

Because many research students start doing research before declaring a major, research experiences are provided to many students who majoring in other areas. This is an important additional benefit to this approach in that non-science majors are trained in research. In terms of increasing the general level of scientific literacy, having English or Economics majors who have been involved in meaningful scientific research is the highest level of scientific literacy.

A second focus of the department involves students from predominantly Hispanic schools in chemical research at Trinity. These efforts offer research opportunities during the summer to students from local colleges and universities with very limited research opportunities at their home institutions. This group of local schools includes both four-year institutions and two-year community colleges. The program, which supported ten students per summer, guaranteed places in research groups for students from seven local schools with large enrollments of Hispanic students. The remaining three slots were reserved for Trinity students who then served as mentors. Typically safety, ethics, and research seminars were included among the list of activities. A number of social activities helped build community. It was not unusual for students who had participated in research through this program one summer to be picked up by individual research grants in subsequent summers.

The Trinity University Chemistry Department has seven full-time faculty members. The faculty members maintain externally funded research programs, and involve undergraduates in those programs. Peer-reviewed papers based on the research of these students are routinely published. Research students are encouraged to present the results of their efforts at local, regional, and national meetings. These publication and presentation opportunities are not restricted to the best students; rather *all* students involved in the program have real opportunities to work on meaningful, publishable research. Faculty at many institutions tend to assume that students need to be reasonably far along in their academic careers in order to contribute effectively to a research project. This has not been the experience at Trinity. Students are particularly good at rising to expectations. Contact: Michelle Bushey, Department of Chemistry, Trinity University.

Rollinson Fellowship Program, University of Maryland. For the past three spring semesters (2001–2003) the Department of Chemistry and Biochemistry at the University of Maryland, College Park has implemented an initiative designed to provide a number of first year undergraduate majors with the opportunity to pursue independent research under the mentorship of research active faculty members and graduate students. Entitled the Rollinson Fellowship Program (RFP), this initiative has matched motivated – although not necessarily experienced – students with small, self-contained projects that fit into the larger goals of participating research groups. Support from the both the Department (through the Carl Rollinson Endowment) and the College of Life Sciences enables the RFP to match eight applicants to eight individual research projects each semester.

Participating undergraduates are named Rollinson Fellows and receive a $500 tuition allowance. In addition, each Rollinson Fellow is able to spend up to $300 dollars to help defray costs associated with their research. The RFP requires that Fellows work ~7-10 hours per week on their respective projects. The program culminates with a Rollinson Fellowship Research Symposium during which all participating Fellows present their work in 10-12 minute, ACS-style research talks. Following the symposium, Fellows submit 4-5 page papers summarizing their results and their impressions of the RFP.

A unique aspect of the RFP is its acknowledgement that mentoring first year undergraduates is time intensive, both in terms of planning manageable, self-contained projects, and day-to-day supervision in the laboratory. In recognition of a research group's commitment, the RFP provides partial RA support for participating research groups. This support encourages faculty to contribute research projects as well as commit their time and the time of graduate student mentors.

Typically ~75% of all first year Rollinson Fellows continue to do research in their groups after the program ends. Many students acquire support from the College's Howard Hughes Medical Institute (HHMI) program. Rollinson Fellows have appeared as co-authors on papers in *J. Chem. Phys*, *J. Phys. Chem. B*, *J. Org. Chem.*, among others. The RFP remains a popular mechanism for introducing first year undergraduates to independent research as well as a means of developing mentoring skills within the graduate student ranks. Contact: Robert A. Walker, Department of Chemistry, University of Maryland.

Research enhances the future instructional workforce at the **University of Michigan.** As first-year students, Ian, Sarah, Nicole, Scott, Desiree, and Jason were in a special section of the first-year chemistry course that emphasized project and literature-based work. They designed, did library research for, proposed, ordered compounds for, and synthesized a compound via a multi-step synthesis. In another project, they worked on analyzing the chemistry from a recent journal article, ultimately presenting their understanding as part of a multimedia, web-based text (on which their final exam was based). Their undergraduate leaders (juniors and seniors who had excelled in this course previously) selected them as the next generation of leaders based on their potential. All six of them also joined research groups by the end of their first year of college. As juniors, they did join the instructional program of the first-year course as leaders. All six students aspire to academic careers at research universities.

When the Dental School received a large grant for offering a 5-week early intervention course for a group of 30 at-risk, first- and second-year students from mainly HBCUs, they approached the chemistry department for assistance. Jason took his experience in teaching first-year students in the Honors program and designed a 36-hour program (20 facilitated discussion, 16 laboratory) for the chemistry unit. He integrated his growing subject matter knowledge, laboratory research experience, and teaching experience into a novel program. Collecting survey and performance-based educational research data, he was also able to show the striking effect of an intense mastery experience on the confidence of these at-risk students. The next year, Scott picked up this chemistry unit and two other students used Jason's experience as a template to expand to a biochemistry unit and a physics unit.

The College wished to offer a series of 2-week (80-hour) intensive short courses to promising high school students. As juniors, Scott, Ian, and Desiree designed a program that would have these students analyzing NMR spectra as the entrée into the course goal: understanding structural chemistry. They, like Jason, drew from both their research and teaching experiences in designing this unit. During the implementation, Ian also collected, and did discourse analysis on, videotapes of students doing performance-based tasks, comparing the skills of these students to solve and NMR problem compared with some experienced senior students. The next year, Sarah, Nicole and another colleague used the 2-week period to design and implement a molecular biology unit.

As a senior, Ian joined a 7-person team (2 faculty, 1 post-doc, 4 graduate students) in the design and development of instructional materials for implementing a studio-format version of General Chemistry. He joined the team on their weeklong fact-finding trip to Cal Poly, where some studio implementation had been done. He brought his design experience to the team, and wrote the first draft of the acid-base unit.

Two other chemistry majors, Laura and Kim, are also pursuing secondary education certification. They joined a team of 2 faculty, 2 graduate students, and 2 in-service teachers working on a high school textbook project. Laura and Kim, both of whom had done 2 years of undergraduate research, brought a valued perspective to developing, testing, and writing materials for the laboratory program as well as the teacher's edition. Contact: Brian Coppola, Department of Chemistry, University of Michigan.

Chemistry isn't what it used to be! Over the past several years, whole new chemistry-dependent disciplines have been created or reinvented: genomics, nanomaterials, computer simulation and modeling… The list goes on and on. Anyone who is familiar with the **University of Minnesota**'s Chemistry Department knows that it's helping lead the charge into chemistry's brave new world. Other departments, especially small ones, are not so lucky. How can they stay vibrant in an era of such unprecedently rapid change?

That's where the Research Site for Educators in Chemistry (RSEC) comes in. The RSEC, which is directed by chemistry professor Jeff Roberts and funded by the National Science Foundation, aims to foster new scientific interactions between faculty at the University of Minnesota and faculty at Upper Midwestern undergraduate institutions. Those institutions run the gamut from large public schools, like **St. Cloud State University**, to small private colleges, for instance **Carleton**. The RSEC is organized around four interdisciplinary clusters: chemical biology, computational chemistry, environmental chemistry, and materials chemistry. RSEC participants can apply for financial support, including summer stipends and sabbatical salary, for new research collaborations in those areas. Beginning in 2003, the RSEC will deliver to participating departments an Internet seminar series featuring presentations by internationally prominent scientists. Lastly, the RSEC provides participants with assistance in obtaining external research funding through feedback and advice on proposal.

The Minnesota RSEC was inaugurated in September 2001, and so far it has been able to support fifteen new collaborations involving professors and students from nine undergraduate institutions. What have participants had to say about the RSEC?

Mark Vitha of **Drake University** spent six weeks with Ilja Siepmann in the summer of 2002 working on the application of computational chemistry methods to liquid chromatography. Mark writes, "I would certainly recommend the U of M RSEC to my colleagues. The flexibility built into the program in terms of the arrangements of the collaborations is a definite strong point, as it should allow for many faculty members to find some way to participate in and benefit from the program."

University of Wisconsin River Falls Professor David Rusterholtz and his students collaborated with Tom Hoye in the winter of 2002. They worked on the synthesis of a fragment of the peloruside A structure. Dave is a big supporter of the RSEC. "I highly recommend this program to others. I see no way to keep up with the forefront of chemistry without the aid of others, i.e., the U of M Chem faculty." Contact: Jeff Roberts or Vicki Woodcock, Department of Chemistry, University of Minnesota

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The Chemistry Department at **UNC-Charlotte** offers B.A., B.S. and ACS-approved B.S. degrees. Two semesters of research are required for the B.S. degree. While some students are involved in research only for the required time period, many elect to become more extensively involved. Many students learn about research through their course instructors and from other students.

The Chemistry Department has several mechanisms for introducing students to research at early stages in their academic careers. A special laboratory section in the second semester sophomore organic chemistry course allows students to work on independent projects in a research laboratory rather than enroll in the "regular" organic chemistry laboratory course. Students in this special section are there by invitation of the faculty, so only the top few students have the opportunity to participate in this activity. Most of the students who enroll in this course continue to do research in the same research laboratory for the remainder of their career at UNC Charlotte. Another way of exposing students to research is through the project component of the Quantitative Analysis course. Sophomore and junior chemistry and biology majors account for the majority of students enrolled in this course. Midway through the semester, students choose a short research project either from a provided list of possible projects or a project of their own design. Students work on their projects during the last quarter to third of the semester, after they have learned some basic laboratory skills in the earlier part of the course. At the end of the semester, a "poster day" is held in which students present their projects in poster format, much as they would do at a Gordon Conference or an ACS meeting. Faculty and students attend the poster sessions and interact with the students. The poster session shows the students that scientists learn much from one another by socializing. The project experience is usually quite successful as students take ownership of their work. Students sometimes join research groups as a result of meeting faculty at the poster sessions. Individual projects are also conducted in the laboratory components of the Instrumental Analysis courses, which enroll junior and senior chemistry majors, many of whom are already involved in undergraduate research. Contact: Bernadette Donovan-Merkert, Department of Chemistry, University of North Carolina-Charlotte.

University of North Carolina Undergraduate Research Consortium. In the spring of 2002, in response to the growing prevalence and importance of undergraduate research, the UNC Office of the President formed the UNC Undergraduate Research Consortium. The mission of the consortium is to support and promote high-quality undergraduate research, creative work, and inquiry-based learning in all fields of study with faculty and other mentors. Composed of representatives from the UNC Office of the President and each of the 16 constituent institutions, the consortium serves as an advisory council to the Vice President for Research and Sponsored Programs at the UNC Office of the President. It also serves as an inter-institutional UNC forum for recommending and implementing activities supporting undergraduate research. The members of the consortium meet quarterly, either in face-to-face or teleconference meetings. During its first year, a web page for the consortium was created. The web page describes the consortium, offers a working definition of undergraduate research, states the goals and activities of the consortium, lists the members and subcommittee members, and provides links to campus web sites. The consortium seeks to pursue activities that will facilitate and promote research on and among each of the sixteen campuses. See
http://www.northcarolina.edu/aa/departments/research/initiatives/urc.cfm

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For the last five years, **Williams College** has cooperated with the **RFK Science Research Institute**, a summer program for New York City high school students from underperforming academic settings. By performing multidisciplinary hands-on science research, 6-10 high school students each year develop their critical thinking, logical reasoning, scientific writing and presentation skills. Supervised by Williams College Electron Spin Resonance (ESR) Lab staff, students prepare teeth and other fossils from archaeological and paleontological sites for ESR dating. They are involved in the all aspects of the research, from selecting and preparing the fossil samples for dating, to running the Williams ESR spectrometer, and calculating ages. In these respects, this program is similar to other collaborations between schools and colleges. However, there are two significant differences. This program reaches out to an ethnically diverse population many of whom would not consider college because it is not within their family's cultural experience. We have, for example, had an Afghani woman whose mother came to Williamstown with her, despite severe criticism, to enable her to complete her project. Further, the mentoring available reaches well beyond guidance in how to complete a research project. This program provides college application guidance through visits to the Williams admissions office during the time on campus. Then program scientists continue mentoring through the fall and winter as students prepare detailed reports, and present their data not only at science fairs, but also to science classes in their home schools. Every student who has completed the program (45 of 49) has entered one or more science fairs and other competitions, and has won some level of prize. Five students have been national semi-finalists in Intel or Westinghouse competitions, while one placed in the top ten for New York State. Another was a NYC representative to the International Science and Engineering Fair where he won several awards. These results demonstrate that the students genuinely comprehend their work and can explain it to others. In turn, science fair recognition catches the eye of college admissions officers, boosting the chances for students who might not otherwise seem eligible for acceptance. One student is currently a Williams student, and committed to a career in medical research, others are, or have been, students at Brown, Cornell, Barnard, Hobart & William Smith and other four-year programs, and with substantial financial assistance. The electronic news list for The Chronicle of Higher Education, on Monday, March 3, 2003 described a study of what makes a good early intervention program to encourage high-risk young people and cited the RFK/Williams model as a good example of what is required for success.

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