

Implementation of Undergraduate Research Centers: A Report on a National Science Foundation Workshop

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Introduction: Background and Context

The National Science Foundation (NSF) hosted a workshop on “Implementation of Undergraduate Research Centers” (URCs) on September 17, 2004 in Arlington, Virginia. Organized by Drs. Amy Shachter (Santa Clara University) and Michael Doyle (University of Maryland, College Park), the workshop was attended by approximately 100 participants, including current recipients of URC full and planning grants, educators from all types of institutions, and representatives from foundations and funding agencies. Announcements for the workshop detailed three distinct but interrelated purposes. A “mid-term adjustment” aimed specifically to clear up common misconceptions about the URC program, and generally to improve understanding of the URC program by facilitating communication between the NSF and the community. A second objective was to explore ways to improve implementation of the URC program, both by eliminating common difficulties in developing plans for URCs and by sharing successful strategies and best practices. Finally, the workshop was intended to promote the continuing growth of the program by encouraging new developments in the pilot program consistent with the original URC program intent.

That original intent can be best understood in the context of the overall mission and activities of the NSF. The NSF is specifically authorized to: “Recommend and encourage the pursuit of national policies for the promotion of basic research and education in the sciences and engineering. Strengthen research and education innovation in the sciences and engineering, including independent research by individuals, throughout the United States.” It is also supposed to “support activities designed to increase the participation of women and minorities and others under-represented in science and technology.” (<http://www.nsf.gov/home/about/creation.htm>)

The NSF’s mission and activities have acquired greater urgency in recent years due to the declining number of students earning bachelor’s degrees in physical sciences. A number of recent reports reflect broad concern that this decline threatens the United States’ global scientific leadership. In its 2000 report, *Ensuring a Strong U.S. Scientific Technical and Engineering Workforce in the 21st Century*, the National Science and Technology Council (NSTC) observed that if current demographic trends persist, the United States may soon be unable to meet its technical workforce needs or to maintain the innovation process that has supported its international leadership in science, technology and engineering. The report urges that “our nation must take steps to ensure that it is developing the human resources it will need, paying particular attention to seeking out talent in groups currently under-represented in the scientific, technical and engineering (ST&E) workforce” (<http://clinton4.nara.gov/media/pdf/workforcercpt.pdf>). The National Science Board’s (NSB) *Science and Engineering Indicators—2002* (<http://www.nsf.gov/sbe/srs/seind02/start.htm>) echoes these conclusions and notes several challenges to “the nation’s ability to retain its innovation capacity and international position in S&T.” Those challenges include, “preparing scientists and engineers to fill needed workforce requirements and provide the capacity for long-term innovation (Romer 2000 (<http://www.stanford.edu/~promer/Mkt-forSE.pdf>); NSTC 2000), providing understanding of basic science and mathematics concepts for all students, and measuring what students learn (National Center for Public Policy and Higher Education 2000 (<http://measuringup.highereducation.org/2000/>)).” The same report goes on to note that “the workforce requires people competent in mathematics, S&E, critical thinking, and the ability to

work in teams.” The URC program was conceived to address these concerns and recommendations.

The First Workshop (2003):

The foundation for the URC program was developed, discussed and refined in an NSF workshop entitled “Exploring the Concept of Undergraduate Research Centers,” held March 30—April 1, 2003 at the NSF in Arlington, Virginia. That workshop, organized by Jeanne E. Pemberton (University of Arizona) and Moses Lee (Furman University), brought together representatives from a broad cross-section of institutions invested in undergraduate chemistry education and related disciplines. Participants included administrators and faculty from diverse educational institutions (including research and comprehensive universities, four-year colleges, two-year colleges, minority serving institutions, and K-12 schools) as well as representatives from government laboratories, funding agencies, and industry. The workshop participants focused on issues associated with the goal of expanding undergraduate research opportunities. Their specific objectives 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.

The structure of the workshop advanced these objectives by maximizing opportunities for discussions among participants. Through these discussions, the participants formulated three primary hypotheses to ground and guide (their recommendations concerning) the development of the URC program:

- 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.

As a result of their discussions, the workshop attendees endorsed the concept of the URC as “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.” They also crafted a set of recommendations for the URC program, many of which helped guide the development of the program announcement. The full report on this workshop may be found at <http://urc.arizona.edu>.

The First Program Solicitation (2003):

The NSF's program solicitation for the Undergraduate Research Centers Program (<http://www.nsf.gov/pubs/2003/nsf03595/nsf03595.htm>), posted August 28, 2003 closely follows the recommendations developed in the workshop. It invites proposals for both planning and full URC grants, and offers funding for the latter in amounts up to \$500,000 per year for up to five years, plus an additional \$200,000 in the first year for equipment. Planning grants are offered for one to two years, in amounts of approximately \$50,000.

The Program Description captures the essence of the workshop recommendations:

The program aims to create national models in the chemical sciences and allied disciplines for: expanding collaborations; broadening undergraduate research opportunities; and enhancing capacity for, infrastructure in support of, and commitment to excellence in undergraduate education. Individually, the URCs will have significant impact on the undergraduate programs of participating institutions. Collectively, they will strengthen the nation's research enterprise by providing new mechanisms for attracting a larger, more diverse group of students to careers in the chemical sciences. Their emphasis on participation of first- and second-year students will challenge the imagination and creativity of the community to rethink the directions of undergraduate education.

The program announcement also emphasizes that “there are many potential types of inputs to URCs and many possible desirable outcomes. For this pilot program, proposers should propose bold experiments while being realistic about their outcomes.”

The Second Workshop (2004):

In the URC program's first year, after receiving well over a hundred proposals describing the participation of over seven hundred colleges and universities, the NSF awarded twenty planning grants—the maximum number anticipated in the program solicitation. One proposal for a full URC, out of a possible five, was funded. During the review process, reviewers noted some common difficulties in the proposals that suggested the need for a workshop to improve the communication between the community and the NSF regarding the URC program. Presentation topics at the workshop reflected the most common areas of weakness or confusion in the first round of proposals, just as the abundant opportunities for discussion worked to increase communication and common understanding. Better communication and understanding not only between the community and the NSF, but also within the community itself, can facilitate the exchange of successful strategies and development of creative solutions to shared questions. Through these exchanges, participants explored ways to improve implementation of the URC program and contributed to the continuing growth of the program.

The workshop consisted of two reports on present URC activities, five presentations on critical determinants of URC success, two breakout group discussion sessions—each followed by group reports and general discussion, and two open question-and-answer/discussion periods.

Session One: Implementation of the First Year of the NSF-URC Program

*Speakers: Arthur B. Ellis, Director, Division of Chemistry, National Science Foundation
Rosemary Haggett, Director, Division of Undergraduate Education, National Science Foundation
Robert Kuczkowski, University of Michigan and former Program Director, Division of Chemistry, National Science Foundation*

This session reviewed the first year of the URC program's operation. Dr. Ellis' presentation established a context for the URC program by providing an overview of undergraduate research in higher education. His talk also surveyed the pedagogical and disciplinary advantages of including undergraduates in research, examined the limitations of existing undergraduate research programs supported by the Division of Chemistry, and explained the development of the URC program. After describing the brief history of that program, he sketched a vision of future program developments. Dr. Haggett's presentation discussed various ways that the URC program intersects with other programs run by the Directorate for Education and Human Resources (EHR). EHR programs are a rich source of both partners and funding opportunities for those putting together URC proposals. Dr. Kuczkowski reviewed the previous program announcement to create a foundation for discussion of the next program announcement. He explained the recommendations developed at the previous workshop, the program announcement, and the review process. He presented a detailed analysis of features common to winning proposals. Each of the three presentations was followed by a question and answer period. A broader, open question-and-answer/discussion period followed Session One.

Session Two: Presentation of an URC: The Center for Authentic Science Practice in Education (CASPiE)

Speaker: Gabriela Weaver, Purdue University

This session analyzed the URC developed by CASPiE, a consortium of chemistry faculty from Purdue University, Ball State University, University of Illinois at Chicago, Northeastern Illinois University, Chicago State University, College of DuPage, Harold Washington College, Moraine Valley Community College, and Olive-Harvey College. The presentation explored the principles around which the center was developed, and is organized, reviewed the centers' administrative structure, and provided an example of the kind of research module around which the program is built. Definitions of research, partnering strategies, pedagogy, instrumentation, and evaluation were also discussed. A question and answer period followed. (<http://www.purdue.edu/dp/caspie/>)

Session Three: Sustainability and Scalability

Speaker: Jim Gentile, Dean for the Natural Sciences, Hope College

This session focused on strategies for building sustainability and scalability into URC models. Dr. Gentile provided examples of working models, and raised specific questions to be considered in breakout groups. A question and answer period followed.

Session Four: Assessment and Evaluation

Speaker: Diane Bunce, Catholic University of America

This session detailed the various ways that evaluation and assessment inform program design and operation. Dr. Bunce discussed various methods of evaluation (quantitative, qualitative, mixed methods) and the importance of matching methods to both the kinds of questions being asked and overall project goals. She explained formative and summative evaluation, their interdependence and their differing roles in the overall assessment process. She suggested several strategies for evaluation design, funding and staffing. A question and answer period followed.

Session Four was followed by breakout sessions at which participants discussed questions and issues raised during the morning presentations. When the breakout groups were reassembled, each group briefly reported on their conversation. A general discussion followed.

Session Five: Partners and Center Management

Speaker: Jeff Roberts, University of Minnesota, Twin Cities

This session explored strategies for managing partnerships and administering large projects. Dr. Roberts drew on his experience as Director of the Research Site for Educators in Chemistry (RSEC) at the University of Minnesota, Twin Cities (UMTC) to develop perspectives and principles that might inform general center management practices. He developed a philosophy of collaboration that included selection criteria, participation requirements, and governance. He then inferred a number of specific lessons about administration and management from his own experience. A question and answer period followed.

Session Six: Curricular Models

Speaker: Nancy Mills, Trinity University

This session proposed two distinct approaches to involving students in research. The first asks how to integrate research into the curriculum. The second asks how to create a curriculum that allows students to participate effectively in research. The difference between the two approaches has substantial implications for curriculum development, for sustainability and for productivity. Dr. Mills provided an example of the second approach based on her experience at Trinity University. She also developed a model of how the first approach might work, built around moving students through evolutionary stages from cookbook labs to full participation in genuine research. She provided an extensive bibliography to demonstrate the feasibility of this approach. A question and answer period followed.

Session Six was followed by breakout sessions at which participants discussed questions and issues raised in sessions five and six. When the breakout groups were reassembled, each group briefly reported on their conversation. A general discussion followed.

Session Seven: Student Recruitment

Speaker: Isiah Warner, Vice-Chancellor, Office of Strategic Initiatives, Louisiana State University

This session proposed a model for recruiting students based on two programs developed by Dr. Warner at LSU: the LA-STEM Research Scholars Program (LA-STEM) and the Howard Hughes Medical Institute Professors Program (HHMI). These programs work together seamlessly to support talented students with interests in STEM-related fields through mentoring, research and education. They target potential leaders who are dedicated to diversity, community, and service, and they surround them with the resources, confidence and opportunities they need to succeed. Although both programs are still quite young, both are highly successful. Dr. Warner described the recruitment and selection processes, the functioning of the programs, and the philosophies that guide their operation. A question and answer period followed.

Following Session Seven, there was an open discussion followed by concluding remarks.

Second Program Solicitation

Undergraduate Research Centers (URC) (NSF 05-539)
<http://www.nsf.gov/pubs/2005/nsf05539/nsf05539.pdf>

Letter of Intent Due Date (required): *March 7, 2005*

Full Proposal Deadline (due by 5 p.m. proposer's local time): *April 4, 2005*

Opening Remarks

**Michael Doyle (University of Maryland, College Park)
and Amy Shachter (Santa Clara University)**

The organizers of the workshop started by defining the purposes of and context for the workshop and explained that the workshop was intended to refine the idea of what an URC is, and perhaps more importantly, what it is not.

Models for successful URCs are many and various. No particular model is preferred and paradigms are still being developed; what an effective URC might look like is fluid. With that fluidity in mind, the present workshop was designed to help participants understand and develop ideas about the infrastructure issues involved in creating and developing a successful program. The organizers emphasized that the *presentation topics specifically targeted the infrastructure issues most critical to the success of URC proposals*. Sustainability and scalability, assessment and evaluation, center management, and student recruitment were identified as the four issues of greatest concern. The breakout groups were designed to offer participants an opportunity to discuss these critical issues in light of those presentations and to jointly develop strategies for overcoming difficulties that commonly attend these components of program design. The organizers noted that these infrastructure issues are different from those encountered in the Research Experiences for Undergraduates (REU) models, which are usually based on one-on-one faculty-student relationships. The new models sought through the URC program solicitation will *require* different ways of thinking about infrastructure, because *the fundamental premise of the URC is to provide exposure to research to a large, diverse group of first- and second-year college students*.

On the one hand, the workshop was designed to help attendees develop and refine ideas together. On the other, it was intended to help the NSF gather feedback from the community to help them continue to improve the URC program. To both ends, the workshop was structured to be as interactive and dynamic as possible.

Michael Doyle introduced the first speaker and emphasized that the URC program is an experiment. It is risky—but with great risk comes the possibility of great success.

Implementation of the First Year of the NSF-URC Program

Part One: Arthur B. Ellis (Director, Division of Chemistry, National Science Foundation)

Dr. Ellis established a context for the URC program by providing an overview of undergraduate research in higher education. The breadth of interest in this topic can be seen in the diverse sponsors of the program. It is primarily a Division of Chemistry effort, but the Office of Multidisciplinary Activities and Directorate for Education and Human Resources (EHR)—through the Divisions of Undergraduate Education; Human Resource Development; and Research, Evaluation, and Communication—are also key partners.

Nationally, there is also widespread interest: a number of recent reports have shown that research has tremendous potential to shape an undergraduate's collegiate experience in a positive manner. The Carnegie Foundation's "Reinventing Undergraduate Education: A Blueprint for America's Research Universities" issues a challenge to research universities, asking "Why can't every undergraduate have the opportunity to participate in a research project?" In a sense, this may not be sufficiently ambitious: this question could be asked of all postsecondary institutions. "Bio 2010," a report issued by the National Research Council and supported by the Howard Hughes Medical Institute and NIH, asks what the undergraduate experience should be for students interested in pursuing a career in biomedical research. *U.S. News and World Report* rankings of colleges now include undergraduate research as a category. Together, these reports suggest that this is an appropriate time to significantly expand undergraduate research.

To build a successful undergraduate research program at the national level, we need to understand why undergraduates should be involved in research. Why is it an important part of their experience and education? First, it demonstrates how knowledge is created. Second, it shows how new knowledge is communicated. These are not only essential elements of an undergraduate education, they are the foundations of the profession. Thus, undergraduate research enhances education and contributes to the growth of the profession simultaneously. The diversity of institutions that do provide undergraduate research opportunities testifies to the richness of our academic enterprise in terms of its ability to provide these kinds of opportunities.

In most cases, these opportunities fall within the traditional undergraduate research model, which centers on a faculty member working individually with a few undergraduates. Most of these students are juniors and seniors who have already decided on science majors. However, this model misses a huge group of students (first- and second year students, non-majors) who could potentially share in this experience if the right opportunities existed to broaden participation. The Division of Chemistry has already made a large investment in the effort to expand this experience. The Research Experiences for Undergraduates (REU) program in fiscal year 2004 supported over sixty sites, dispersed across the country, which provided chemical research opportunities to nearly 700 undergraduates. Yet even reaching this number of students leaves a tremendous potential audience untapped and raises the question, "How can we strategically expand the opportunities for undergraduate research?"

The current Undergraduate Research Center (URC) strategy aims to significantly expand the college population engaged in chemical research, by targeting first- and second-year students at all post-secondary institutions (2-year institutions as well as 4-year, comprehensive, and research institutions). The broad aim of dramatically increasing participation in undergraduate research suggests certain principles that drive the new program: it should have an academic year focus that facilitates participation by large numbers of students. It should provide *new* models and partnerships that are scalable and sustainable. It should involve real research that is potentially publishable and based on cutting-edge problems, tools, and methods, so that students can learn how knowledge is created in the chemical sciences.

The workshop that was held in 2003 helped guide the development of the new URC program to expand undergraduate research opportunities strategically. That workshop informed the writing of the program solicitation. Today's workshop will help shape the next program announcement.

For last year's initial URC program, funds were available for up to five full awards, each at up to \$2.7 million over five years (one award was made); and up to twenty planning awards, averaging about \$50k each for one to two years (twenty awards were made). The response to the program solicitation was overwhelming by Division of Chemistry standards: over 700 institutions were involved. Colleagues in EHR provided assistance in the mechanics of evaluating the large number of proposals.

In evaluating the proposals, the NSF and peer reviewers were looking specifically at how the proposed URC would impact students, faculty mentors, and institutions. For students, reviewers were asked to consider the number and diversity of students impacted, as well as the kind of experience they would have. The effect on faculty was assessed in terms of their professional development. Institutional impact was determined by the program's ability to increase research capacity, develop infrastructure, and enhance research culture across the institution.

The long-term vision for the URC program involves creating national and international research communities linking all the REUs and URCs and individual Principal Investigators (PIs) who work with undergraduate researchers. A Cyber-Enabled Chemistry initiative aims to create an infrastructure that will allow any person in any part of the country to collaborate with anyone else. (This idea was further developed at a Cyber-Enabled Chemistry Workshop, which was held Oct. 3-5, 2004.) There is an REU Leadership Group, comprising some of the REU site PIs, that is also planning a national on-line poster session called "A Celebration of Undergraduate Research." A pilot project was conducted in the summer of 2004, and full-scale implementation will take place in 2005.

For the next URC program solicitation the tentative timeline is for the program announcement to be released in late 2004, with a submission deadline of late spring, 2005. Awards would be made in late summer, 2005.

Implementation of the First Year of the NSF-URC Program

Part Two: Rosemary Haggett (Director, Division of Undergraduate Education, National Science Foundation)

Dr. Haggett discussed some of the ways the URC program intersects with other programs run by the Directorate for Education and Human Resources (EHR). Because the URC program and other programs run by the EHR's Division of Undergraduate Education (DUE) grew out of a common mission, they are complementary in many ways. The alignment of program goals, for example, means that existing EHR/DUE programs offer rich opportunities for partnering and for leveraging resources to those developing URC proposals.

Dr. Haggett began by reviewing EHR's mission statement, emphasizing those goals most relevant to the URC program and the present workshop:

To achieve **excellence in U.S science, technology, engineering and mathematics (STEM) education at all levels and in all settings** (both formal and informal) in order to support the development of a **diverse and well-prepared workforce** of scientists, technicians, engineers, mathematicians and educators and a **well-informed citizenry** that have access to the ideas and tools of science and engineering.

Achieving the first goal, “excellence in U.S. science, technology, engineering and mathematics (STEM) education at all levels and in all settings,” she said, requires EHR to attract more Americans to STEM careers and to prepare the next generation of STEM professionals. As the origins of the URC program make manifest, this is a critical need—one that will necessitate retooling the STEM workforce and supporting the development of a new cohort. Existing efforts will help create a well-prepared workforce, but additional efforts are needed to broaden participation and achievement to create the diversity desired in the STEM workforce. Like the URC program, EHR also seeks to increase the scientific and technical literacy of all Americans. This confluence of the URC program's goals with EHR's mission creates a natural bridge between URCs and other EHR programs that could enhance the productivity of both.

Within the EHR Directorate, Dr. Haggett identified two divisions as being particularly germane to the URC program, the Division of Human Resource Development (HRD) and the Division of Undergraduate Education. HRD programs focus on increasing the presence of minorities, women and girls, and persons with disabilities in science and engineering. Their mission is to broaden participation. It therefore makes sense to look at the people and institutions that HRD supports as likely partners when developing URC proposals and programs. Dr. Haggett urged proposers to specifically target minority-serving programs and institutions, such as:

- Alliances for Graduate Education and the Professoriate Program (AGEP) (<http://www.ehr.nsf.gov/EHR/HRD/agep.asp>);
- Centers for Research Excellence in Science and Technology (CREST) (<http://www.ehr.nsf.gov/EHR/HRD/crest.asp>);
- Historically Black Colleges and Universities (HBCU-UP) (<http://www.ehr.nsf.gov/EHR/HRD/hbcu.asp>);

- The Louis Stokes Alliance for Minority Participation Program (LSAMP) (<http://www.ehr.nsf.gov/EHR/HRD/amp.asp>); and
- Tribal Colleges and Universities Program (TCUP) (<http://www.ehr.nsf.gov/EHR/HRD/tcup.asp>).

She also urged participants to look at programs and projects that are already funded and operating. Ongoing activities may offer natural bridges that could help found new partnerships and strengthen both programs.

DUE programs serve a broad audience. They aim to strengthen and ensure the vitality of undergraduate STEM education for a diverse constituency that includes: science, mathematics, and engineering majors; students in science and engineering technology programs; future teachers at the elementary and secondary school levels; and non-science majors seeking scientific and technical literacy. There are nine of these programs, two of which are notably pertinent to the URC program, the STEM Talent Expansion (STEP) program and the Course, Curriculum and Laboratory Improvement program (CCLI). The STEP program seeks to increase the number of students (U.S. citizens or permanent residents) receiving associate or baccalaureate degrees in established or emerging fields within science, technology, engineering, and mathematics (STEM). Because STEP projects are designed to attract students to STEM fields and to retain them, they should be a rich source of partnerships. An URC might also be eligible for STEP funding. Leveraging existing STEP-funded projects and taking advantage of STEP funding in an URC project might be a way to increase the success of both projects. (<http://www.ehr.nsf.gov/ehr/DUE/programs/step/>)

The Course, Curriculum and Laboratory Improvement program seeks to improve the quality of STEM education for all students, based on educational research and empirical data. It targets activities affecting learning environments, course content, curricula, and educational practices, with the goal of improving learning. The program has four tracks. The first (EMD) supports development of educational materials. The A&I track facilitates adapting and implementing existing educational materials, including laboratory expenses and support for instrumentation. Large-scale faculty development is enhanced through national dissemination of exemplary materials and practices (the ND track). New development, adaptation or dissemination of tools for assessing student achievement is handled by the ASA track. (https://www.ehr.nsf.gov/pirs_prs_web/search/) Dr. Haggett stressed that workshop attendees should capitalize on their participation in these ongoing projects when developing their URC proposals.

Finally, Dr. Haggett suggested that people looking for partners should check DUE's Project Information Resource System for up to date information on DUE projects and results. The URL is https://www.ehr.nsf.gov/pirs_prs_web/search/.

Perspectives on Proposal Design from the Division of Undergraduate Education:

- Because the goals of the URC program are aligned with EHR/DUE's mission, that mission significantly informs the fundamental criteria used to evaluate proposals.
 - ♦ A successful URC proposal will demonstrate the ability to impact a *large and diverse* population of undergraduates.

- ♦ The goal of increasing science literacy in the general population suggests that an ideal URC would affect *all* students at partnered institutions. This suggests a need for curricular reform.
- ♦ The goal of increasing the STEM workforce suggests that the URC program should have a strong, positive impact on students with an interest in STEM fields.
- ♦ A successful URC proposal ought to demonstrate an ability to involve a substantially increased percentage of students belonging to demographic groups currently underrepresented in the STEM fields, as well as students from certain categories of educational institutions, geographic locations, and students from underserved socio-economic groups.

Suggestions, Strategies and Solutions offered by the Division of Undergraduate Education:

- A number of EHR/DUE programs exist that are complementary to the URC program. These programs would be an excellent source of partnerships. Leverage these existing resources to flatten the learning curve, shrink implementation timetables and increase the financial viability of your proposal.
- Because the URC program overlaps so extensively with DUE goals, parts of an URC program might be eligible for DUE funding. Use existing programs (STEP and CCLI) to increase, diversify and distribute your financial foundations.
- Increase the diversity of the populations the URC impacts by creating partnerships with programs HRD supports: AGEP, CREST, HBCU-UP, LSAMP, and TCUP.

Implementation of the First Year of the NSF-URC Program

Part Three: Robert Kuczkowski (University of Michigan and Former Program Director, Division of Chemistry, National Science Foundation)

In the final segment of the NSF presentation, Dr. Kuczkowski reviewed the previous URC program announcement to create a foundation for discussion of the next URC program announcement. He began by examining the recommendations from last year's workshop. The primary motivation behind all of the suggestions that came out of that workshop was to increase the number and diversity of students who have a research experience. Participants at the last workshop sought to accomplish this through four general strategies: focusing on first- and second-year college students; insisting on multi-institutional participation, especially by institutions that do not usually offer significant research experiences to undergraduates; focusing on community and other 2-year colleges—the largest growing component of college education and the segment offering the most diverse population; and requiring curricular integration of research.

The final report of the initial URC workshop specifically recommended that full awards be made for five years at up to \$500K/year. That report also suggested that planning grants be offered, an idea that grew organically out of the workshop. It reflected workshop participants' recognition that potential URC proposers would have widely different degrees of readiness, and that planning awards could help groups to nucleate and develop ideas and to conduct pilot projects.

The program announcement (NSF 03-595) emphasized three key objectives endorsed at the workshop: broadening undergraduate research opportunities; expanding collaborations, and; enhancing capacity, infrastructure, and commitment leading to excellence in undergraduate education. The program announcement was deliberately vague in many respects: the intent was to encourage the community to respond as creatively as possible.

Dr. Kuczkowski then explained the URC review process. The NSF, he said, received about 150 letters of intent involving over 700 collaborators. The letters of intent enabled the Division of Chemistry to make an early start in planning the review process. The program announcement yielded 141 proposals: 53 for full grants, and 58 for planning grant proposals. (The disparity in number is due to the fact that 30 were linked-collaborative proposals that did not have to be reviewed separately.) The final grant applications represented some 600 collaborators. The NSF then divided the proposals into three panels and distributed both planning and full proposals evenly among them. The panels reviewed full proposals first and planning proposals second; they made recommendations for each category. This [map](#) shows the geographic distribution of planning grant applications and planning awards.

Dr. Kuczkowski observed that the planning grants were very broad and very different from one another. Some were aimed primarily at developing collaborations, others at developing curricular materials, and still others at holding workshops or establishing pilot projects. The twenty planning grants involved eighteen Research Intensive or Comprehensive Universities (12 PIs), fifty-four predominantly undergraduate institutions (PUIs) (7 PIs), thirty-one 2-yr Institutions (1

PI), fourteen minority-serving institutions (MSIs) (2 PIs), two international institutions, two national labs, five industrial labs, three research institutes and one high school. As a whole, the planning grant applications represented a very strong, diverse and attractive set of ideas for how URCs might be created and implemented.

One full URC award was made to CASPiE, a collaboration involving Purdue; Ball State; the University of Illinois, Chicago; Northeastern Illinois University and many community colleges. Dr. Kuczkowski emphasized that CASPiE is *one* example of what an URC can be. It is *not* a template but simply one possible model.

Winning proposals had a number of elements in common:

1. **They created new partnerships and models.** Dr. Kuczkowski suggested that participants be mindful of this requirement. Many applications were received from institutions that already had existing undergraduate research programs in place. They wanted to expand their existing programs—essentially expand their REU programs. In contrast, the URC program seeks projects that greatly expand the reach of undergraduate research to first- and second-year students, faculty and institutions who would likely not be involved through existing research models like the REU program. The goal is to excite these younger college students and to increase the number of majors and scientists, as well as to enhance science literacy for all participating students through their exposure to the process of creating new knowledge.
2. **They focused on real research.** Reviewers agreed that real research was characterized by two elements:
 - a. it looks at a problem to which the answer is not known, and it is a problem for which the answer, when known, should potentially be publishable (and of interest to the community); and
 - b. it should engage the student as a genuinely involved partner
3. **They reached out to students who would not normally have the chance to do research,** truly broadening research opportunities.
4. **There was partner equity.** Partners should share the work, resources, and responsibility in real ways.
5. **They were sustainable.** This was a hard problem, and the “bang for the buck” is relevant here. Working with a very small numbers of students is not feasible because it is so expensive that it will be hard to fund indefinitely.
6. **They had strong assessment models.** If we are going to have new models and new experiments, we are going to have to assess them. If the URC program is to develop into something that is more than an experiment, we have to assess it. We have to explain it to the national chemical sciences community and to give them solid evidence that it works.
7. **They expanded research capacity, infrastructure and excellence in undergraduate education.** This is the bonus category: we will all profit from these experiments.

Question and Answer Session:

In the question and answer period that followed the NSF presentation, a number of questions probed the boundaries of appropriate partnerships. Participants wanted to know, for example, if colleges and schools within one university could partner, if international partnerships were desirable, if partnerships might include high schools or even middle schools? Would it be

advantageous to have students migrate from this program to an REU or to interact with other programs that have seminars or other types of activities that promote research? The answer to all of these questions is yes. The program announcement was written to emphasize collaboration, but the mechanism was left open to the community to decide what they see as viable, interesting, creative models of collaboration. The primary objective is to reach out to large numbers of first- and second-year college students. It was noted that an effective URC is likely to interact with a number of other programs that are ongoing at the participating institutions and organizations.

One participant observed that the program announcement's emphasis on regular academic year programs could adversely affect students in rural areas. He wanted to know if it would be possible to have a summer program in an URC proposal. Dr. Kuczkowski indicated that summer research could be included in an URC proposal, along with academic year research, and he suggested that this point be discussed more fully in the breakout sessions.

A common set of questions concerned what kinds of schools and students the URC program targets. Dr. Kuczkowski explained that the NSF is targeting the first two years at any post-secondary institution in the US. It is still the exception rather than the rule that first- or second-year students would have the opportunity to engage in real research. Providing research opportunities for these students allows the research enterprise to draw from a much larger and more diverse talent pool. The objective is to give all students some idea of how knowledge is created in the chemical sciences. Some of them will be excited by research and some will not.

A participant stated that the key to creating a successful research experience in a community college was to catch students in high school and prepare them so that when they arrive at college, they will have done research already and seek new research opportunities, as opposed to looking for a job.

Questions were asked about the proposals that were not funded: Did the reviewers see any patterns or trends that would guide revisions of full proposals? Dr. Ellis responded, referencing the large size – nearly \$3M – of full-scale URC awards. For comparison, he noted that this amount of money would support twenty REU sites for three years each, or ten new assistant professors for three years each. Five such awards constitute a major investment. It is NSF's responsibility to perform due diligence, including arrangement of site visits. This process ensures that when such investments are made, there is a reasonable likelihood of success. He observed that there were many excellent ideas in the planning grant proposals and in the full proposals, but according to peer reviews and/or staff reviews, for one reason or another they were not ready for implementation. A key motivation for this workshop, in fact, is to clarify for the community the objectives of the URC program. Proposals in the next year's competition that receive enthusiastic peer reviews and staff reviews will be supported to the extent that funding permits.

Will the NSF expand the URC concept beyond chemistry research to include multidisciplinary research? Dr. Kuczkowski responded that because the present announcement comes from the Division of Chemistry, it specifies that projects should be in the chemical sciences or in interdisciplinary areas supported by the chemical sciences. The main requirement is that there be a strong chemical sciences component. Dr. Ellis added that the URC program is an experiment within the Mathematical and Physical Sciences Directorate, to which the Division of Chemistry

belongs. (The other divisions are Physics, Mathematical Sciences, Astronomy and Materials Research.) The participation of the Office of Multidisciplinary Activities illustrates the disciplinary breadth of this experiment, as the chemical sciences overlap, for example, with physics, chemical engineering, the life sciences, nanotechnology, and biotechnology. These connections were demonstrated in the proposals that were received in the first URC competition. If the URC program goes well, there may be interest in extending it to other NSF disciplinary divisions.

Another question was whether the Globe program would be considered a viable model for adaptation to higher education. It involves students from over 95 countries in real research that is conducted by collecting environmental data using relatively simple, but very strict and uniform protocols. It was noted by the participant that first- and second-year college students could do research at an even more sophisticated level, and if they adhered to strict protocols, the model could involve large numbers of students. Dr. Kuczkowski felt that this was a very interesting idea that could potentially serve as the basis for an URC pilot project.

Perspectives on Proposal Design from the Division of Chemistry:

- Widespread interest in undergraduate research within the NSF and across a broad spectrum of the scientific community means that the URC program is a high-profile experiment. Proposals are encouraged to “push the envelope” in a manner consistent with program objectives.
- Undergraduate research demonstrates how knowledge is created and how it is communicated. The URC program’s objectives of increasing the number and diversity of students exposed to chemical research and enhancing science literacy require that undergraduates engage in genuine research that is potentially publishable.
- Because the URC program seeks to impact dramatically larger numbers of students and a more diverse group of students, it is receptive to projects involving new models and partnerships beyond traditional one-on-one, mentor-student relationships.
- The Division of Chemistry has a long-term goal of linking URCs, REUs, and individual PIs working with undergraduate researchers to create a national and international community through the use of cyberinfrastructure. Undergraduate research will be an important element of the Division’s investments in cyber-enabled chemistry.

Suggestions for Proposal Design from the Division of Chemistry:

- Projects should have an academic year focus that facilitates participation by large, diverse groups of first- and second-year college students.
- Projects should provide new models and partnerships that are scalable and sustainable. Partnerships can include, for example, multiple academic institutions, industry, government laboratories, K-12 communities (administrators, teachers, and students), and international collaborators.
- Projects should involve real research that is potentially publishable and based on cutting-edge problems, tools, and methods, so that students can learn how knowledge is created in the chemical sciences.

Presentation of an URC: The Center for Authentic Science Practice in Education (CASPiE)

**Gabriela Weaver and Fred Lytle (Purdue University),
Dennis Lehman (Harold Washington College), and
Pratibha Varma-Nelson (Northeastern Illinois University)**

(CASPiE is a consortium of chemistry faculty from Purdue University, Ball State University, University of Illinois at Chicago, Northeastern Illinois University, Chicago State University, College of DuPage, Harold Washington College, Moraine Valley Community College, and Olive-Harvey College.)

Dr. Weaver introduced her talk by echoing Dr. Ellis' and Dr. Kuczkowski's statements that the CASPiE model is only *one* model for an URC, not *the* model. It is an experiment, one of many possibilities. It is being presented today to stimulate ideas and discussion.

Dr. Weaver described the CASPiE URC as organized around three main principles. 1) First- and second-year students will be immersed in an authentic research experience integrated into the mainstream curriculum. 2) The center will provide students access to advanced instrumentation by means of a network that enables remote access. 3) Students will work in a collaborative learning environment as similar as possible to the research group environment they would work in as professionals.

The center's administrative structure, Dr. Weaver explained, models this collaborative relationship: it comprises several equal partners bringing complementary talents and resources into common cause. Pratibha Varma-Nelson (Northeastern Illinois University) has been closely involved with a Peer-Led Team Learning (PLTL) project, a mature, well-tested model for student learning (funded by DUE), that has been running for approximately 10 years. She is responsible for integrating practices developed through that project into the CASPiE model. Donald Wink (University of Illinois, Chicago) will be using his expertise in community college and PUI faculty development to strengthen CASPiE's partnerships and ensure that the center facilitates the professional development of participating faculty. Dennis Lehman (Department Chair, Harold Washington College) will be the community college liaison. He will also ensure that the curriculum develops so that the pedagogy will be effective at all partner institutions. Dr. Weaver is responsible for curriculum development and program coordination. Fred Lytle (Purdue University) will be in charge of instrumentation. Working closely with him will be Debbie Steffen, the laboratory coordinator, who is returning to academe from working in industry. Bob Morris (Ball State University) is in charge of linkages to summer programs so that participants in the CASPiE program get connected with summer programs (and possibly REU programs) that will allow them to continue their research experience. Bill Robinson (Purdue University) is responsible for creating new student assessment models appropriate to a research-based curriculum. William Boone (Indiana University) is the external evaluator. A general coordinator will be hired to handle day-to-day operations and management issues. Dr. Weaver stressed that the diverse and complementary talents of the center's administrators help ensure the equality of the partners because each one has something unique and vital to contribute.

Dr. Weaver emphasized that CASPiE leadership wanted their center to provide as many students as possible the opportunity to fall in love with chemistry. This desire led to the first principle of their center: research would be an essential element of the curriculum. In their experience, the best way to engage students was through research, so they decided to develop research modules that would integrate into the regular curriculum. When research is a part of normal coursework, everyone taking the course has the chance carry out scientific research without having to do anything special—it is part of their course plan. They hope to involve 90-150 students (30/section) each year at Purdue. Another advantage of using modules that integrate research into the curriculum is that they are exportable. If the modules—and the curriculum that they fit into—satisfy the needs of diverse institutions, those modules and curriculum should be exportable to other institutions with similar needs. Curricular integration thus makes it easier to cross institutional borders. As the modules proliferate to other institutions, even more students will become engaged. Finally, integrating the research experience into an exportable curriculum eases a student's transition from a community college to a research institution and removes any question of whether credit will transfer.

Having settled on using research modules as their vehicle, the center faced the problem of defining research. The collaborators quickly rejected the traditional cookbook approach; for them, research meant being involved in the discovery of new knowledge. More importantly, it required that students be actively *involved* in that discovery. CASPiE operationalized active involvement by giving student ownership of ideas, involving them in asking the questions, and having them develop experimental procedures (at least in part, if not completely). Students are allowed to revise experiments until they are satisfied that the procedure is trustworthy and valid.

| Dr. Weaver explained that CASPiE also modified the way they teach data analysis, to put greater emphasis on analyzing its meaning, and asking what kinds of conclusions could be drawn from it. Being involved in real research also means that peer interactions are vital. Research scientists work collaboratively, contributing to, and supported by, a community. Involving students in research communities creates the need to communicate, so the final requirement of real research is that students disseminate their knowledge and results through presentations and publications.

The “Authentic Science Practice” in CASPiE’s name reflects a desire to capture these essential aspects of real research in their program. Each of the three core programmatic elements of the project contributes to this capture. Opportunity to be involved in the creation of new knowledge will come from the research modules that are being developed for the new course. CASPiE will give students access to advanced instrumentation through a network. Using old and outdated equipment inhibits the ability to practice real research, but you also can’t give each student physical access to expensive equipment. CASPiE’s network solves this problem by giving all students remote access to cutting edge equipment. The PLTL (Peer-Led Team Learning) Model creates a collaborative learning environment and integrates students into the scientific community. The model hinges on a cognitive apprenticeship approach: students are given some autonomy, but also some guidance. They are given the ability to make real contributions, but they are also steered and supported to maximize the chances of success.

| In the presentation, Dr. Weaver described the CASPiE’s courses as built around research modules which will be used in regular first-year chemistry as well as the first two semesters of

organic chemistry. They will grow out of faculty members' current research and will incorporate basic scientific concepts appropriate to the lab course. CASPiE will ensure their pedagogic relevance by mapping the modules onto a preexisting list of skills and concepts that they want to cover in a given semester. Modules will be developed by "research" faculty and "teaching" faculty working side by side. For research faculty, development of a module will fulfill their teaching obligation for a semester, so that creating research modules does not add to faculty workload. A professor whose primary responsibility is teaching will work with that researcher to develop the module. (Usually, the "teaching" professor will come from a community college or PUI, but not always.) The design is intended to benefit both faculty developers professionally. Because the module develops out of their own research, the researcher gets a way of expanding the scope of their inquiry. "Teaching" faculty are able to connect closely with a current research project and gain access to research-level instrumentation.

Because official module development was not scheduled to begin until after the workshop, Dr. Weaver had no real module to present. Instead, she showed a likely candidate to become a module—a collaboration of a physical chemist and an atmospheric chemist looking at snowflake growth. This kind of experiment would normally be done in a pure laboratory environment, but real snowflakes grow in a real atmosphere, which has real impurities, and different levels of water super-saturation. These affect how the snowflake grows in both shape and rate. The undergraduate research environment will allow a comprehensive search of this parameter space—not only temperature and super-saturation levels, but also impurity levels and types. The model is similar to the Globe project mentioned earlier: students can search a parameter space openly and decide what parts of that space they want to look at. The involvement of students will aid in the production of snowflake phase diagrams that help the researchers develop a molecular level understanding of how impurities affect crystal growth.

The experiment involves several fundamental chemistry concepts: kinetics, hydrogen bonding, acid ionization and atmospheric chemistry. These are concepts students would normally encounter in their second semester general chemistry lab. Other concepts that might creep into the module include unit cells, crystal phases and growth, and surface science. To cope with these more advanced concepts, students will need background information that they would not get in their regular curriculum. They will need, for example, to understand growth planes, crystal structures, snowflake types, and the instrumentation itself. Students can control a number of variables in the experiment: temperature, super-saturation level, impurity concentration and impurity type. They can collect data for calibration curves for water vapor concentration vs. temperature or vs. flow rate. They could also examine the growth of crystals remotely with a digital video camera—monitoring shape, rate of growth and size. (They can control flow remotely.) They can collect information on temperature during snowflake formation or monitor impurity type and concentration. The experiment offers many points of entry, many ways to become involved, and strong potential for creating new, publishable knowledge.

Dr. Weaver described a module development process that is designed to promote the partnerships that make up the Center. The development process includes voices from all institutions because all modules are designed to be used by all chemistry students at all of the Center's partner institutions. The instrumentation network is built around these modules as well and is designed for all partners to use. This will help make the modules more usable across the

diverse campuses in our network. It should also improve the chances of dissemination: CASPiE hopes to entice schools outside the original partnership who might be interested in using the instrumentation network to begin using the research modules as well.

The process of developing modules is also intended to enhance research capacity, Dr. Weaver continued. Because “teaching” faculty are intimately involved in module development, they become close to the research project and can continue it through the summer, through CASPiE classes, and through close collaborative relationships with research faculty. They become part of the research team. They also gain continued access to expensive instrumentation and equipment that they wouldn’t have access to otherwise. If developing modules increases research at PUIs, their undergraduates at those schools, whether involved in CASPiE courses or not, will have increased opportunities to do research with those faculty who are themselves now more involved in research—so it has a multiplier effect.

To create the collaborative working and learning environment so important to practicing Authentic Science, Dr. Weaver explained that CASPiE borrows innovative teaching and learning models already developed through other DUE projects and modifies them for its own purposes. The PLTL model was originally designed for use in lecture-based courses. CASPiE has extended it to serve as the basis for their lab course. Due to the large number of students involved, it is not possible to have a faculty member in the lab working with every pair of students. The PLTL model solves this problem by using peer leaders to facilitate group work. Peer leaders are students who are a year or two ahead of the students they work with. Each leader facilitates two teams of three students. They work with students in the lab as guides, and run workshops outside the lab to help create the research group environment. They are not involved in grading or curriculum development because involving peers in evaluation destroys the PLTL atmosphere. They tend to enjoy this experience very much, so in many of the PLTL models, financial support isn’t even needed, but CASPiE supports the peer tutors by paying them. The leaders benefit in other ways as well: their teaching experience deepens their own learning, and their lab work provides a pipeline to further research experiences.

Dr. Weaver clarified that the instrument network is also an adaptation of other similar projects. PNNL (Pacific Northwest National Laboratory) is a good example of a similar network, although CASPiE’s network is designed to handle a much larger number of samples. In CASPiE’s network, research quality instruments physically located at all the partner institutions will be linked virtually so that students will be able to access all instruments through one web interface.¹ The network will allow students to do calibrations, as well as operations, and it will be available 24/7 so they can run samples outside of class time and repeat them as often as they want. The server will store their data and provide access to archived data and sample data. It will also furnish instructional materials on how to carry out calibrations and do the data analysis. Because both the data and instruments can be accessed through the web, they can be used in the lecture hall as well.

¹ The tentative list of equipment includes gas chromatography (located at NEIU), liquid chromatography (PU), gas chromatography/mass spectrometry (PU), Fourier transform infrared spectroscopy (NEIU), ultraviolet/visible absorption spectroscopy (BSU), Raman spectroscopy (PU), and nuclear magnetic resonance (UIC).

In the presentation, Dr. Weaver described CASPiE's evaluation methods as driven by two questions. The first concerns exportability: What are the best ways to adapt and implement the CASPiE model at other institutions? Because CASPiE wants their model to be capable of being picked up by any institution who desires to do so, one set of evaluation criteria revolves around exportability. The second question—What is the structure of a research module that best achieves the goals of this project and can be utilized elsewhere?—addresses sustainability and scalability. CASPiE's focus on real research precludes developing a lab manual; indeed, it requires continual injections of fresh research ideas. How can one build a sustainable program, let alone an exportable one based on such a dynamic foundation? CASPiE hopes to use their early experience building research modules to develop a template for how a researcher might take their research ideas and apply them to a course. Rather than developing a canned course design, they are aiming to create an approach or process by which a researcher could easily apply their research problem to the classroom. They hope also to learn how best to teach fundamental concepts/skills while still doing authentic research.

Question and Answer Session:

A question was asked about the composition of the advisory board. Dr. Weaver replied that it is composed mostly of people from universities not involved in the partnership (although they could become partners later). It is being coordinated, however, by a man in Purdue's chemistry department because he is local and that makes coordination easy.

Someone asked a question about numbers—how many students would be involved? Dr. Weaver said that CASPiE is aiming to involve 150 students at Purdue, 30 each in one section of general chemistry and 2 of organic chemistry. If you add in the students at all the other sites, it comes to about 500. That number assumes that only one section in each course is a CASPiE section. They hope to go well beyond that number once everything is up to speed.

The sustainability of the CASPiE model was another question that was raised. Dr. Weaver explained that this was one of the most important and integral parts of their project. Even though this is a generous grant, they can't keep going back to NSF for instrument costs. Therefore, they will eventually have to support the instrument network through a subscription format. That format will be phased in over time. As new partners get involved in the project, they will bring new instruments, and they will help spread the costs of maintaining and replacing those instruments. CASPiE also thinks that because the lab curriculum relies on a template rather than a group of set experiments, new faculty will bring new research that can be matched up with the template and turned into new modules when they join the center. Finally, because it will be part of the regular curriculum, CASPiE doesn't have to worry about getting faculty buy-in to do extra work. When faculty teach this course, CASPiE hopes that they will see it as an opportunity to have 30 research assistants help them with their research.

Key Implications of Dr. Weaver's Presentation:

- The CASPiE program represents one successful solution to the program solicitation, among many possibilities. It is *not* a definitive model.
- The CASPiE program is based on turning professional research plans into research modules which are then integrated into the curricula of all partner institutions.
- CASPiE's model of student research:

- ♦ Genuinely involves students in real research that is potentially publishable and based on cutting-edge problems, tools, and methods by giving them ownership of ideas, engaging them in asking the questions, and allowing them to develop the experimental procedures (at least in part).
- ♦ Creates a collaborative research community that replicates professional working conditions as much as possible.
- Working together closely in designing the research experience can provide substantial professional benefits to both “teaching” and “research” faculty.
- Careful development of research modules can allow faculty to teach multiple concepts simultaneously—making it possible to cover all the content required by the present curriculum model.

Suggestions, Strategies and Solutions offered by Dr. Weaver:

- Integrate research experience into the mainstream curriculum (rather than thinking about it as something added to the curriculum).
 - ♦ Integration maximizes recruitment potential because it involves students in research as a matter of course.
 - ♦ Integration increases the diversity of the population being affected by reducing institutional discrimination.
 - ♦ Integration into the curricula of diverse institutions increases the exportability of the model.
- Use a network to allow students access to advanced instrumentation. This maximizes access to (and use of) expensive equipment,
 - ♦ provides students with access to research-quality instrumentation/data,
 - ♦ removes physical access limitations (and liabilities),
 - ♦ allows students to repeat experiments as often as they like,
 - ♦ makes equipment available 24/7, and
 - ♦ facilitates use in multiple classrooms simultaneously.
- Use existing projects and funding sources to maximize use of resources, flatten the learning curve, and minimize the time required to get the program started. (Example: leverage an existing peer-led tutoring project.)
- When designing the URC’s administrative structure,
 - ♦ make sure that each partner brings something unique that complements the contributions of others. Absence of duplication makes your administrative structure leaner and ensures that all partners remain equal because each one controls a resource needed for the overall success of the program.
 - ♦ put faculty development people on the core team. This program is about teaching and learning, so it can both be usefully informed by current pedagogical theories and practices, and contribute meaningfully to their advancement.
 - ♦ put someone who understands the curricular requirements of *all* the partner institutions in charge of curriculum development.
 - ♦ put someone on the core administrative team whose primary responsibility is communication and coordination. Hire someone else to be the operations manager—the one who deals with day-to-day details. Put someone *else* on the core team to handle outreach and connections with existing programs (e.g., summer programs, REU’s, etc.).

- ♦ have an expert on assessment on the core team. They can help with curricular and course-design problems and serve as the internal evaluator.
 - ♦ get your outside evaluator involved early in the process so that they understand what you are doing and why.
- Make your students' research experience as real as possible.
 - ♦ Involve them as fully as possible in the discovery of new knowledge: make sure that students have autonomy, guidance and the ability to contribute meaningfully.
 - ♦ Focus students' attention on understanding the data they have collected. Help them learn to analyze data in terms of what it means.
 - ♦ Create a collaborative learning community similar to a research group environment.
 - ♦ Emphasize the necessity of communicating research results through presentations and publications.
- Pair "teaching" faculty with "research" faculty to develop research programs.
- Allow "research" faculty to count development work as part of their teaching load, so that participation in the program doesn't add to their workload.
- Involving "teaching" faculty in research increases the number of faculty available to work with students on research beyond their first two years.
- Using peer tutors deepens the experience for everyone and enhances sustainability.
 - ♦ It multiplies greatly the number of leaders who can work with students in the labs.
 - ♦ It enhances the learning and research skills of the tutors.
 - ♦ It emphasizes the collaborativity of the lab environment.
- Modular design increases the exportability of the model.
- Use a subscription model to support the long-term financial requirements of the instrumentation network.

Dr. Weaver's Challenges to the Community's Creativity:

- Can one make a template that makes it relatively straightforward to turn real research plans into modules capable of being used in a lower-division chemistry classroom?
- Right now, plans call for running one section in each of the three basic chemistry classes as URC classes. What would be required to expand the program to include all sections in all classes?
- How can we guarantee the necessary influx of new ideas to continuously develop new research modules?
- To what extent can we really require new faculty to participate in this program? Is it fair? How will it affect recruitment? How will it affect the tenure process?

Implementation of Undergraduate Research Centers – Sustainability and Scalability

Jim Gentile (Dean for the Natural Sciences, Hope College)

Dr. Gentile structured his introduction around three key points that would resonate throughout his presentation: collaboration, revolutionary thinking, and the need to experiment. He opened by giving credit to those who had worked with him on this presentation, especially Jeanne Narum. All the better insights, he claimed, were hers. In the present context especially, it is good to seek input from others, and “others” can be interpreted broadly. Victor Hugo, for instance, is relevant here: “Nothing, not all the armies of the world, can stop an idea whose time has come.” Dr. Gentile is convinced that the URC’s time has come. But... we must also remember Abbie Hoffman, who said, “The first duty of a revolutionary is to get away with it.” And we all need to be revolutionaries to make this program work. You will need to be revolutionaries on your campuses, and Bob Kuczkowski, Art Ellis and the other program officers will need to be revolutionaries at the NSF. We must also remember that you cannot ask research scientists to take the lead on anything and not do experiments.

Dr. Gentile strongly stressed that this program *is an experiment*. Therefore we need to think about it as an experiment; you need to remember that it may not work. You need to plan for the possibility of failure, and you need to think about what you will need to triage along the way, as opposed to what you will need to sustain and scale up. This distinction is critical to planning because sustainability has to be built in from the start. You need a sustainable construction model *and* a sustainable development model and they have to go hand in hand and continually revolve around each other. Natural ecosystems are closed loops that change slowly; to be stable, your program must also develop through a slow-change evolutionary process. Thus, you have to plan for the long run. If your proposal has a clear plan that extends for five years, but doesn’t plot an equally clear direction after that, you are behind the curve already. Your plan needs to extend well beyond this. Drawing on both his biological and administrative expertise, Dr. Gentile observed that the only truly sustainable change is one that becomes part of your institutional DNA. Genetic toxicologists study mutable systems, and you might have to mutate your institutional DNA to make your URC work.

The next section of Dr. Gentile’s talk, Key Aspects of Sustainability of URCs, explored some of the various ways that institutional structures might be changed to facilitate the ongoing success of an URC. He began by applauding the CASPiE presentation. He admired the numerous ways sustainability had been built into the design, and said he now understood why it was a good investment as a first project. His exploration of sustainability included eleven pointed suggestions:

- **Design a project with clear goals relating to student learning through research.** The model, he said, needs to focus on student learning far more than on collecting new data—which is research. This is undergraduate education—so *learning* through research is what we are looking for. This is critical. Models of how undergraduate research plays a role in learning have to be part of your design from the beginning, because if you are going to infuse that design throughout the structure of your academic institution, learning is what it’s

all about—without learning models, you won't get anywhere. We, as a community, are going to have to promote the URC program as aiding student learning.

- **Design into the process points where you can step back, determine progress, change when appropriate, and move forward again (*formative evaluation*).** You need to be able to step back and assess your progress regularly because you need to know when it is appropriate to change directions and when to keep going. This is formative evaluation—it has to be built in, not thought of afterwards.
- **Secure ownership of *all* stakeholders.** All of the institutions in your partnership must be involved. Students have to know what they are getting into. Faculty have to know what they are getting into. Administrators have to know what they are signing off on. You all know that something that rains down upon you from above won't work; anything that is going to be sustained has to be built and grow from the ground up.
- **Infiltrate the successful, ongoing processes at each institution or organization. (*Be covert.*)** These processes will be different at all institutions. Don't create a new process—take advantage of processes that already exist and already work. For example, if your institution provides faculty summer funds, use those avenues to support incoming faculty. Take advantage of your new hiring process—make this experiment a priority when you bring new people on board. Make it a priority in the way you disseminate and distribute startup funding. Startup funding for research might provide a faculty member an incentive to become invested in your undergraduate research program.
- **Be clear with the leadership team as to both what goals must be achieved and what processes will be employed to achieve those goals.** Don't start with a divided team; you need to be together from day one. Developing this unity might be a good use for a planning grant.
- **Affirm the leadership effort. This affirmation should focus on the efforts of the leadership team and not on the efforts of any single individual(s).** When you focus on the work of an individual, you undermine collaboration right from the start. Administrators are in a good position to affirm the leadership effort.
- **Take time to play in the “sand box.” (*Non-threatening internal approaches to change can make things even better.*)** Allow experiments within experiments within experiments. (This from Jeanne Narum.)
- **Remember that projects that are people-specific are hard to sustain; projects that are site-specific can be sustained locally, but models may not be easily transferable.**
- **Always remember what problem you are trying to solve as you move forward on the effort.** Don't get sidetracked.
- **Keep all on-campus advancement and public relations officials informed and involved in the process – publicity and money always help.** If you are fired up, other people will get fired up too; but only if they know about it.
- **Remember the PKAL motto “Different pieces that fit.” It is unlikely that all partners will be the same, so the roles and contributions from each will be unique.** Take advantage of that uniqueness.

Dr. Gentile followed his discussion of sustainability with a series of related questions designed to jump-start the discussions in the breakout sessions.

- **How will you fund students who seek to continue in subsequent years?** A student who starts in their first year and stays on in the lab consumes more resources over their career than one who starts in their third or fourth year. Such a student also takes spots away from others who might come later. You *WILL* increase the numbers of continuing students involved in research. This will affect the students who choose not to get involved in basic research until their third or fourth year. What are you going to tell them when these students come to you looking for a research experience?
- **How will we compensate students? With money, with academic credit, both?**
- **How can undergraduate research be integrated into curriculum?** It *has* to be. CASPiE showed a good model.
- **How can you properly adjust faculty work loads during the academic year to give teaching credit for mentorship of young URC students?** Undergraduate research *is* education.
- **We must engage large cohort of faculty. So how are faculty rewarded for their participation?** Volunteerism won't work in the long run.
- **We must find opportunities for students of diverse pre-college background that are meaningful.** Traditional research programs work because the kids have been shaped through a common pool of knowledge. Now we'll be working with unshaped students early in their career and doing the shaping on the fly—that's a different process.
- **To change the scientific human infrastructure of the future, we must find ways to bring students of diverse ethnicities and a good gender balance into the program.** When this happens, we won't just be teaching ourselves anymore.

Before turning to the issue of scalability, Dr. Gentile provided examples of successful, sustainable programs that might serve as models for URCs: The Pew Midstates Science and Mathematics Consortium and the Keck Geology Consortium. The Pew Consortium is a stable, sustainable model that consists of one research university and several liberal arts colleges. The goals of the program are common: effective collaboration among faculty, improving undergraduate science and math education and research, assisting research efforts of the faculty at the undergraduate colleges and assisting the undergraduate students at all member institutions. The consortium began in 1989 with an award from the Pew Foundation of about \$750K and a follow-up award of about \$500K (also from Pew). It is sustained through the commitment of member institutions, who contribute about \$10K annually to support programs and the consortium's office. New institutions have been added over the years and all partners are equal in management and decision-making processes. The gene has been mutated; administrators now sign off on this program without even thinking about it. Dr. Gentile then wondered if an institution like this with a firm infrastructure could now ask the question, "Could we now leverage our existing connection of committed institutions to get involved in an URC?" It seemed to him that existing connections and memberships make an exceptional foundation for an URC to develop on.

The Keck Geology Consortium also began with a grant (from the Keck Foundation), but is now continued through commitments from the colleges and universities involved. The past two rounds of grant opportunities offered by the Howard Hughes Foundation—including those involving comprehensive and liberal arts schools as well as research universities—require collaboration. One current NIH initiative, the Embree Initiative in Maine, also requires consortial

connections. Increasingly, these initiatives involve research institutions and smaller colleges. Your school may be participating in some of them already. How can you take advantage of them?

The last segment of Dr. Gentile's talk concerned scalability. Here too, he built his presentation around a list of design imperatives.

- **Keep the goals of the URC firmly in mind when presented with the opportunity to scale up the program.**
- **Practice appetite control when envisioning scalability. (Don't try to eat everything at the buffet).** Think about this—what is the most meaningful thing about that last bite of food you eat?
- **Scaling up will enhance your program as well as enhance the programs of other groups.** Understand that you are being a model when you scale up—a model within your institution and a model for other institutions.
- **Build logical adaptability into the process but always have a single story that can be told.** Speak with a single voice.
- **Develop your effort from the beginning as a model that can be adapted by other institutions or departments.** Do this intentionally because as other URCs grow, so does the scale of the overall national effect.
- **Re-envision your advisory board...who else can facilitate your efforts?**
- **Remember that science is becoming every more interdisciplinary in research and factor that into new directions for your URC.**
- **Connect with ongoing national efforts (PKAL, CUR, NCUR, NSDL, disciplinary societies, NAS/NRC, etc): partner whenever and wherever you can.** For example, National Research Council is partnering with the Howard Hughes Institute to provide summer institutes to train R1 faculty to bring research-like opportunities into year-one courses. The first summer institute just happened. This is a perfect foundation for what an URC might take advantage of. Ask how you can partner, how you can get involved.
- **Always remember that faculty buy-in is the coin of the realm.**
- **Become advocates....pass the 7/11 test.** That means that when you walk into the local 7/11 (think of that as funder) everyone knows about your work, how effective it has been and continues to be, and how wonderful you are. Humility gets you nowhere. But you have to have something to be non-humble about. You have to have some product. (This from Jeanne Narum again.)
- **Think about assessment every step of the way.** It must be woven into the fabric of your URC.

To conclude, Dr. Gentile offered a few words from Will Rogers: “To succeed, you must know what you are doing, you must like what you are doing, and you must believe in what you are doing.” Always remember, he added, who you are doing it for—it's these kids that are working in our labs.

Question and Answer Session:

A participant pointed out that the model proffered seems to be predicated upon paying students for their mentoring work. He wondered how sustainable that model was. Dr. Gentile pointed out

that this would be a good topic for discussion during the breakout groups. He added that the academic year-focus of the URC program might encourage programs to offer students academic credit rather than money. He also wanted to explore other ways of weaving in credit, perhaps outside of the “natural” course sequence. There might be other ways of paying the students—using different models. The primary point is that students need to get something out of it besides the education if it is going to be sustainable.

Someone wanted to know more about the assessment project in which Dr. Gentile is involved. Dr. Gentile replied that he was working on an assessment model published by Elaine Seymour in which she looked at the learning experience that comes out of undergraduate research. It turns out that this learning experience is not quite the experience that everyone assumes it to be. David Lopatto at Grinnell College developed a questionnaire and assessment tool that complements what Elaine Seymour did when she interviewed 186 undergraduates over three years. Dr. Lopatto’s tool performs the same way Dr. Seymour’s did, so we can apply that tool to research modules being used in classes to see if that same kind of experience is occurring. This would then confirm one approach that one could take with an URC.

Another participant asked if Dr. Gentile could expand on his remarks about scalability, noting that the Pew Consortium asks each institution to contribute \$10,000 per year. That’s not a lot of money if you have to replace huge instruments down the line. Dr. Gentile responded that the \$10,000 is just the buy-in; it only covers administrative overhead, etc. But, he noted, getting that money up front was important because it meant that an institutional commitment was made. If the institution is willing to kick this money into a pot to be part of the project, then the institution will be willing to put the other items needed by the consortium into other regular budget lines. Different institutions buy in at different levels, depending on what kinds of projects they want to support and how they want to support them.

One participant was concerned about the emphasis on diversity, because his school doesn’t have much of it. Since enhancing diversity is an important goal of the URC program, is an institution lacking diversity at a disadvantage? Dr. Gentile replied that diversity is a diverse word. It includes, for example, economic diversity. He also observed that one can also partner outside of a region to get around this issue. More importantly, intentionality is really the key to this issue. Tom Cole, past president of Clark-Atlanta University, once said, “The biggest thing you have to think about with diversity is N plus one.” Whatever you did last year, this year do one better. Pretty soon, you have built a movement. He also suggested thinking about native peoples that could be brought in. Look at connecting with SACNAS (The Society for the Advancement of Chicanos and Native Americans in Science) and see what arrangements could be made there. Michael Doyle pointed to some other studies that confirmed the contributions of research to undergraduate education: one by the University of Delaware and one by the Reinvention Center. He suggested that these are both ways of being connected in a diverse sense.

Another participant said that Dr. Gentile had spoken eloquently about the need to build sustainability in from the very beginning, coupled with this desire to scale up. He pointed out that all of the examples given were institutions that had very similar cultures: they were all highly-ranked research universities. He wanted to know more about the challenges of bringing together consortia of very different types of schools with very different cultures serving very

different types of students, because that will be an important challenge for all URCs. Dr. Gentile agreed that this is a serious problem, but he did not apologize for his choice of examples, because those are the examples that are out there now. It will be up to the people in the room to go out and create new and better ones. He concurred that the culture problem will be real, so we're going to have to get to know one another very, very well to be able to make viable collaborations so that we can take advantage of the strengths that arise from our differences. There are, for example, consortia that work with the K-12 communities, and connect them to networks of 2-year colleges. Chris Chaney's work at Occidental College is an excellent example of this approach. But it takes a significantly larger effort to do that and make it work. That is going to be part of the genius of the way these URCs are put together: how does one take advantage of the talents and the strengths of the diversity of institutions?

A participant saw the merit in this kind of sustainability, but also a problem. If we are collectively successful in increasing the opportunities for first and second year undergraduates, how will we handle the increased numbers? How will we be able to take advantage of their heightened interest as they move into their third and fourth years? Dr. Gentile suggested that one solution might lie in the kind of networking with REU sites that Dr. Ellis showed earlier, but he agreed that this is going to be a real problem. He provided an example from his own school, where they run a small summer research program for about 120-130 kids in the sciences. It costs about \$500,000 just for student salaries and some ancillaries. If the number of these students increases by just 40 students, you can do the math to see where the cost is going to go. Success is going to require a serious institutional commitment to undergraduate research because it will require major internal resources and program officers from your development office to go out looking for sustainable funds to support it. Most importantly, it's going to demand that you as faculty are willing not to take a summer or two or three off from working with undergraduates because they tire you out. If faculty start pulling away, the research slots disappear and you're telling the kids that we're really not interested in you after all.

Key Implications of Dr. Gentile's Presentation:

- A broad collaboration enhances both sustainability and scalability.
- Sustainability has to be built in from the start. Both construction and development models have to be sustainable and they have to reinforce each other. Natural ecosystems suggest that stability requires a slow-change model.
- Sustainability depends on institutionalization.
 - ♦ Undergraduate research *must* be integrated into the curriculum.
 - ♦ You need a plan for mutating institutional structures at all partnering institutions to control how the URC gets integrated into the institution.
- Sustainable collaborations focus on the team; when one person, institution, or site becomes special the team concept is undermined.
- Scalability requires staying focused on specific goals. Allowing project creep will doom scalability because it multiplies goals and increases tension among them. Control your appetite.
- Scalability is enhanced by thinking about your program as a model.
 - ♦ Your students will become role models for other students.
 - ♦ Your faculty will become role models for other faculty.
 - ♦ Your institution will become a model for other institutions.

- ♦ Your URC will become a model for other URCs.
- ♦ The entire URC program may become a model for other NSF programs.
- ♦ If you plan your program as a model from the start, it will be scalable.

Suggestions, Strategies and Solutions offered by Dr. Gentile:

- Sustainability requires long-term planning. Proposals should have clear plans extending well beyond the five years they will be funded by the URC program.
- The URC program functions within the context of undergraduate education; sustainability therefore requires that the fundamental goals of an URC be framed in terms of clear learning outcomes.
 - ♦ An URC should focus on improving learning first, research second.
 - ♦ This emphasis on learning is the key to initiating, sustaining and controlling institutional change because the primary function of participating institutions is education.
 - ♦ Marketing your program both within and outside your institution is going to have to be in terms of promoting student learning.
- Building formative evaluation into your design from the beginning allows you to adapt quickly and in a principled, guided way to what you discover along the way. It enhances sustainability, because it allows you to understand what is happening as it happens, and to adjust your practices continuously to keep them in line with your overall goals.
- For a program of this magnitude to be successful, it has to grow from the ground up; it cannot be imposed from above. This means all stakeholders have to know what they are doing and why all along.
 - ♦ Use planning grants to create a unified leadership team that agrees on goals and processes by which those goals will be reached.
 - ♦ Get public relations and campus advancement people involved. They can help sustain your efforts through publicity and money. Enthusiasm is infectious.
- To be sustainable, an URC has to be built into the institution, and connected with everything else around it.
 - ♦ Infiltrate—build it into existing structures (funding and hiring practices).
 - ♦ Leverage local institutional processes that already work.
 - ♦ Capitalize on existing consortia and interdisciplinary connections.
 - ♦ Connect with ongoing national efforts: NCUR, NSDL, NAS/NRC, etc.
- To last, the URC has to become financially independent.
 - ♦ One way existing consortia maintain financial independence is to require each member institution to make a buy-in contribution that covers administrative and other overhead costs. Beyond that initial buy-in different institutions buy in at different levels, depending on what kinds of projects they want to support and how they want to support them.
 - ♦ Don't allow student mentoring to become a long-term cost. Find a better way: give them academic credit, make it a part of the curriculum.
- Sustainability depends on maintaining good relationships among the partners.
 - ♦ Find a way to make all partners equal in the decision-making process.
 - ♦ Uniqueness of each partner means that they have something to contribute that no one else has.

- Re-envision your advisory board regularly—always be thinking about who can help the program move forward.

Dr. Gentile’s Challenges to the Creativity of the Community:

- To be sustainable over the long term, undergraduate research has to be integrated into the curriculum and into the institution. How do we do that?
- Integrating undergraduate research into curricula and institutions require us to enlarge the cohort of faculty involved.
 - ♦ How do we interest faculty—especially new faculty seeking tenure—in this program? How do we reward participants?
 - ♦ How can we properly adjust faculty work loads during the academic year to give teaching credit for faculty mentorship of young undergraduate research students?
- The URC program is going to substantially increase the numbers of students involved in research, requiring us to create new systems to ensure continuity for them.
 - ♦ When students get involved in research earlier in their academic careers, they have to be supported over a longer period of time. This is expensive.
 - ♦ The increased number of students involved puts pressure on other scarce resources as well—lab space, instruments, faculty time, etc.
 - ♦ We will need to find ways to both expand resources and reduce the amount of resources expended per student.
- Involving students in research in their first and second years means that we will be working with students who have had negligible exposure to science. How do we shape the common knowledge required to perform real research on the fly to create meaningful research opportunities for such students?
- How do we integrate students from different cultures, who don’t share our values and assumptions about science, goals, careers, etc. into scientific research?
- The URC program aims to create consortia of specifically heterogeneous institutions. We will need to create new models of collaboration not based on assumptions of essential similarities. Equally importantly, we need new models for collaboration that teach us how to take full advantage of real diversity.

Assessment and Evaluation

Diane Bunce (Catholic University of America)

To leave more time for questions and discussion at the end of her talk, Dr. Bunce began with her last two slides, references and conclusions. She singled out two references as being particularly useful, the 2002 User-Friendly Handbook for Project Evaluation (the green book) and the User-Friendly Handbook for Mixed Methods Evaluations (the blue book), both published by the NSF. She recommended beginning with the green book, especially for people new to evaluation. It is user-friendly, easy to read, and it provides a helpful overview of project evaluation that systematizes the most useful information. After reviewing various kinds of evaluation strategies (quantitative, qualitative and mixed designs), it recommends mixed designs. Mixed designs are the focus of the blue book—the one most people will use. Its worksheets will guide even a novice through designing and implementing a solid assessment plan from scratch.

Dr. Bunce then previewed her conclusions. First, evaluation depends on project goals because they are the criteria by which you measure effectiveness. A clear vision of those goals is therefore prerequisite to developing an assessment plan. Each project goal should have a clear evaluation step that gauges how well that goal is realized. Because goals are defined relative to the project's stakeholders, the assessment plan should be designed around the needs of the audience; in particular, it must take into account what counts as evidence of success for each group of stakeholders. To meet the needs of the stakeholders, you will need to conduct both formative and summative evaluation.

Second, Dr. Bunce recommended making one of the PIs the evaluator, rather than bringing in an outside evaluator. An inside evaluator understands the value of the project, can interact with the project along the way, and can adapt the evaluation plan to changes to the project. An inside evaluator can also identify components of the project that will and will not inform the formative and summative components of your evaluation plan. Perhaps most important, having an inside evaluator helps prevent an adversarial relationship develop between the project and its evaluation.

Third, the evaluation methodology must match the evaluation questions. Certain methods are appropriate for answering certain kinds of questions and not others, so methods and questions have to be tied together and integrated. Qualitative methods should inform quantitative methods, and vice-versa. Therefore, both are necessary; use of multiple methods also validates choice of methods by triangulation.

Finally, the results of evaluation should inform stakeholders and lead to action. Effective evaluation should provide guidance about what to do next and furnish evidence compelling to stakeholders that this course of action is warranted.

Having presented her conclusions, Dr. Bunce turned to the beginning of her presentation. Project evaluation is the systematic investigation of the worth of the project. It is an attempt to articulate what the project is meant to accomplish, how the goals are being met, and how effectively the

individual pieces of the project are working. If one of the pieces is not working well, it isn't necessary. Evaluation furnishes the argument to justify eliminating the non-functional element based on data.

Project evaluation provides information that keeps stakeholders involved in the project. Evaluation must therefore be ongoing (formative) as well as summative. Stakeholders for an URC will be various: the NSF, administrators, department chairs, and students involved in project. They might include the faculty who elected not to participate in your project; they could be the students who opted not to go into the special program. They could be parents of students, they could be alumni. Figure out who the stakeholders are and work with them. Project evaluation provides the data that is the foundation of this communication.

Accordingly, evaluation has to be integral with your project. If it is going to provide information that will help improve the project, it needs to be woven through the fabric of the project. That means not only that the evaluation plan must be fully fleshed out in the proposal, but that it must be integrated into all the steps of the project. It has to address each goal of the project.

Evaluation does not have to be adversarial. Dr. Bunce said that in her experience evaluators on big projects are often too far removed from the culture of the researchers. This distance may cause them to misunderstand the value of what the researchers are trying to accomplish. The resulting evaluation is therefore useless—to the funders and to the researchers. It is therefore a good idea to have an evaluator who is part of the native culture, one who understands the purposes of the project and the culture the project operates within. Evaluation should not be antagonistic: it is supposed to help the team improve the project, help them understand it better.

Fund your evaluation at a level appropriate to what needs to be accomplished; the NSF recommends about 10-20% of total budget. Dr. Bunce recommended against spending all the money to pay an evaluator to write a final report. Some of the money might be best used for that purpose, but some of it should be spent on making the evaluation effective. It could be used, for example, to pay students for hour-long interviews. It could pay for getting evaluators out to the other sites. It could mean many different things.

There are two stages to evaluation: formative and summative. Formative evaluation happens in process. It provides the opportunity to measure progress and suggest modifications during the project. It has two components: implementation and progress evaluation. Implementation questions are designed to demonstrate that the project is being conducted as planned or offer evidence that you should be changing your plan midstream. Questions about implementation arise out of the novel idea that decisions about changes should be based on data! Progress evaluation measures the usefulness of the project components at each relevant stage. If a component does not advance the project, progress evaluations provide evidence for changing or eliminating it. Summative evaluation assesses the quality and impact of the project at its completion. This is the element that most people concentrate on when they talk about evaluation, but it is only one part of the evaluation plan. As a general rule, it should take up only 30% of the evaluator's time, because your evaluator should be part of the team effort. Most of their time will already have been spent on assessment plan design, and various formative evaluations. The assessment plan should include both: leaving out formative evaluation is like telling a student,

I'm not going to tell you anything about your performance all semester, but at the end of the term, I'll give you a grade. Leaving out summative evaluation, is like giving them a quiz every day, but refusing to give them a grade for the course. You need both.

Project goals are shaped by those who have an interest in the outcome. Evaluation is therefore also shaped by those stakeholders. The list of stakeholders relevant to a project is often longer than most people realize.

- The funding agency is obviously going to judge the success of your individual project. They may also have to judge the overall impact of your project on the broader goals of their program. This is clearly evident in this case—because each project is a model and an experiment. The whole program may be pushed ahead or scaled back based on the outcomes of your projects. Your goals are very important to the sponsors of your project, far beyond the limits of your project.
- The administrators of your own institution. If they do not have buy-in, are not part of it, do not understand where you are going, and do not have evidence to understand your successes, they are not going to be willing to make changes in staffing, scheduling or the facilities of the institution. You must therefore have data that speaks effectively to administrators.
- Your faculty. If your faculty are not willing to buy in, the project dies on the vine. Your evaluation data must therefore be compelling enough to change the way they teach and the curricular materials they choose. It has to work not only for the faculty in your project, but the ones who work with them. If you do not convince them, sustainability, will not happen; neither will scalability.
- Students. This project is for and about them. Therefore we have to collect evaluation data from them: Does the data challenge or support their academic or career choice? Did they come in apathetic and are they now on fire for chemistry? Are they on fire enough to change their career plans? Are more students now attracted to STEM majors? We also have to convince them that this is worth doing; if we do not, none of the rest of it matters.
- Professional peers. To make this project work on a national level, we have to present enough data to convince someone sitting in the audience that they would like to be involved in it. PLTL was a good example of that. It set the world on fire. When people heard about it, they wanted to get involved. Maybe they were not ready to start today, but it immediately changed the way they were thinking. That's what you want your project to do—generate that kind of enthusiasm.

What counts as evidence, as proof, will differ from one of these audiences to the next. These differences must be taken into account in the design of the evaluation.

The evaluation design should also match evaluation methodology to evaluation questions. Qualitative methods are useful for understanding what, how or why something occurs. They are

appropriate when variables are unknown, complex, interwoven or difficult to measure. They involve the researcher as a tool of the investigation, since the purpose of qualitative research is to interpret the reality of the situation—to find out what is actually happening. They result in the formation of a hypothesis. Quantitative methods answer the question, “Does what occurs make a difference?” They pertain when variables can be identified and relationships measured. They begin with a hypothesis and manipulate formal tools like surveys or achievement tests to test that hypothesis. Quantitative methods are concerned with generalizability because they aim at prediction.

Qualitative research ends with formation of a hypothesis; quantitative begins with one. Quantitative research results in a prediction; qualitative research is needed to understand what that prediction means. This circularity suggests that qualitative and quantitative approaches are complementary and that both are necessary for comprehensive evaluation. This brings us to mixed methods. The advantage of using mixed methods is triangulation. The validity of a claim is strengthened by using more than one method to investigate a question. If you had a \$1,000,000 grant to get an accurate weight of a sample from Mars, would you take one measurement on one balance? No, you would take multiple measurements on multiple instruments to see whether they give you consistent data. Why would you do it any differently with evaluation? This may come as a shock to many bench chemists, but chemical education research follows the same rules of engagement as scientific research.

Question and Answer Session:

One question concerned the relationship between assessment and the URC’s target audience. Since the URC aims to involve large number of students in their first and second year, it is likely that large numbers of them will not choose STEM majors or careers, but they may nevertheless get something useful out of it. How do we assess them and do we even care about them? Dr. Bunce affirmed that we do care about them. The percentage of them who go into STEM careers is a goal (although not the only goal), so it should be measured. Perhaps only 5% will go into STEM careers. Another goal of the URC program is to increase the scientific literacy of the citizenry; anyone who is going to be voting in a democracy is going to be voting on science-related issues. They should be able to discern whether the data being put out on both sides of these debates follows the rules for good data. You assess progress toward this goal by interviewing program participants, by surveying them, by looking to see how they used what they learned from this in their daily lives.

Another person wanted to know what the NSF thought about using evaluators as co-PIs. He had the impression that the NSF frowned on that practice. Dr. Ellis replied that the NSF has tried to be as non-prescriptive as possible. He added that he knew from personal experience how valuable it can be to have an evaluator as one of the PIs on the team, and that that model could certainly fit within the URC concept. At the same time, he noted that there is nothing to preclude someone from using an outside evaluator if that is what they want to do. Dr. Bunce observed that it was also possible to have two evaluators, using an outside evaluator to validate what the internal evaluator is doing. Having both an internal and external evaluator eliminates the question of bias and the need to have what the internal evaluator says validated. The internal evaluator is generally able to provide a lot more information on the formative side of the evaluation process than an outside evaluator could. It would even be possible to divide the

evaluation: have the internal PI work on the formative evaluation, then have them collaborate with (or perhaps stay away from) an external evaluator who would handle the summative evaluation. Such arrangements are especially attractive in view of the prevailing practice of using professional evaluators on these kinds of large NSF projects. Those evaluators often don't speak the same language as chemists, so it is difficult to get the right combination of insight, culture and objectivity necessary for a really useful evaluation.

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Key Implications of Dr. Bunce's Presentation:

- Since the URC project is an experiment, assessment and evaluation play a larger role in determining the acceptability of proposals than they do in more mainstream programs. They provide the NSF with information that helps them determine which parts of the program are working, which ones need tuning, and which ones should be abandoned. They will substantially shape if and how the URC program is exported to other disciplines as well.
- Evaluation is always relative to audience/stakeholders and overall program goals.
- Evaluation should lead to action—it should show you what needs to be done next. It also justifies that course of action (including the need for a follow-up grant).

Dr. Bunce's Suggestions, Strategies and Solutions:

- Effective evaluation includes project goals as criteria against which to measure progress. Every goal enumerated in the proposal should have a specific evaluation step associated with it.
- Adapt your evaluation methods and the language you use to describe them to the needs of the audiences you need to convince. You will need to identify *all* of your stakeholders and determine what counts as evidence for each of them so that you can set up your evaluation in ways that will be compelling to them.
- A comprehensive evaluation plan includes both formative and summative evaluations.

- ♦ Use formative methods to measure progress and suggest modifications while the project is underway. They provide evidence to support decisions about whether you should be changing your plan midstream or not. Communicate data collected in progress and the decisions based on it to your stakeholders.
 - ♦ Use summative methods to evaluate your results.
 - ♦ Spend 70% of your time and evaluation budget on formative evaluation and only 30% on summative.
- Include both qualitative and quantitative evaluation methods to create a thorough and reliable evaluation plan.
 - ♦ Use the Green and Blue books from NSF to help shape your evaluation plans and practices.
 - ♦ Qualitative methods explore what is happening, how it is happening or why it is happening.
 - ♦ Use quantitative methods to find out if what you are doing is making a difference.
 - ♦ Mixed methods help you answer both kinds of questions (Blue book).
 - ♦ Use multiple evaluation techniques to triangulate your results so that you know they are reliable.
- Don't allow evaluation to become an adversarial process. To that end, you should carefully consider whether you want to use an outside evaluator. It is possible to make the evaluator part of your team. Because they are part of the culture of the project, they can understand project goals in ways that external evaluators usually cannot. Internal evaluators are also in a much better position to conduct formative evaluation than external evaluators. Another possibility is to have two evaluators—an internal and an external. If the evaluation plan is well-designed, their work will be complementary and increase the validity of your results.
- Dedicate 10-20% of your budget to evaluation. Rather than spend it all on a final report, be creative with it—multiple approaches will diversify the perspectives from which you are evaluating the project, thereby providing you with more rounded and useful information about what is working, what isn't, and why.

Breakout Session One

Many of the issues that emerged during the first breakout sessions revolved around the core of the URC program. The most common concerns directly engaged the primary purposes of the URC: recruiting students into STEM professions and increasing science literacy in the general population. In connection with this question, many wondered about the true target audience for the URC program. Most groups also debated the necessity of involving large numbers of students, the nature of real research, the need for curricular integration, the significance of cultural and institutional change, and how to manage faculty recruitment. Other significant topics included student recruitment, assessment, and financial sustainability. A few people also raised important questions about program operations. This session focused heavily on questions of definition and the scope of the program. There were a number of requests for greater specificity in the next program announcement.

Goals of the URC Program:

In all but a couple of breakout sessions, participants raised the question of whether the primary goal of the URC program was to increase the number of students on the path to STEM professions or to increase science literacy for all students. Many people saw tension between these goals, noting that they seemed to entail different target populations, require different procedures, and suggest different emphases. If the primary goal is to increase the number of students in the STEM pipeline, then it makes the most sense to target the best students (among those who have not yet decided to pursue a STEM career path) and devote the most resources to attracting and retaining them. (Some saw tension here too, wondering whether more emphasis should be put on attracting new students or on retaining those we already have.) CASPiE seems to be following this model in that only one of thirty-two sections will actually be doing research and the only the best students get chosen to participate. To some, this model doesn't seem that much different from business as usual; after all, many faculty already take their best undergraduates to work in their labs. They argued that this aspect of the program is not that new (in fact, it seems a lot like the old REU model of skimming the cream off the top), and it doesn't seem likely to solve the problem. Moreover, these are the students the most likely to go into STEM fields, so this approach doesn't really attract a significant new population into research careers. And if recruitment into the profession is the main goal, what about the rest of the students? How do we assure that a broader range of students gets addressed by this program?

On the other hand, if the principal goal is to increase general science literacy for all students, then the primary audience should be those who are not the best students—those who are perhaps least interested in science. In this case, the most resources should be devoted to students and sections least likely to be successful within the traditional teaching model. However, many felt that authentic research was not necessary in this scenario. Others suggested that even for non-science majors the best way to increase literacy was to integrate research into the curriculum so that all students would be exposed to the same things. Still others thought that the best way to educate non-science students was to design a whole new course for them. Some even suggested that it might make sense to extend the program into courses not designed for science majors. Along similar lines, one group wanted to know how this program might apply to people in the colleges of education who are teaching the next generation of science teachers. Nearly

everywhere this question arose, people related it to the need to prioritize resources. They wanted the NSF to prioritize the goals of the program so that they could allocate resources to facilitate outcomes that would match those priorities.

The issue of size—of the number of students that should (or must) be involved—was also discussed in nearly every session. Several people wanted to know if the NSF had a minimum range of numbers in mind. Many questioned whether it was really desirable to involve everybody. Does it even make sense to talk about involving a thousand students or more, or would it be wiser (and allowable) to concentrate on a subset of 50-100 students at the beginning? Several people worried that there is not enough money or even physical space to accommodate a thousand students. Some groups explicitly recognized the value of emphasizing the need to impact large numbers of students, but at the same time wanted to encourage flexibility in the consideration of models which might not be easily transferable among institutions and situations. They observed that those institutions most in need of this type of program may be the least able to make it work for large numbers of students. They proposed that there be different budgets for different kinds of programs. They advocated smaller budgets for smaller programs that would reach fewer students. A number of people also mentioned that the emphasis on size seemed likely to work against the long-term success of the URC program. If large numbers of people become interested in research, what is going to happen to these students when they want to continue in their third and fourth years? It is already difficult to find enough research opportunities for juniors and seniors, and the REUs are overtaxed. Won't we be turning students off when we can't find space for them? Is the NSF willing to fund programs to accommodate all of these people? A number of groups noted that the apparent lack of opportunities at the third and fourth year levels would adversely affect both sustainability and scalability.

The Definition of Research:

Nearly all breakout groups engaged the definition of real research. Many groups asked in so many words, "What does authentic research mean?" Does that mean it has to be publishable? What kinds of publication would count? How appropriate is it to have general chemistry students conducting publishable research? Is that really what NSF is looking for? NSF needs to clarify this. Here again, some people noted tension in the program requirements. According to their understanding, real research is chaotic, spontaneous, inspirational; it cannot be organized and systematized. If it is, it is no longer real research, yet this program asks for organized structures and programs. Other groups wanted to know if the NSF would allow alternatives to research. One group suggested that guided inquiry has all the positives of research, but not so many of the negatives. And it can be organized. Another group also advocated inquiry-based teaching as being effective and less messy than real research. They thought that the CASPiE model initially seemed inquiry-based. When they began to incorporate their own research, they turned it into real research, but then it became less portable. A third group said that it is possible to get students to think about procedures and meaning without involving them in authentic research. They drew support from Norm Hackerman's presentation of Stephen Hawkes recent article in the Journal of Chemistry Education, "Chemistry is not a Laboratory Science," which argues that lab work is not nearly as productive as most people think it is. A fourth group sought to differentiate authentic research from authentic research *experiences*. A participant from this group expressed his conviction that the difference between exposure and experience is not the same in everybody's minds. He thought that what counts as an exposure should be different for

majors, non-majors, and non-science majors. He argued against trying to do experience for all groups because he didn't think it was possible. Most groups seemed to agree that the NSF needs to define authentic research with clear criteria and clear degrees of latitude. A few added that proposals also need clear definitions of authentic research and its latitude.

Integrating Undergraduate Research into the Curriculum:

Issues of curriculum and curricular integration of research were also widely discussed. The most popular question was, does research have to be integrated into the curriculum, or would it be acceptable to use a one-on-one model if it were expanded to accommodate more students? Some felt that it would not be possible to work with 150 students using a one-on-one model, let alone 1000, but a few people suggested that by using upper division students, it might be possible to significantly expand the numbers of students conducting research but still use the one-on-one model. Others saw difficulty on the other side: they wondered if it was possible to run an entire course using the very tight integration they saw in the CASPiE presentation. Both groups wanted to know if the NSF was open to both models, or if they preferred a curricular model over a one-on-one model.

Another area of curricular concern was the issue of coverage. Several people argued that there is a certain minimal amount of material that has to be covered in introductory courses to ensure that students attain basic literacy in the field. They felt that engaging first- and second-year students in research would force curricular changes that would delete content, jeopardizing this basic literacy. They worried in particular that the emphasis on research would narrow students too early, noting that research almost always focuses on particular questions, not broad ones. How will the essential issues be covered in a practical and theoretical way as they would in lecture? They also wondered when these students were going to master the basic skills and concepts needed to *allow* them to participate meaningfully in research.

The tremendous diversity in levels of preparedness among first-year students is also relevant here. Some students have had no chemistry in high school, and they need to gain basic factual knowledge in the first 2 years. Others are fairly proficient. How do we deal with this massive disparity in knowledge in the context of a research-oriented curriculum? This matter pertains especially to community colleges. They only have students for two years, so if they have to spend one year bringing a student up to speed so that they are capable of participating in a research project, that student will only get one year of research before they go off to a four-year institution. Many of the community college faculty felt that to make this project work, it must involve high schools. Getting high school teachers involved would facilitate bringing high school students to community colleges to get them started in general chemistry so that when they enter as college students they are ready to participate in research. If we wait until they arrive, it is already too late; let's prime the pump by reaching out to high schools.

The consumer model of education also came up in this context. Students already have possible career paths in minds before they matriculate, and how they take (and look at) classes is filtered through that lens. Too many times, we are preaching to the choir: by the time these students get to us, they have already made up their minds. So perhaps we should be trying to convince people before they have made up their minds that the pursuit of science is a worthwhile endeavor. This also suggests that we need to involve high schools.

Along similar lines, a few groups noted that integrating research into the curriculum on the scale being suggested is going to require wholesale institutional changes. While some may be interested in forwarding these kinds of changes, others are worried because of the corporate mindset at their institutions. They anticipate fierce resistance.

Recruiting Faculty (and Students):

The final issue that surfaced in most breakout sessions was that of faculty recruitment. Many groups thought that it would be extremely difficult to get star faculty, or even faculty in major research institutions, to work with first- and second-year students. They said it was hard enough getting them to work with juniors and seniors. Getting them to work with people who have no lab experience and often little or no knowledge of chemistry seems virtually impossible. Strong institutional disincentives to their engagement with this kind of project—e.g., deans telling them to stop wasting their time and focus on getting tenure—add to already long odds. If we are to have any success at all, we need to be able to convince them that it is authentic, that it is a productive use of their time. How do we do that? Is it worth the effort? How can we compensate faculty in a meaningful way for their participation? We face similar problems maintaining administrative interest over the long haul, but it is essential for long-term sustainability.

A few groups raised questions about target populations and student recruitment. Two groups observed that the models presented so far presumed a model of student that doesn't exist everywhere. The 4-year residential experience is no longer even the dominant model. Their students are part-time commuter students, often with full-time jobs; some take many of their classes online. They don't even have time to do the reading consistently, let alone commit to a research project. How are we going to make time and space for all of these different types of students? How are we going to adapt to their needs? Economic diversity is of particular concern here. Being able to offer financial incentives to students will be a major issue in sustainability, particularly for colleges who serve disadvantaged populations. These groups wanted the next program announcement to recognize the diversity of students and of educational models and missions.

Assessment:

Assessment questions also occupied a couple of groups. One group was glad to see internal evaluation being pushed. They had struggled with external evaluators with marginal success. They also struggle with money spent on assessment: No one wants to spend it. They suggested—to their own chagrin—that the NSF may just have to mandate a certain portion of the grant be spent on assessment. Another group was also concerned about the cost of external evaluators. Because some of them did not have institutional access to people who have the relevant expertise, they were going to have to hire outside evaluators. They would like more guidelines about how to choose them.

Sustainability:

A couple of groups were also concerned about how to sustain programs financially. Funding is so low across the country, they said, that asking institutions to pony up money for subscriptions isn't going to happen. The community colleges and the PUIs that need this program the most don't have any money to allow them to participate. Many don't even have the most basic

equipment that they need to compete. Some schools aren't even computerized yet. They can't virtualize equipment that they don't have and can't get because it is too expensive. How can we collaborate without this equipment and with travel costs so high? They felt that NSF procedures and assumptions seem to disadvantage the groups and institutions that need it most—especially regarding resources and pedagogical approaches.

There were also a few questions related to program operations:

- A couple of groups wanted to encourage continuation of the planning grants. They felt that there are groups out there with good ideas that need that time to develop them further, who were not funded in the first round, or who did not participate in the first round. Some people also wanted to know if those who were awarded planning grants had a major advantage over those who didn't. They particularly wanted to know if it is necessary to have a planning grant to be considered for the next round of full grants. Dr. Ellis responded that there is no expectation that groups with planning grants will have an advantage: peer reviewers and NSF staff will be evaluating proposals in whatever form they arrive, and there is no reason to assume that groups with planning grants will have developed a stronger proposal than groups that did not have a planning grant.
- One group advocated a two-year term for planning grants, because one-year grants mean that “we are only half-way into our project before we would need to be submitting our full proposals.”
- One group wanted to know how a two-year institution could become the lead institution on a URC. Is there any chance at all? Dr. Ellis responded that a two-year institution could be the lead institution and is, in fact, on one of the planning grants.
- Another group wanted to know if all the successful planning grants involved a research-intensive institution? They wanted the NSF to answer this because it has an impact on the non-research intensive institutions. Dr. Kuczowski replied that approximately half of the planning grants do not involve a research intensive institution.

N.B.: During the discussion after the breakout sessions, a number of people referred to the CASPiE program as “the Purdue model.” This was upsetting to the CASPiE leadership, who explained that they had worked very hard to come up with a name that made clear that all partners are equal. They felt strongly that referring to their program as “the Purdue model” undermined their partnership and jeopardized the success of the whole URC concept by reinforcing the impression that collaboration with large research universities would not be possible because they would simply swallow up the smaller partners. They suggested forcefully that they would appreciate it if participants would call their program by its name—CASPiE.

Implications of the First Breakout Sessions:

- The target audiences of the URC program are diverse, as are the ways that the program seeks to affect them. Strategies for accomplishing various program goals will be equally diverse and may even be in conflict. Many approaches to balancing these tensions can be successful. No single strategy or model is preferred, nor is consistency among strategies necessarily a virtue.
- The variety in types of students that exist in different institutions (e.g., residential vs. commuter, physical vs. online, full-time vs. part-time) provides a means for institutions in

areas with little racial or ethnic heterogeneity to demonstrate that their program is reaching an increasingly diverse group of students.

Suggestions, Strategies and Solutions Developed in the First Breakout Sessions:

- Because many of the programs most in need of this kind of program may be the least able to make it work for large numbers of students (at least for a few years), the NSF should consider making smaller awards to smaller programs that affect fewer students.
- To equalize and enhance levels of preparedness among first-year students and to facilitate their early engagement in research, URCs should work extensively and intensively with secondary schools in their regions.
- Continue to offer planning grants to allow groups with good ideas to continue to develop them. Consider offering two-year planning grants.

Challenges to the Community's Creativity Posed during the First Breakout Sessions:

- If large numbers of students become interested in research, what is going to happen to them when they want to continue in their third and fourth years? It is already difficult to find research opportunities for juniors and seniors, and the REUs are overwhelmed. Won't students be turned off when we can't find space for them? Is the NSF willing to fund programs to accommodate these new researchers?
- Can authentic research be organized and systematized sufficiently to allow it to be sustainably integrated into teaching practices?
- Engaging first- and second-year students in research could force curricular changes that would delete content, jeopardizing basic literacy. When will students master the basic skills and concepts needed to *allow* them to participate meaningfully in research?
- Strong rewards for faculty participation will be needed to countervail strong institutional disincentives and to engage initially indifferent faculty. What rewards are possible aside from release time and equipment?

Partnerships and Center Management

Jeff Roberts (University of Minnesota)

Dr. Roberts began by emphasizing that center management and forming partnerships are very big jobs which are critical to the success of your center. URC grants are large grants, and whether your center is successful or not will depend on how good your management is and how strong your partnerships are. You need to begin planning them right at the beginning of your proposal.

His presentation focused on his experience as the Director of the Research Site for Educators in Chemistry (RSEC) at the University of Minnesota, Twin Cities (UMTC) as a means of grounding his perspective on management. His comments, he suggested, might then be refracted through that perspective.

The RSEC involves the Department of Chemistry at UMTC and 30-35 PUIs. It is a five-year \$2M project that is mostly regional in focus. Faculty at participating institutions are offered a variety of ways to work together that advance the RSEC's goals of promoting education and research. The RSEC can provide:

- financial support for nascent research collaborations involving PUI and UMTC chemistry faculty;
- technology initiatives, in particular an Internet seminar program that annually webcasts ten seminars to PUI institutions; and
- assistance to PUI faculty in obtaining external funding for collaborative and independent research efforts through helping them write proposals, etc.

The goal is to help develop the capacity of the nation's PUIs and to offer their students meaningful research experiences.

The Center is divided into four interdisciplinary research clusters: chemical biology, computational chemistry, environmental chemistry, and materials chemistry. The people participating in these four clusters include almost two-thirds of the chemistry faculty at UMTC. This is a satisfyingly high percentage, and standards are high. The percentage could be even higher, but center management discourages some faculty from participating because they suspect that the quality of their participation will not be up to the center's standards. The commitment of the core group makes it easy to be tough about who is allowed to participate.

The RSEC has a strong regional focus because the upper Midwest is rich in PUIs and those PUIs exhibit a lot of diversity. This [map](#) shows only four-year institutions; if we added the two-year schools, there would be many more. Not all of them participate—these are the range of schools that we have to work with. Thirty-three schools are presently participating in the project and they exhibit a great range of diversity. Twenty of the thirty-three have applied successfully to do a collaboration at the UMTC. The RSEC is not exclusively regional, however; it includes several Historically Black Colleges and Universities (HBCUs), such as Alcorn State, Florida A & M, Fisk University and Xavier University.

For a faculty member to apply for support, their department must first become a member of RSEC. When a department expresses a desire to join RSEC, a member of RSEC's executive committee visits that department to determine whether its goals mesh with those of RSEC. The committee member is looking for evidence of broad-based support. RSEC will only work with departments, not with individuals. There are (sadly) examples of faculty members applying from departments or institutions that have no interest in building an active research culture. That one person is not a good fit—RSEC is only interested in working with departments that want to enhance their research cultures. Doing that requires department-wide commitment.

Assuming the faculty member is eligible to apply for support, the process is simple. The application consists of a simple, web-based form, accompanied by a letter of support from the faculty member's chair. Advice is available from center staff. The application must describe some sort of pathway to sustainability. The program does not support one-time projects; projects must nurture the home institution and develop their research program and culture. There are two application rounds per year, and the budget is sufficient to allow the program to support a variety of projects. RSEC has a very diverse portfolio of collaborations, both in terms of the kind of science supported, and the collaborative structures.

Dr. Roberts is particularly proud of the range of collaborative structures supported. Examples include:

- Group visits by faculty from a single PUI (usually with their students) during the summer. In one case, faculty from Drake University came to learn about computational chemistry because they didn't have any expertise in it. Shortly thereafter, they invited a UMTC graduate student to teach a class on computational chemistry at Drake, which the faculty members audited. They got to acquire some expertise in computational chemistry and the graduate student got valuable experience and feedback on his teaching. (Examples: St. Cloud State University, University of Northern Iowa, N=33)
- Academic year partnerships that integrate small school and UMTC research groups. (Example: University of Wisconsin-River Falls, N=6)
- Sabbaticals, coupled to teaching internships for University of Minnesota graduate students. (Example: University of St. Thomas, N=5)
- Short faculty visits during the academic year, coupled to summer support for a PUI student. (Example: Fisk University)

RSEC supported forty collaborations out of forty-seven applications received. Unsuccessful applicants are given feedback on how to improve their applications.

Three key features of RSEC allow it to support all of these programs. First, it has a very lean but inclusive management structure. An executive committee of five members meets twice per year to assess operations and evaluate applications. It is composed of the RSEC Director and two faculty members each from UMTC and the PUI departments. Second, it is supported by colleagues who are committed to program goals. The program was designed from the beginning to have clear benefits for the participating departments. Consultative proposal writing was part of that design. Dr. Roberts maintains that enlightened self-interest is no evil. UMTC draws large numbers of graduate students from member PUI schools, so UMTC benefits from these programs that increase the preparedness of the PUIs' students. Students at the member PUIs benefit because they learn about UMTC and about its programs; everyone wins. The design

structure is flexible enough to allow new ideas to be tested and implemented as they come up, and the executive committee is open to experiments. You don't want a one-size-fits-all kind of program that can't accommodate itself to innovative ideas. Third, RSEC has a superb support staff—a program assistant who is adequately compensated, and who enjoys this type of work. Her prowess means that the director has much less to worry about.

Based on his experience at RSEC, Dr. Roberts offered a few insights on center management. In his view, management involves four types of tasks:

- financial tasks—keeping track of the budget is no small thing when your budget is \$500K/year (processing purchase orders, payroll...),
- organizing (meetings, workshops, symposia, poster sessions, record keeping...),
- communicating (web site, mailing / e-mailing announcements, flyers, annual reports, presentations...), and
- steering the ship (assessing your program, deciding on changes of direction, bringing new people and ideas on board,...)

Center directors should spend most of their time on the fourth set of tasks—on vision. This is the most nebulous task, but also the most critical to the operation of your center. Because it is nebulous, it is easy for it to fall to the bottom of the to-do pile. You will have other tasks as well—scholarship, administration, etc.—but you have to arrange things so that these tasks do not fall to the bottom of the pile. You have to spend time thinking about how things are going. Adequate support (from colleagues or, ideally, designated staff) is essential! Without this support, you can't do the big job.

There are three essentials to forming strong, productive partnerships. First, involve your partners from the beginning, so that they are fully committed to your program. All parties should have some ownership. This begins with proposal writing. Don't just ask your partners for their *vitas*; you need their ideas too. Second, share the power as well as the work. Avoid even the appearance of hierarchy, or the suggestion that one type of institution is "better" than another. Because real partners have a share in program design and decision making, they also have responsibilities. Third, design the management structure to ensure that your center delivers on its promises. It is up to center management to see that these responsibilities are executed. Make sure that you have the power to fix things if they don't work. (One way is to make sure that when the money flows, it does what you want it to do.)

Dr. Roberts closed his talk by propounding five lessons he had learned from directing RSEC.

- 1) The success of a program like this is determined (mostly) in the initial planning. You probably cannot spend too much time on writing the proposal.
- 2) Programs must be structured to be mutually beneficial. If you want your colleagues to value it, they need to get something from it. "Enlightened self interest is no evil." One of the reasons why we are so enthusiastic is that we see this as a department building exercise. We get better graduate students as a result of it. That isn't the only reason that we do it, but it is a concrete benefit for all of us and it keeps my colleagues very enthusiastic.
- 3) Expectations should be high. All parties should contribute as well as receive.

- 4) Flexibility is key. Faculty members have widely different needs and constraints. You need to have structures that can accommodate the variety of talents and constraints that will exist in your group.
- 5) Programs must budget for adequate administrative and organizational assistance.

One final thought—Keep it Simple!

Question and Answer Session:

One person wanted to know about the faculty who weren't allowed to participate. Dr. Roberts pointed out that there are various ways by which one can know that a certain faculty member will not promote the success of your program—someone who leaves town every summer, for example, or someone whose idea of supervising a student is to give them a desk and then come back in eight weeks to see how they are doing. Good management requires that you say no to these people. Sometimes you will take some heat for that, but that's part of being a good manager too.

Another participant wanted to know if it was possible to be too flexible. Once you got good partners, say, wouldn't it be unwise to keep rethinking and or changing them? Dr. Roberts replied that of course that was correct. One of the reasons RSEC targeted a finite number of institutions was that they hoped at the end of five years, to have done projects with at least two or three faculty members from each of those institutions. So, yes, there are some lines you can't cross. However, the flexibility that was built into the design of RSEC was envisioned as making it possible to respond to the individual needs of interested faculty members. There are, for example, faculty who for professional or personal reasons, are unable to leave their homes for significant time during the summer. We still wanted to make it possible for them to be involved if they wanted to.

A participant asked if Dr. Roberts could comment on managing your time as you manage your program. Dr. Roberts replied that obviously you are going to have to give something up as you add all these new responsibilities. This is why institutional buy-in is so important. The details of how this happened were somewhat complicated, but the bottom line is that he was able to get release time from both the administration and from his department to manage the RSEC. And, he added, you should too.

A question was asked about how much of the budget went to assessment, how much to faculty and how much to staff overhead and other infrastructure costs. Infrastructure costs are kept quite low, Dr. Roberts said. The administrative assistant (the only support staff) is very efficient and so she only works half-time. Her salary is about \$25K, plus benefits and other associated costs. That's all we pay for infrastructure. Our faculty costs are also very low—the only money we pay to UMTC faculty is a little bit of money to Dr. Roberts for summer work. In fact, the university administration hates this grant because there is so little overhead in it. Almost all of RSEC's money goes to projects, to visiting faculty and student participants. With regard to assessment, Dr. Roberts admitted that when he wrote this grant, he was a bit naïve about assessment, and perhaps the NSF was too. There wasn't really a plan. We have one now, and although it would have been better if we had thought about this earlier, we are getting some good data from it. We are spending about 10% on assessment.

Implications of the Dr. Roberts' Presentation:

- Center management is a complex, time-consuming task critical to the success of your project.
- The success of a program is determined (mostly) in the initial planning. Spend ample time developing an effective management plan in the proposal.
- Your center is only as strong as your partners. Choose them well.
- Work only with departments that enjoy a broad base of support for the goals of the project. Individual faculty and uncommitted departments will contribute more drag than momentum.
- Make sure that all activities sponsored by the center contribute to the long-term goals and sustainability of the center. Do not allow resources to be drawn off by short-term ventures.
- Keep the application process short, accessible and easy to use. Offer consulting to make the process easier, more directed and more successful.

Suggestions, Strategies and Solutions offered by Dr. Roberts:

- Set high standards for partners and enforce them. If you have doubts about any applicant's commitment to high-quality participation, don't allow them to join until those doubts are dispelled.
- Keep the management structure as lean as possible, but ensure that partners are adequately represented.
- "Enlightened self-interest is no evil." Increase support for and commitment to the center by structuring programs to provide clear benefits for all participants.
- Keep the management structure open to new ideas and flexible enough to implement them.
- Hire superb support staff and compensate them adequately.
- Managers must have time to steer the center. Although this task is the most nebulous, it is the most critical to the success of the center. Managers need to make time for it, and support staff need to handle enough of the other tasks to allow managers adequate time to do it well.
- Involve your partners from the beginning, so that they are fully committed to your program.
- Share the power as well as the work. Real partners have a share in program design and decision making; they also have responsibilities.
- Make sure that center management has the power to fix things if they don't work.
- Keep it as simple as you can.

Curricular Models

Nancy Mills (Trinity University)

When most people think about curricular models, they think about how to integrate research into the curriculum. Another approach would be to think about how to create a curriculum that allows students to get involved in research early on in an effective way. Dr. Mills proposed to consider both models in her talk, starting with the latter. Agreeing with Dr. Roberts that enlightened self-interest is a good thing, she argued that involving students in a research program early in their college careers is only sustainable as long as it provides benefits to the faculty. It will not last if it is simply a service commitment. The question then becomes how can the curriculum support faculty research through involving younger students?

Dr. Mills proposed to examine this question through the lens of her experience at Trinity University. Before investigating the Trinity model, however, Dr. Mills proposed that listeners consciously adopt a broader perspective. She recommended that of the Committee for Professional Training (CPT)—the arm of the American Chemical Society (ACS) that approves programs—of which she is a member. According to Dr. Mills, the general perception is that CPT is an incredibly rigid organization. That perception comes from the fact that the chemistry curriculum is very rigid and the fact that the community continues to add to it. It therefore becomes more and more difficult to deliver the curriculum effectively. CPT, she said, understands the perception and the pain behind it. To address this problem, CPT will be sending out a survey soliciting input into a new curriculum. This will be an opportunity to give feedback and to create greater flexibility. Dr. Mills suggested that while she was explaining her experience at Trinity, participants might want to be thinking about how to take advantage of this opportunity at the same time. Specifically, participants should be asking themselves “if your own curriculum could be changed, how could it involve students in research early on?”

Trinity University, Dr. Mills observed, is not every university. Trinity University is located in San Antonio, Texas, and is a primarily undergraduate institution with about 2400 students. It offers small graduate programs in education, psychology and health care, but no graduate programs in any of the physical sciences. Trinity attracts very good students (average SAT ~1300), and the Chemistry Department is quite lean, with only seven faculty. Given the small size of their department, they could not deliver the kind of research-intensive program that they offer if they only used students who had completed their junior year. This is where enlightened self-interest comes in; they can run a substantially larger program by involving students early. Over the past five years, between thirty and forty-two students participate in research each year. Over two-thirds of those are first- and second-year students. The only reason faculty can involve so many lower division students, and the only reason they continue with the program, is that the students are productive.

There are two main reasons why such young students can be so productive. First, Trinity gets great students; almost all of them have had high school chemistry, so very few are starting from scratch. That allows Trinity to trim down the curriculum and to offer organic chemistry in the second semester of the first year. This curricular change is the second reason: introducing

students to organic chemistry in their first year offered many benefits to Trinity's research program. According to Dr. Mills, there is a coherence to organic chemistry that is not present in general chemistry. That coherence gives students a more satisfying sense of mastery. It also gives them a skill set that allows them to be more effective in research. That effectiveness is not limited to organic chemistry either; because they have experience doing more sophisticated manipulations, they seem to make the translation to other research groups more easily. Trinity enjoys a larger than average number of chemistry majors as a result. There is a greater sense of vitality in the department, and of course, students get to do research.

Trinity employs a couple of unusual curricular strategies to encourage this high level of participation. To make their program more inviting and easier to join, they renumbered the course that allows students to get credit for doing research to identify it as appropriate for first- and second-year students. The low number allows students browsing the catalog for classes to stumble across it easily and to see that they are qualified to enroll. Trinity also offers non-credit based participation: they allow students to volunteer. Volunteer students are paired with students taking the course for credit. This allows them to get up to speed much more quickly when they work for credit in the summer. There is also a hidden feature in the curriculum that works to the advantage of the undergraduate research program. The Biology Department requires a year of chemistry before a student can enroll in the third semester of biology. All premed students therefore take chemistry, usually in their first year. That gives us a large pool of people to pull from. It also encourages curricular exchanges between the Biology and Chemistry that benefit both departments.

The Chemistry Department realizes several advantages from involving these inexperienced students in research. Because the students start early, the faculty get to work with them for a long time. The Chemistry Department gets more majors than they would otherwise because they attract them with research in their first year. The research projects create a greater sense of community in the department, and the faculty think it is important for students to have research experience early in their careers so that they can make informed decisions about careers. The results are so compelling that the entire department supports the program. In her recap, Dr. Mills identified the key elements determining the success of the program as: organic chemistry early in the curriculum, support from the biology program, and buy in from chemistry faculty.

Dr. Mills closed the first section of her talk by speaking about exportability. Trinity recently participated in a REU project in which they hosted students from local community colleges and schools that didn't have research programs. They brought these students into the lab just as they do with their own students. These students started a little more slowly than the usual Trinity students, but they turned out to be very capable and did a very reasonable job. Dr. Mills concluded that if the faculty feel that students can do it, then they usually can. This is why faculty buy-in is so critical.

In the second section of her talk, Dr. Mills proposed to examine the issue of curricular integration from a different angle. If you cannot redesign the whole curriculum around research, how can you still integrate research into the traditional curriculum? She began by defining research. Research, according to Dr. Mill's way of understanding, consists of: asking a question, obtaining data to answer it, and creating new knowledge. What elements of this definition can be

incorporated into the curriculum? She suggested thinking about lab experience as a continuum that stretches from cookbook labs to real research. There is a parallel in the behavior of professional chemists, extending from routine technician work to research.

The first evolutionary stage is an extension of the cookbook approach. The problem with cookbook labs is that students have no independence; they simply follow procedures as if they were making brownies. So the first step is to increase their intellectual engagement. One way to accomplish this is through a “single-experiment lab with a question.” The essence of this evolutionary stage is the question: all students do the same experiment, but instead of trying to make a specific compound they try to answer a question. At Trinity, they do a single-experiment lab with students in the second semester of their first year. It involves the preparation of a propyl benzhydrol ether. In essence, you react propyl benzhydrol with 1-propanol in the presence of an acid catalyst. Students have to discover first whether they get the rearranged or the non-rearranged product; then the question is, why did it form? The issue is that Nafion is an acidic catalyst with pores. The most stable cation that can form is the one from benzhydrol, but does it form? If you get the rearranged product is that because the benzhydrol doesn't fit within the pores and the 1-propanol does (and rearranges)? This is not real research, of course, but it might be thought of as proto-research. It asks the students to figure out what happened and why. It stimulates them to *understand* what is happening, rather than simply accepting it.

At the second evolutionary stage, the goal is to incorporate more independence and diversity into the experiment. At Trinity, they accomplish this by running a single experiment beginning with an unknown substance but using different starting points—again, with a question. They use a single experiment here too because it is bounded; they are uncomfortable with students having the entire world of chemistry available to them. So this is a way of incorporating some unknowns, some research-like experiments within bounds. They do a Friedel-Crafts acylation of an “unknown” aromatic compound using vacuum distillation. The important thing here is that students process NMR data and analyze it to figure out what they have isolated. Another lab uses aldol condensation with many different combinations of substituted benzaldehydes and symmetrical and unsymmetrical ketones. They originally began using it because they wanted a way to involve students in the chemical literature, and finding the melting point of their compound is one way of doing that. This lab also builds understanding of recrystallization and NMR analysis. Finally, they use a Grignard reaction to prepare a suite of substituted benzoic acids. In this synthesis, they know what they start with and they know the outcome; they use capillary electrophoresis to examine relationships between substituents and acidity. In all of these experiments, students seek to answer a question, preserving the engagement begun in the first evolutionary stage. By starting students with different materials, this second stage increases diversity and forces them to work independently.²

At the third stage, we introduce student-designed questions into the curriculum. Trinity does this in the first semester of the sophomore year in the second semester of organic sequence. They do

² Other examples from the literature include: Preparing Students for Research: Synthesis of Substituted Chalcones as a Comprehensive Guided-Inquiry Experience, J. R. Vyvyan, D. L. Pavia, G. M. Lampman, G. S. Kriz *J Chem Ed*, **2002** 79, 1119; The Oxidation of Alkylbenzenes: Using Data Pooling in the Organic Laboratory to Illustrate Research in Organic Chemistry, James C. Adrian Jr. and Leslie A. Hull, *J Chem Ed*, **2001** 78, 529; and, The Centerpiece of a Research-Oriented Curriculum, T. W. Hanks and Laura L. Wright, *J. Chem. Ed*, **2002** 79, 1127.

an enzymatic reduction of a β -keto ester. The students do the reduction using baker's yeast. They also do both an enzymatic reduction and a chemical reduction using NaBH_4 . The question is, can you model the active site by varying the size of the β -keto ester? The possibilities available to them are to look at changing the alkyl group of the ester by transesterification, changing the other end by a synthesis involving Meldrum's acid, or doing a Claisen condensation. This experiment comes from a *J Chem Ed* article by Michael North. The point is that students decide which aspect of this experiment they are interested in participating in, so it is driven by the students' interests (or at least their sense of what would be the best question to ask). Dr. Mills identified three other "research-type" labs in which the experiments are designed by the students.³ Although, in the literature, these are called research-type experiments, Dr. Mills thought their real value lies in encouraging student independence; they aren't real research yet.

So the final stage is to incorporate faculty research into the curriculum. Dr. Mills found two examples of this in the literature. The first is by Greg Kharas, a polymer chemist.⁴ He has students make trisubstituted alkenes and look at their polymerization and their copolymerization, which is his area of research interest. The students make substrates for him, and they look together at the polymerization and the effect of substituents on that. There is also the Michael North experiment mentioned above. Notice that it appeared in *Tetrahedron Lett* first; he had a group of students who ran this experiment and he published it. So this is a proof of concept.

Not only can this be done in an undergraduate setting, it can also be done in a high-school setting. Students from Wichita Collegiate School—a good high school in Wichita, KS—looked at the ratio between linoleic and linolenic fatty acids in french fries.⁵ There is a direct relationship between this ratio in the foods we eat and breast cancer. The students extracted the acids from french fries and analyzed them by GC. What they discovered was that most of the french fries had the bad ratio of the acids, but that some people coated the french fries and that then the ratio was not as bad.

If they can do this in high school, we can probably do it in general chemistry. So the bottom line is that it *is* possible to design experiments that are research experiments and that involve students in research very early on in their career in a very effective way.

Question and Answer Session:

A participant wanted to know if Dr. Mills had observed a distribution shift in Trinity's research students among the various disciplines as a result of the way they have restructured their curriculum? Dr. Mills said that they had not. She thought that the characteristics of the faculty

³ A Research-Based Sophomore Organic Chemistry Laboratory, D. Scott Davis, Robert J. Hargrove, and Jeffrey D. Hugdahl *J Chem Ed*, **1999** 76, 1127; Organic Chemistry Lab as a Research Experience, Thomas R. Rutledge *J Chem Ed* **1998** 75, 1575; and, Honors Cup: Incorporating a synthetic project competition in second semester undergraduate organic chemistry. A.C. Gottfried, B. P. Coppola, Philadelphia ACS meeting, CHED 74.

⁴ A New Investigative Sophomore Organic Chemistry Laboratory Involving Individual Research Projects, Gregory B. Kharas. *J Chem Ed*. **1997** 74, 829.

⁵ Classroom Research: GC Studies of Linoleic and Linolenic Fatty Acids Found in French Fries, Janice P. Crowley, Kristen L. DeBoise, Megan R. Marshall, Hannah M. Shaffer, Sara Zafar, Kevin A. Jones, Nick R. Palko, Stephen M. Mitsch, Lindsay A. Sutton, Margaret Chang, Ilana Fromer, Jake Kraft, Jessica Meister, Amar Shah, Priscilla Tan, and James Whitchurch *J Chem Ed* **2002** 79, 824.

mentors were far more influential than the curriculum structure when it came to retention and recruitment.

Another participant asked if Trinity was getting biology majors doing research with the chemistry faculty now. Dr. Mills said that they are, but cautioned that students don't have to declare a major until the end of the second year. Since the chemistry faculty are working with them in the first year, they have no idea what those students will eventually major in. Some turn into biology majors, economists, historians; that's OK. It doesn't matter to the Trinity faculty what they decide to major in because the system works for them.

Someone wanted to know how students in the REU project were distributed among research groups. The Trinity faculty agreed that each faculty would take one REU student. They jointly developed a special program to get the REU students up to speed and to allow them to bond with each other. Then they were divided among research groups. The students received REU stipends for their participation.

A follow-up question directly concerned stipends: Are student stipends (for summer or the academic year) good or bad or neutral as far as the URC program is concerned? Dr. Kuczowski said that there was no restriction on that. The last round of proposals included a whole range of solutions. He advised that proposers think carefully about the matter of sustainability and scalability when developing models that include student stipends.

Another person wanted to know if the Trinity approach would work at a place where the students were mediocre students? The key thing, Dr. Mills said, is to include organic chemistry in first year. She agreed that that might involve a paradigm shift in the chemistry curriculum. Several questions need to be considered. Would it be possible to start with organic? What skills and knowledge should students learn in their first year? We will also have to have textbooks, but there is no reason in principle why all students couldn't do what our students do.

Another person wanted to know what percentage of Trinity's research students have stipends from the university (not REU stipends)? All forty of them—but all of them are supported by external grants. No internal money is used.

A participant wanted to know how one could teach a course like this in physical chemistry. He understood how it would be possible in organic, but couldn't see how it would work in a course that involved a lot of instrumentation. Dr. Mills responded that perhaps it is a mistake to start with general chemistry. Maybe it would be better to start with something that wasn't so math-intensive. Perhaps the present way of thinking about the chemistry curriculum is inappropriate.

Following up on that comment, another participant said that they have rearranged their sequence. They begin with conceptual general chemistry, then do organic chemistry, then do a second, quantitative general chemistry. A four-year review shows excellent outcomes. Prior to this change, they had a 65% failure rate. Now they see 70-75% success. Rather than giving out mostly Ds and Fs, they are now giving mostly As and Bs. Their biology students are now outperforming everyone else. Biology faculty are now embracing the chemistry faculty. This makes sense to Dr. Mills because the largest population in introductory chemistry classes is

biologists, who are often math-phobic. If we can postpone the math a bit, and let the students grow into some facility with it, they will do much better. This goes against the Bio 2010 report, but it might not go against reality.

Key Implications of Dr. Mills' Presentation:

- The question is not so much how to integrate research into the curriculum as it is how to make student research clearly beneficial to both students and faculty.
- Involving younger students in research allows faculty to run a much larger research program than is possible if only upper division students participate.
- It is easier to get widespread faculty buy-in if they obtain clear benefits through their participation.
- If faculty believe that the students can do it, they usually can.

Suggestions, Strategies and Solutions offered by Dr. Mills:

- Revise the lower division chemistry sequence so that students get to organic chemistry early, ideally by the second semester of the first year.
- Number the research course to make it attractive to lower division students.
- Allow students to volunteer in the lab as preparation for for-credit work. Pair them with more advanced students to help them become productive quickly.
- Work with the Biology Department to develop both Biology and Chemistry curricula in ways that will benefit both departments.
- Use inquiry-based methods to build students up to working on real research.

Breakout Session Two

Most of the conversations during the second breakout session concerned partner equity and curricular models. There were also significant discussions of the definition of research, project management, and the review process.

Curricular Models:

By far the most popular topic was the curriculum: it was the main focus in eight of the ten sessions, and was talked about in all of them. There was widespread agreement that the sequence of courses proposed by Dr. Mills—one semester of general chemistry, followed by a year of organic chemistry—was a good idea. A number of groups debated whether it would be better to follow the second semester of organic chemistry with another semester of general chemistry or move straight to physical chemistry. A number of groups also mentioned that curricular integration would increase the transferability of courses and credits within a partnership. They further thought that it would increase the involvement of two-year institutions and promote partner equity. One group suggested that the program take advantage of laws in many states that allow courses to transfer from two-year to four-year schools without question. Another group warned that if curricular integration happened asynchronously, it would jeopardize this portability.

A number of groups noted the connection between integrating research into the curriculum and sustainability. They held that the way to secure improvements in chemical education over the long term is to integrate them into the curriculum. Several groups also realized that curricular integration was going to pose a serious challenge. It seemed to them to imply a whole new philosophy of teaching chemistry. The biggest obstacle, they thought, would be faculty inertia and territoriality. Chemistry professors, they said, are especially prone to both, so they expected resistance to curricular changes from both individuals and departments.

Groups came up with three possible strategies for circumventing these kinds of resistance. First, they suggested that if the NSF is supporting curricular change through this program (and others), they should publish this intention more clearly. That will directly motivate some departments to change, and those changes will spur other departments to follow suit. Second, a couple of groups suggested starting with revisions to the lab curriculum, because they thought there might be less resistance there than in the lecture curriculum. To make room for research and to improve the quality of the experience, they suggested reducing the number of experiments and making them more in-depth. Another group suggested that the labs could make more room for research by focusing less on reinforcing concepts being explained in lecture. Third, a number of groups suggested using inquiry-based approaches as a means of transitioning younger students into research. Because inquiry-based methods are already understood and accepted, their use as a foundation should mollify resisters.

Groups also expected to encounter faculty resistance to curricular integration due to their investment in existing models for involving undergraduates in research. Some groups even found that resistance present at the table: several people who have conducted considerable research

with first-and second-year students said that they found much of the value of that work in the personal mentoring relationship between the faculty member and the student. That personal relationship is lost in a curricular model, and along with it, some of the motivation for faculty to work with undergraduates in the lab. Some faculty also expressed that they needed to be personally involved in the way younger students were prepared for lab work; without the direct knowledge facilitated by the personal mentoring relationship, they couldn't know if a given student was adequately prepared to work safely and productively in the lab. Some people also argued that mentoring was a more efficient way to teach young students lab skills, because it allows instruction to be personalized for each student. They did see a problem, however, with scaling up the mentoring approach: it cannot accommodate hundreds or thousands of students per year. Finally, they felt that curricular approaches are less appealing to faculty because they impose more restraints than mentoring. Curricular models require students to take courses in a certain order so that they will have the right knowledge and skills at the right time, so that they can participate in curriculum-driven research. This required sequence makes students less free to work with faculty who might specialize in areas that don't get covered early in the curriculum.

Another group member suggested that adopting a more collaborative model of research might ease some of these concerns. She said that if a faculty member's model of research includes spending a lot of time thinking about an idea and reading relevant literature until they have a clear understanding of what they want to do, there is no way first- and second-year students can really participate. They lack the context and experience to make that kind of reflection and focused reading productive. However, if the model of research being used says that research is collaborative—that it isn't built up inside the head of any one person, but instead exists in the shared space of the team where everyone can work on it, then students can participate meaningfully. When students are part of a team, and they are assured that their role is necessary, and their role grows over the course of the semester, they can be incorporated into authentic research. Collaboration helps first- and second-year students make real contributions because it provides them with support and context. Even so, the participant acknowledged that although this description works with a group of five, it would be different with five hundred. She suggested that a good strategy would be to start from the ideal and work toward practicality. That means beginning with your definition of authentic research.

Another participant said that this approach didn't seem much different from teaching graduate students. When they first arrive, they don't know how to do research either: they've never had a class in research. The approach that works for them should work just as well for undergraduates: start them on the basics and build them up to more advanced skills. Because undergraduates start at a lower level, and may not have as much commitment to the process as graduate students, it would be wise to begin with easier tasks than graduate students, but the basic method would be the same in both cases.

Wanting to preserve the considerable advantages offered by mentoring approaches, yet recognizing the need to simultaneously serve a much larger population, many groups wondered if it was really necessary to choose between them. Perhaps both approaches could exist side by side.

In a similar vein, a number of groups wanted to explore options beyond curriculum reform. One group noted that the RFP did not require curricular integration. Most agreed that direct integration of research into the curriculum is a powerful method of implementing this program, but they also wanted to hear about and think about other alternatives. Responding to this call, a couple of groups proposed integrating research into the undergraduate experience outside the classroom. Wisconsin, for example is developing extra-curricular approaches. Another group suggested dissociating the lab in general chemistry from the course. This would allow the lab to function semi-independently and to focus much more on research. If an URC proposal chose not to depend on curricular modification, a third group wondered, would there be any other features or aspects that the NSF might find useful?

Partner Equity:

Nearly every group discussed partner equity extensively. The most common concern was how to balance the relationships between large research institutions and smaller schools. Participants agreed that in any URC collaboration, there would be real inequalities—research institutions, for example, would have more instruments, money and other resources. Some participants also pointed to an attitudinal inequality: they felt that large research institutions often exhibited a “big brother”-like attitude they found offensive and threatening. Many representatives from smaller schools expressed fears that they would get swallowed up, ignored, patronized, or otherwise marginalized by their larger, more powerful partners. Some smaller schools also worried about getting “cherry-picked”—losing their best students to better equipped or more prestigious partners. To compensate for these inequalities, workshop participants recommended a variety of strategies.

One group suggested approaching the problem of inequality through proper design of the partnership’s administrative structure. They stressed that the most important thing was that each partner feel like an equal, like all relationships were two-way streets. This would be promoted by giving all partners an equal say in all policies and decision-making, including operations. Don’t sign the agreement until you know that you have a say in what is happening. Another way to reinforce equity and the perception of equity would be to make one of the smaller schools the lead institution. Although some smaller schools might not initially have the infrastructure to support the administration of a large center, one of the goals of the URC project is to develop infrastructure. Still, some participants wondered how a smaller school would go about interesting larger schools in a partnership. One person suggested a co-lead arrangement, whereby a smaller school having less experience with the kinds of infrastructure required to support a project of the magnitude of an URC might partner with a larger school having greater experience in these matters.

Other groups thought that the best way to minimize imbalances was to set up the collaboration in a way that distributed essential resources among the various partners, so that each partner had control of a resource required for the success of the partnership. Thus, although it might be true that the large research institution held most of the instruments, a two-year college might have the largest supply of students. Another school might offer an especially diverse student demographic.

A third solution to this problem was to equalize the education and experience being offered at all member institutions. If the curriculum was the same across the partnership, to the point that students could almost trade schools—taking the classes they needed wherever they were being offered—without noticing significant differences, then smaller schools would be less worried about losing their students to the larger schools. That would make it easier for the smaller schools to send their students, even their best students, to REUs and other projects run by larger schools, because they wouldn't worry so much about not getting them back. The academic year focus of the URC program also helps in this regard. Most importantly, this group stressed that one can't allow partner schools to compete among themselves for students.

A fourth group stressed training equity. They thought that if all partners had equal access to training on the equipment they would all feel like they belong and that the benefits that accrue will be equally distributed.

One final matter concerned not so much partner equity as departmental equity. If research is primarily vested in first- and second-year students in introductory courses, how is internal equity with respect to the participation of other stakeholders in your department maintained? This program puts the onus on whoever is teaching general (or organic) chemistry to manage all the first- and second-year research.

The Definition of Research:

The questions of what constitutes authentic research and the role of authentic research in undergraduate education occupied more than half of the groups. No one arrived at a satisfactory answer to the first question. A couple of groups questioned whether the “real research” step at the end of the evolutionary scale laid out by Dr. Mills was in fact authentic research. They felt that it was more like an inquiry-based approach than real research. Five groups wondered exactly how suitability for publication fit into the definition of authentic research. Does genuine research focus only on actually publishable research? Some groups also wanted to know what counted as publication—for example, would publication in newspaper articles count, or did it have to be peer-reviewed journals? They thought that different models would be appropriate to different kinds of institutions, so they advocated some flexibility in the definition. All the groups who discussed it requested clarification from the NSF on exactly what counts as genuine research, what publication means, whether there is a necessary relationship between research and publication, and what NSF's priority is.

Everyone agreed that it was going to be very difficult to incorporate real research into the lower division curriculum. Some wondered if it was even possible to bring real, cutting-edge research into the classroom. These doubts and difficulties led many to explore alternatives. Some suggested that from the point of view of the pedagogical goals, it might not be worthwhile to distinguish between original research and actual research experiences. Perhaps students can get the same benefits from programs which use an inquiry-based approach that may be related to real research, but is not held to the same sort of expectations original research would.

Pedagogical Goals of the URC Program:

The various discussions of authentic research and possible alternatives inevitably brought up questions about the goals of the URC program. One group suggested that the greatest return on

faculty efforts might be obtained by not doing real research in the first semester, but instead by tracking the students during that time, identifying those who were most interested and likely to become STEM majors. Those students could then be targeted in the second semester, and the school could go after them aggressively, offering them research opportunities, scholarships, etc. This would foster the goal of increasing the number of STEM majors. Others wondered if at the first-year level, the goal wasn't simply to increase their scientific literacy as citizens and to strengthen their foundation for being future researchers through some type of curricular approach. A third group noticed a possible divergence in the goals of attracting and retaining STEM majors. They felt that it might be better to spend resources on retaining the interest of high school students who find STEM fields attractive rather than on trying to convert students interested in other things to STEM majors. They suggested that currently high school students interested in STEM fields usually have a bad experience early on that turns them off before they even get to college. As a result, they major in something else. Rather than trying to win these students back, or to recruit students who were never really very interested in STEM fields, it would make sense to invest resources in making sure that they didn't get turned off in the first place. Another group seconded the idea of increasing involvement with the high schools, noting that many states are now pushing that. If student come to our institutions with the foundations in place, we can get them involved in research earlier, we can begin the curriculum with organic chemistry, and we won't have to fight as hard to get and maintain their interest.

A final question was about how many more Ph.D. chemists are needed. This group was thinking about assessing the success of an URC. One way of measuring it would be to look at how many students want to go on to participate in their third and fourth year, and how many went on to PhDs. That caused them to wonder if that was really one of the primary goals, considering that there is a glut on the market. Perhaps it would be better to focus on educating the citizenry. And would the brief research experience obtained by those who only took first-year chemistry do any appreciable good? Would it make sense to evaluate the success of the URC not only by how many students go on to become PhDs, but also by how many students vote more knowledgeably than they otherwise would have?

Center Management:

A few groups talked about the need for strong center management. Mostly they agreed that it was necessary because this project was going to be so large and complex. Two groups said that they didn't talk about it very much because they felt that they had learned a lot from Dr. Roberts' presentation, and thought they now understood pretty well how to do it.

Another group was less sanguine; they suggested that it would be a good idea to have one of the PIs do nothing else but financial management. They also advised looking carefully at management models from EPSCoR and AMPs, both of which involve many institutions. They might have useful features that URCs might replicate.

The Review Process:

Two groups talked extensively about the review process. One group expressed concern about how the reviewers are trained. Since this is a very young program, they wanted some assurance that the NSF was as specific as possible when instructing the reviewers about how to read and evaluate proposals so that all reviewers are looking at the same things. They also wanted to make

sure that reviewers are given sufficient information about the programs and the project so that they can review the proposals in an effective manner. They especially wanted the reviewers to be well-informed about what happened in the workshop today.

The second group focused more on the process by which grants were approved. They were concerned about the integrity and viability of the process. They observed that it takes a tremendous amount of faculty time and energy to put together a proposal of this magnitude. The feedback they received on their proposals was minimal and contradictory. They pointed specifically to a disparity between the panel review process and the site visit decisions. Both disparities are causing some people to lose confidence in the process. The effect is strongest for those who believed in the project the most: they feel that the faith of the review did not match the faith of the effort. They expressed some reluctance to go through the process again.

Miscellany:

One group suggested that more emphasis needed to be put on communication. They thought that the ability to communicate is central to being able to do good science, so teaching students how to write and speak should be emphasized in this project.

One group was very drawn to the idea of using peer leaders. They noted that juniors and seniors at their schools feel almost like they own the department. They are enthusiastic, especially about wanting to share their experience. We should let them.

Another group realized that although they had talked a lot about integrating research into the laboratory, no one had thought much about how to bring research into the classroom. They thought that this could be a good way to encourage peer-led team learning or collaboration in the classroom.

One group reported that the problem of diversity in URCs came up for them not in sessions, but in conversation last night. Areas like western Wisconsin lack ethnic diversity, so although they may have a coalition of the willing, they have no real diversity to work with. They wonder how to foster collaborations that will broaden diversity among institutions that don't already have a natural link. This will be a big problem for institutions in parts of the country that don't have a lot of diversity.

Key Implications of the Second Breakout Session:

- Curricular integration increases the involvement of two-year institutions, promotes partner equity and facilitates the transferability of courses and credits within a partnership.
- Integrating research into the curriculum promotes long-term sustainability.
- Integrating research into the curriculum requires a whole new philosophy about what teaching chemistry means. It will revolutionize chemistry education.
- Teaching undergraduates isn't much different from teaching graduate students; the students start at different levels, but the method of teaching research is basically the same.
- Feeling like an equal is critical to the success of a collaboration.

Suggestions, Strategies and Solutions Developed in the Second Breakout Session:

- If the NSF is promoting curricular change through the URC program, they should be more explicit about this. Their leadership could trigger a cascade.
- Begin curricular changes in the lab curriculum rather than the course curriculum to minimize and postpone resistance.
- Use inquiry-based methods to transition students from traditional laboratory experiments to real research.
- Collaborative, vertically integrated research models help first- and second-year students make real contributions because it provides them with support and context.
- Begin with the ideal and work backward toward reality. Start with your definition of authentic research.
- Dissociate the lab in general chemistry from the course. This would allow the lab to function semi-independently and to focus more on research.
- Consider the possibility of a smaller institution being the lead institution.
- Distribute essential resources so that each member institution controls at least one resource vital to the success of the collaboration.
- Give all partners equal say in all policy- and decision-making, including operations.
- Use a common curriculum as a way to equalize opportunity and education across partner institutions and to increase trust.
- Work extensively and intensively with high schools to get students ready to participate in research in their first year of college.
- Have one of the PIs do nothing but center/financial management.
- Borrow management models from EPSCoR and AMPs.
- Make the review process more consistent and transparent to increase participants' faith in the fairness of the system.

The Second Breakout Sessions' Challenges to the Community's Creativity:

- Integrating research into the curriculum will face considerable resistance from entrenched and territorial faculty.
- How is it possible to preserve the personal satisfaction (and willingness to participate) that grows so easily out of the mentoring model of student research while involving vastly larger numbers of students?
- Can curricular models be flexible enough to accommodate student research in faculty specialties not part of the mainstream, lower division curriculum?
- Direct integration of research into the curriculum is a powerful method of implementing this program; what are some other ways?
- The attitudinal inequality between larger and smaller schools is at least as much of a problem as resource differentials.
- How can smaller schools prevent larger schools in their partnership from "cherry picking" their best students?
- How can internal departmental equity be maintained when the bulk of the responsibility for managing student researchers will fall on faculty teaching introductory courses?
- Is there a necessary relationship between research and publication and how does NSF prioritize them? Is it legitimate to target specific groups of students, or does an URC have to impact all students?

Student Recruitment

Isiah Warner (Louisiana State University)

The student recruitment model Dr. Warner presented consists of two symbiotic programs, the LA-STEM Research Scholars Program (LA-STEM) and the HHMI Professors Program (HHMI). The mission of both programs is to promote diversity in the STEM disciplines by increasing the number of under-represented students seeking terminal degrees in those disciplines (Ph.D.s and M.D./Ph.D.s). The programs also share a common vision: the best way to accomplish the mission is to provide students with a supportive, motivating environment which promotes academic success through a combination of mentoring, education and research.

The LA-STEM is a Meyerhoff-like program funded by Research Corporation, the National Science Foundation (NSF), and Louisiana State University (LSU) that enrolls the best and brightest from Louisiana and beyond. The target population for LA-STEM is graduating high school seniors who plan to attend LSU and who have a high-school GPA of 3.5 or better and an ACT score of 23 or higher. The program takes care to select a diverse group of students. They must be interested in pursuing a STEM major all the way to a Ph.D. or M.D./Ph.D. They must be interested in doing research and have a strong commitment to mentoring and to working in teams. Because of funding source requirements, they have to be U.S. citizens or permanent residents. The program accepts about 25 new participants each year, and is hoping to reach a steady state of around one hundred students by its fifth year of operation.

Dr. Warner developed HHMI with funding from the Howard Hughes Medical Institute, as a way of providing for others some of the resources that helped him succeed. It is also directed toward students who intend to be STEM majors, have the talent to do research, and are interested in pursuing a Ph.D. or M.D./Ph.D. Like LA-STEM scholars, they must also be community-oriented scholars interested in mentoring. The program targets students with strong high school GPAs and test scores who did not do well in their first year at LSU. They become eligible for the program when their GPAs are between 2.5 and 3.0. The program maintains a steady state of approximately thirty students; new students are added when other students graduate or otherwise leave the program.

Because the eligibility requirements are essentially identical, the two programs work seamlessly together. Both programs are sponsored by LSU's Office of Strategic Initiatives (OSI). Students in the two programs take the same courses and learn how to do research. The only difference is that LA-STEM students do it earlier. The program is designed to get LA-STEM students involved in research by the end of the second semester of their first year. Because students don't become eligible for HHMI until they have been at LSU for a year, they can't begin prior to their sophomore year. There is also recruitment between the programs. LA-STEM scholars must maintain a GPA of 3.5 or higher. If they fall below that for two or more semesters (depending on the GPA achieved), they become eligible for the HHMI program. Conversely, HHMI students who attain a semester GPA of 3.5 or higher for two semesters are eligible to join LA-STEM.

Outreach activities to raise awareness and encourage participation in LA-STEM and HHMI are usually handled jointly. Both programs are represented at student events and official LSU recruiting events. They also throw parties for students that are effective recruiting tools. Most importantly, the enthusiasm of current participants boosts recruitment through word of mouth and personal recommendations.

The principal means of recruitment for LA-STEM is a mass mailing of nomination forms to high schools across Louisiana (and a few out of state schools). LA-STEM scholars must be nominated by their high school counselor, teacher or superintendent of education to participate; students cannot apply directly. Once nominated, the students must complete an extensive online application. They are required to write extensively about their reasons for wanting to participate and their commitment to research and to the community. Their application must be accompanied by three letters of recommendations from counselors, teachers, or representatives from member organizations. This recruitment method has been so successful that although it is only its first year, the LA-STEM program is already one of the most prestigious programs on campus. The Dean of the Honors College serves on the selection committee of LSU's most prestigious scholarship—the Chancellor's Scholarship. After sitting with that committee for a week, she came to serve on LA-STEM's selection committee. She told us that LA-STEM is getting students who are so good—bright, outgoing, potential leaders—that she doesn't even have to sit on the committee anymore: any student that is in the LA-STEM program is automatically admitted to the Honors College. One LA-STEM student has already published a paper—as a high school student.

HHMI Scholars are recruited differently. A mass email targets eligible students during their first year at LSU. Interested students must first complete an online pre-application form. The full application is extensive and includes an essay question. Students must demonstrate and justify their interest in diversity, research and mentoring. As with LA-STEM, the application must be accompanied by letters of recommendation from three faculty members or high school teachers. The online system makes the application process as easy as possible. Students can save their work and return to finish it later, and an online checklist tracks the student's progress.

Both programs look for a very specific type of student. They seek students who are

- Focused
- Self-reflective
- Dedicated
- Community-oriented
- Potential leaders
- Outstanding mentors
- Seriously interested in research
- Willing to collaborate
- Motivated towards interdependence
- Seeking academic success
- Committed to pursuing a terminal degree
- Desiring to promote diversity within the STEM areas by learning from fellow students with diverse backgrounds

The programs are not just looking for scholars: they want people who are committed to diversity and to research. They want students who will make a difference in the community by being role models, mentors, leaders. Both programs take considerable care to ensure that the students admitted to the program represent a diverse mix. ([Statistics](#)) A recent study done by the University of Michigan shows that students who work in a diverse environment tend to learn a lot from each other. The same study shows that research is a critical component of learning: participation in research can cause a student's grade to rise by as much as a whole grade. That impact is largest among minorities, and within minority populations, the impact is largest for students in the categories of highest risk. The group most affected, for example, is African-American males.

The selection process for both programs is painstaking. Applications are reviewed by the selection committee mentioned earlier. Once the committee has made the first cut, likely candidates and their parents are invited to Selection Weekend. Both programs make special efforts to court the parents as well as the students. Selection Weekend is an intensive two-day interview process in which the candidates speak with various combinations of faculty, mentors, administrators, and program participants. They are monitored and evaluated the whole time; even their interactions with peers are part of the interview. Candidates must also complete a group project during Selection Weekend. At the end of Selection Weekend, the committee makes its final choices, and appointments are announced.

One of the ways that the success of the program can be seen is through how hard the parents fight to get their kids into the program. Because of Louisiana's history of segregation and racial conflict that has continued to some extent into the present day (schools in Louisiana are almost as segregated now than they were in the 1950s), a program based in diversity was not expected to be popular with parents. Instead, parents are willing to do anything to get their kids in. Many parents have asked that if their children are not admitted, they be allowed to "just sit in" and participate in program activities without receiving any scholarship support.

New HHMI mentors and LA-STEM Scholars participate in the OSI Summer Bridge Program. Participation in Summer Bridge means that students work, study, and live together over the summer. Because schools in Louisiana are so segregated, and because students are used to self-segregating, these students are not used to being around people of other races. So they begin by dividing themselves by race and gender: at the beginning of the summer, black males hang out with black males, white females hang out with other white females, and so on. Program leaders run bonding activities, to force them to interact and to trust one another. By the end of the summer, their social groupings and friendships are deeply integrated.

In addition to developing participants' interdependence skills, Summer Bridge seeks to improve students' metacognitive awareness, improve their study skills and time management skills, help them become better researchers and writers, and help them become better self-managers. Students attend workshops and special classes in addition to registering for four to seven hours of LSU classes. They are mentored by current program participants, and they make extensive use of open house tutoring. They take field trips to stimulate interest in the sciences. (Last year they visited the Pennington Biomedical Research Center, the Center for Advanced Microstructures and Devices, and the Louisiana Science and Mathematics museum.) They design and conduct a

laboratory experiment and a service learning project. (Last year they designed and built a playground.) They also work with learning specialists and other counselors to investigate their own learning styles and study strategies; by the end of the summer, each one has developed a personalized plan for academic success.

In addition to Summer Bridge, there are a couple of other important resources we provide that contribute substantially to our students' success. Both programs maintain a close relationship with the Center for Academic Success, run by Dr. Saundra McGuire. The Center's award-winning website, for example, has some tools that allow students to test their own problem-solving styles, learning styles, and personality, which have been very helpful in raising students' metacognitive awareness. Another factor is outstanding support staff. The three women who run the two programs, Monica Sylvain, Lisa Batiste-Evans and Karin deGravelles, are exceptionally talented and dedicated. They function so well as a team that participants no longer even call them by individual names—they just call them MLK, combining the initials of their first names.

Student enthusiasm for these programs is incredible. Participants in both LA-STEM and HHMI are so involved they refer to the two programs and the community they encompass as "The Program."

Question and Answer Session:

A participant wanted to know if OSI paid students a stipend for their participation in Summer Bridge and how program administrators decide how to get the yield and mix that they want. Dr. Warner said that HHMI students are paid \$3000/year; the LA-STEM scholarship is valued at about \$9500/year. He added that all of these students are on the highest form of scholarship; their tuition is paid in full. In answer to the second question, Dr. Warner said that the program aims to keep both communities together as much as possible, but that some divergence is inevitable, because students study different kinds of science: biology, computer science, chemistry, physics, engineering, etc. Dr. Warner said they also relied on the extensive application, interviews and evaluation to select a group that will work well together. In particular, mixing the groups to see how people interact with each other on Selection Weekend helps ensure a compatible group.

A participant asked how many of these students would be successful if they were not part of this program? He said that it seemed like LA-STEM students would be at the top anyway—and the HHMI students have scores that say they have the talent to excel. Dr. Warner replied that HHMI is really a research program and we are experimenting on these students. He pointed out that some people can get through barriers on their own; others need some help. HHMI is supposed to help students succeed who might not otherwise do so by giving them the self-confidence they need. Provided they have the initial ability, for many students it is that simple: they just need confidence, organization, and some help with study skills. OSI is trying to organize and systematize this approach and eventually publish it.

In response to a question about the University of Michigan study, Dr. Warner referred people to Sylvia Hurtado, who publishes research that supports the educational impact of research on minority students.

Key Implications of Dr. Warner's Presentation:

- Include diversity as a specific goal of programs designed to increase recruitment into STEM fields.
- Programs that target both the talented students who are performing well and those who are not increase retention among both populations.
- It is possible to set very stringent admission standards and still recruit a sizable group of students.
- Creating a community of learners that is integrated both horizontally and vertically promotes the success of all participants.
- Mentoring increases vertical integration.
- A well-designed admission policy can strongly shape the success and prestige of the program.

Suggestions, Strategies and Solutions offered by Dr. Warner:

- Provide students with a supportive, motivating environment which promotes academic success through a combination of mentoring, education and research.
- Test students rigorously before allowing them to participate. Use multiple and redundant means of evaluation. Make sure that you have the right students and that they are participating for the right reasons.
- Publish the program widely and make the application process as easy as possible to create the largest possible pool of applicants. Use conscious strategies to shape selection rather than difficulty of application or lack of knowledge.
- Use prolonged social contact (living together), bonding activities, and teaching to develop interdependence and integration.
- Help students grow professionally (and as students) by developing meta-skills (study skills, metacognitive awareness, management skills, writing and verbal skills) alongside more traditional discipline-based skills.
- Superb support staff make a superb program.

General Closing Discussion

Isiah Warner opened the general discussion session. He recalled that someone suggested that there was not a need for many more Ph.D. chemists. Dr. Warner said that he could not disagree more. One reason is that although right now there is a surplus, in a few years there will be a shortage; relative supply appears to be governed by a sinusoidal curve that had a period of about five years. The other reason there is a need for more Ph.D. chemists is that right now a lot of research is being done at the interfaces between chemistry and many other disciplines. Many jobs that Dr. Warner says should be going to chemists end up going to Ph.D.s in those other disciplines. Why, he asked, shouldn't molecular biology be chemistry instead of biology? Biochemistry also escaped. Biochemistry is chemistry, yet it is now a separate discipline. There is a lot of chemistry going on in these fields that is being done by people whose degrees are not in chemistry. Dr. Warner said the answer is not to produce fewer Ph.D. chemists, but to keep the jobs in the discipline.

Mike Doyle said he noticed some concern about planning grants. Do those who have planning grants have an unfair advantage over those who don't have them in the next round of proposals? And are those who do have planning grants penalized if they submit a proposal for a full grant before they write the final report for their planning grant? Dr. Ellis replied that anyone can respond to the program announcement whenever it comes out, and what everyone submits is peer reviewed the same way at the same time. In terms of the process, it is irrelevant whether you've had a planning grant or not. What matters is how developed the proposal is, how well articulated the goals are, and how likely your plan is to accomplish those goals in the eyes of the peer-reviewing community.

One participant asked what the NSF's commitment to the URC project is. How many URCs there are going to be in the future? Will five be the final number, or will there one day be many of them spread around the country? What is the long-range prognosis? Dr. Ellis said that there was only one this year, even though the budget allowed for as many as five. This is not uncommon in the Division of Chemistry, or for the NSF generally. When a new program comes out, it sometimes takes time for the community to figure out what the program announcement requires, what the objectives are and so on. Three new programs were launched in chemistry last year: the URC program, the Discovery Corps fellowship program for post-docs and mid-career chemical scientists, and the Chemical Bonding Centers program that supports a large, long-term project at the frontiers of chemistry. In all cases, NSF budgeted more than it awarded. In each case, it was evident that parts of the program announcement were misunderstood. That can be the case even with a workshop, because for each of these three programs, there was a workshop that helped to guide the development of the program announcements.

It is also important to remember that the URC project is an important part of a big experiment, as Dr. Doyle said at the outset of today's meeting. We're trying to do something that to our knowledge has never been done before. There is a lot of interest in this project, as evidenced by having workshop participants from other units within NSF as well as from other agencies and foundations. Dr. Kuczkowski and the steering committee for the first URC workshop ensured that there was broad representation from the various institutions that could participate as well as

representatives from industry and national labs. The NSF is challenging the community to develop new models and new partnerships through the URC program.

Dr. Ellis expressed confidence in the peer review process. The NSF is committed to making the process as transparent and fair as possible. He reminded the audience that the NSF is looking not only at the plan for the URC, but also at what kind of research is going to be conducted by the URC. He noted that the NSF has considerable experience evaluating the probable success of research projects because they manage so many of them. Because the NSF runs so many large centers, they have considerable expertise assessing those as well. What they are looking for are new models and partnerships that would enable the URC concept to be developed and implemented. Depending on how the implementation proceeds, and depending on how the community responds to it, other disciplines may become interested and begin to adopt or adapt this model. Other agencies are also interested in participating. Thus, the final number of URCs really does depend on the nature and quality of the proposals and their projects.

Someone wanted to know if the community was going to get answers to the questions that were raised in the breakout discussions? Dr. Ellis reminded him that the NSF tries not to be prescriptive, as they want the community to be as imaginative as possible. They observed some of this creativity in this first round of competition: there were lots of terrific ideas proposed, and in large numbers of cases, with some more development, the NSF saw the potential for these projects to become URCs. The NSF strives to answer as many questions as they can and to provide as much guidance as possible without unduly constraining the community's ability to be creative and to think outside of the box. In this case, especially, the NSF wants the community to think very boldly about what might be possible under the rubric of the URC program.

A participant recalled part of an email received by participants which said that the workshop would provide a mid-term correction of public perception and understanding of the URC program. He wanted to understand the nature of the original misperception and the mid-term correction. Dr. Ellis said that the Division of Chemistry thinks the URC program worked reasonably well in the first round of competition, but that the Division needs to more effectively communicate the objectives of the URC program to its community. He pointed out that the conversations that have taken place in this workshop have been very helpful to the NSF in that regard. They have been listening carefully to the community's concerns, observing the points of confusion, and asking about what the hard issues are. This gives the NSF an opportunity when they write the next program announcement to make some changes to it—if it makes sense to do that. That's really the substance of what was intended by the mid-term correction. This was an opportunity to bring the community together again after the first workshop and to think together about how the program should proceed.

Someone wanted a more definitive position on research. Dr. Ellis said that there is a fairly definitive position in the report of the last workshop; research means something that is potentially publishable. Everyone in this room knows that when, where, and how something gets published can vary tremendously. In view of that variability, the NSF is trying not to be prescriptive, but it does have to be real research, i.e., it has to be aimed at creating new knowledge. That doesn't mean that a program couldn't use some kind of guided inquiry to lead up to real research. However, models built solely around guided inquiry, are not the kinds of

project funded by the Division of Chemistry. The Division of Chemistry funds the leading edge of chemical research, and that's what this program is supposed to share with a much broader community of students. Broadening participation is a very important element of this program; this is something that resonates with Congress and with the White House. There's a tremendous amount of enthusiasm for programs that could really enhance inclusiveness, and that's what this program is trying to accomplish.

A participant wanted others to know that K-12 teachers are already working on inquiry-based programs. If all goes well, soon undergraduates will be ready for and expecting inquiry-based curricula. She encouraged participants to contact K-12 teachers in their local areas and ask what they are doing. She also suggested that participants interested in the debate about what constitutes the core of the chemistry curriculum look at the materials that came out of a recent ACS Society Committee on Education conference called Exploring the Molecular Vision. That conference explored a vision of the essential content that must be learned by future chemical scientists. It doesn't provide answers, but it is a good discussion and might inform the present debate.

Another common thread through many discussion groups, observed Dr. Doyle, was that many people seem to feel being all-inclusive is a very important part of any program. Isaiah Warner's program, on the other hand, is very restrictive. His program just targets a segment of the population and is quite prescriptive in defining who they are and how they might benefit from the program. He asked if Dr. Ellis could speak to the question of inclusiveness with respect to the centers. Dr. Ellis reiterated that such decisions are really up to the proposers and the kinds of models that they might want to develop. The projects proposed in the first round were very diverse. Some models targeted selective groups of students; others tried to do something for all students in the introductory chemistry course, including non-science majors. The NSF does not want to be prescriptive. They would very much like to capitalize, for example, on the great interest among college students in shows like CSI. There's tremendous interest in the kinds of instrumentation that those scientists use, the kinds of sleuthing that they undertake. Research provides the opportunity to learn about the scientific process and to learn about the kinds of tools that the people who create new knowledge routinely use. The real spirit of this project is research—the opportunity to create new knowledge and to communicate it to different audiences.

Amy Shachter noticed that one topic mentioned in the original solicitation hasn't come up today: community-based research. She solicited Dr. Ellis' perspectives on community-based research as a way of integrating research into an undergraduate curriculum or offering opportunities for undergraduate research. Dr. Ellis affirmed that as long as the research is creating new knowledge, this type of service-learning project would be an appropriate model. He observed in passing that since projects of this kind would be informed by the community, they might also report their results back to the community—creating an additional kind of publishing opportunity. He thought that this was certainly a model worth considering.

A participant said that since data collected through community-based research would be most relevant to the community where the research was done, it would make sense to publish it in a form appropriate to that community—most likely a form other than a peer-reviewed journal.

Would that be an acceptable method of publication as far as this program is concerned? Dr. Ellis observed that that kind of research could also be published in peer-reviewed journals. There are journals that publish exactly that kind of research. The important point, though, is not where the data is published; the NSF wants to give proposers as much latitude as possible in this area. The important thing is that you are creating new knowledge.

Someone asked if the NSF expects URC proposals to have outcomes in which research is integrated into the curriculum. Dr. Ellis said that curricular integration is not a required outcome because there are other ways that research might be incorporated that are not curriculum-driven. Again, it is up to the proposer. He did remind participants, however, that one of the NSF's core values is to integrate research into education, so it makes sense to think about this program as the NSF's way of soliciting advice from the community on how to do that. The new models and new partnerships that come out of the URC program are going to be a guide to the future. Integration is important, but how and where to integrate are up to the best judgment of the proposers.

Another participant called attention to the fact that both the first workshop report and the RFP called this a pilot program. He wanted to know if this is still a pilot program. Dr. Ellis replied that it is still an experiment; in that sense it is still a pilot. NSF's philosophy about new programs is to run them for a few years and then evaluate them carefully. The NSF has a Division of Research, Evaluation and Communication (REC), and the URC program managers are already talking to them about how to assess the overall success of this program after it has been in place for a while. We will do both formative and summative evaluation at the meta-level. In the sense that we are just starting the experiment, you could think about this as a pilot, but the NSF will also be actively evaluating the program as it moves forward to see how well it is working.

A follow-up question was related to the perception of what an undergraduate research center was. Today's presentations (with the exception of Dr. Warner's), seemed to the participant like CCLI projects. The participant asked Dr. Haggett before she left, if she would have funded CASPiE under the CCLI program, and she said that she would have funded it, although not for nearly so much money. The participant wanted to know what Dr. Ellis sees as the overlap or the distinctions between the URC and a CCLI program? Dr. Ellis agreed that there may be some synergies in these efforts. That's why Dr. Haggett was part of these discussions from the outset. Moreover, CCLI is not the only overlap: there are a number of programs in the Education and Human Resources Directorate that overlap as well. This program encourages proposers to reach out and to bring other people and resources on board to achieve program goals. One of the jobs of the program managers internally is to look for co-funding opportunities from other parts of the Foundation. In the same way that in institutions we try not to be segregated by departments, but to encourage people to work across traditional boundaries, so at NSF we try to do that also. We will be working with Dr. Haggett and several other colleagues to conduct co-reviews of the project proposals as they come in. We will even potentially co-fund some of the proposed projects that may involve these kinds of overlaps as they occur. Dr. Kuzckowski also commented on the comparison of the URC and CCLI programs. He emphasized that the difference in the amount of money is key: the URCs are major centers, major collaborations, and major awards. The URC program therefore requires a great deal more opportunity potential.

Another participant wanted more information about changes in the next program announcement. Dr. Ellis thought that was a good question, but that it would be premature to answer it now. After today's workshop, the program managers will sit down and talk. The workshop report will have summaries of the breakout sessions, and they will inform how we write the program announcement. It has been very helpful to them to learn from participants what kinds of issues need clarification and what kinds of concerns exist. These considerations will help shape the next program announcement.

Someone wanted to know whether the visuals from today's presentations be available before the program announcement. Dr. Shachter said that they should be up in about a week. The URL is: <http://www.scu.edu/cas/research/urc.cfm>. Dr. Kuczkowski added that participants could also review the abstracts for all the grants that were awarded through this program: the one full grant and the twenty planning grants. The URL is: <http://www.nsf.gov/awardsearch/index.jsp>. On the Search All Fields tab, select CHE – Division of Chemistry from the drop-down list under NSF Organization; enter 1990 into the Element Code box; under Start Date, choose Search Awards on or After a Date; under From, select January 1, 2004. The resulting list of 26 awards contains all URC-related awards. Dr. Kuczkowski recommended that participants examine some of the proposals to get a sense of the range that they cover.

Dr. Kuczkowski mentioned that the common concerns he heard at the workshop focused on fitting into the program's expectations: What are reviewers looking for? What is a good idea? What is a potentially good idea? Am I fitting the program? He wanted to emphasize that the approved planning grants were reviewed and approved by the community; the NSF likes them. There is a tremendous amount of potential here. There is no single thing that is desired, no single rubric. The best advice about how to succeed is therefore to play to your strengths and assets, your passions. Figure out what works best for you in your circumstances and go with those ideas.

Program Officer Brian Tissue offered some comments to put the workshop in context. He said that the NSF tried to pick topics and invite speakers on elements of URCs that were common to many different models. The intention was not to promote a formula, but to develop ideas that would be helpful to proposal writers. The speakers addressed issues of common concern and broad relevance, but it will be the uniqueness and the impact of your model that determine how successful it is. The workshop was mostly intended as another chance for communication and interaction, another opportunity to refine the program as it goes forward.

To conclude the meeting, Dr. Shachter thanked participants for coming. She said that one of the things she learned today was that this project is fundamentally about establishing and building relationships with others: building partnerships in the centers, building appropriate relationships in your departments with faculty, and creating relationships with students to give them the support and mentoring that they need. As participants think about designing their centers, they should consider who their partners are going to be and how they can establish strong, sustainable relationships so that their center will last for a long time and be successful.

Dr. Doyle added that a workshop is intended to provide information and give advice. The information provided today on both sides says that the program is moving ahead pretty well in the direction it was expected to go. There is some confusion about terms, but the advice has

been: Don't interpret the terms restrictively. Use your judgment and creativity. This workshop was intended to be selective. Our criteria for selection were: prior participation; interest in the process as demonstrated by a past application; a known interest; evidence of motivation. In this room, Dr. Doyle said, are the people who are going to make everything we talked about today happen. He urged people as they left to please take this advice: "Go forth! Increase the number of students that are appropriate for this endeavor and allow them to fill the earth."

Invited Workshop Participants

Shafdeen Amuwo, Chicago State University
Richard Anderson, University of Arkansas
Georgia Arvanitis, The College of New Jersey
David Atwood, University of Kentucky
Vera Averyhart-Fullar, Kennedy King College
Ethan Badman, Iowa State University
Mary T. Berry, University of South Dakota
Don Bobbitt, University of Arkansas
Jeff Boles, Tennessee Technological University
Henry Brenner, New York University
Stacey Brydges, Columbia University
Arthur Bull, Oakland University
John Bumpus, University of Northern Iowa
Robert Carlton, Middle Tennessee State University
Jenny Chen, Mt. San Antonio College
Tait Chirenje, The Richard Stockton College of New Jersey
Phillip Christiansen, Clarkson University
Chris Craney, Occidental College
Margaret Czerw, Raritan Valley Community College
Saliya deSilva, Montclair State University
Bernadette Donovan-Merkert, University of North Carolina
Steven Drew, Carleton College
Austin Ferguson, Olive Harvey College
Leonard Fine, Columbia University
James Ford, University of Southern Maine
Harry Gafney, Queens College
Adrian George, University of Nebraska
Brian Gilbert, Linfield College
Anne Glenn, Guilford College
Velda Goldberg, Simmons Center for Teaching and Learning in Science and Technology
Joseph J. Grabowski, University of Pittsburgh
Robert Granger, Sweet Briar College
Neena Grover, Colorado College
Norm Hackerman, Welch Foundation
Standish Hartman, Boston University
Tom Higgins, Project Kaleidoscope,
Christa Hockensmith, New Mexico Institute of Mining and Technology
Steven Holmgren, MSU-Bozeman
Charles Hosten, Howard University
H. David Husic, Lafayette College
Alison Hyslop, St. John's University
Ralph Isovitsch, Xavier University of Louisiana
Wendy Katkin, Director, The Reinvention Center; SUNY at Stony Brook

Mark Kurth, University of California, Davis
Maria Linder, California State University, Fullerton
Ricard Maglizzo, Brooklyn College CUNY
Farzad Mahootian, University of Alaska Fairbanks
Lon Mathias, University of Southern Mississippi
Marc McEllistrem, University of Wisconsin - Eau Claire
Panayiotis Meleties, Bronx Community College - CUNY
Bob Midden, Bowling Green State University
Barbara Murray, University of Redlands
Jeanne L. Narum, Project Kaleidoscope
Karen Oates, Harrisburg University of Science and Technology
Olarongbe Olubajo, Savannah State University
Sheila Pedigo, Case Western Reserve University
Joseph Pesek, San Jose State University
Preetha Ram, Emory University
Greg Salamo, University of Arkansas
Jill Salvo, Union College
Jerry Sarquis, Miami University
Jim Saunders, Towson University
William Scott, Indiana University-Purdue University Indianapolis
David Seybert, Duquesne University
Mike Seymore, Hope College
Dixie Shafer, Augsburg College
Uschi Simonis, San Francisco State University
Thomas Smith, Rochester Institute of Technology
Paul Smolenyak, Northern Arizona University
Larry Spears, University of Houston - Downtown
Susan Stapleton, Western Michigan University
Giselle Thibaudeau, Mississippi State University
Julian Tyson, University of Massachusetts
Mine Ucak-Astarlioglu, Pennsylvania State University
Isai Urasa, Hampton University
James Valentine, Fayetteville State University
Mark Walter, Oakton Community College
Linette Watkins, Texas State
Cathleen Webb, Western Kentucky University
Jodi Wesemann, American Chemical Society
Laura Wesson, Louisiana Tech University
Thomas Wolosz, Plattsburgh State University of New York
Justin Wyatt, College of Charleston
Lori Zaikowski, Dowling College