UNDERGRADUATE RESEARCH AT COMMUNITY COLLEGES

Edited by Brent D. Cejda
National Council of Instructional Administrators

Nancy Hensel
Council on Undergraduate Research

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Young man in suit Michael Jensen Redlands Community College

Three men in white coats, left to right Ramon Ayala, Gerardo Castillo, Mark Gianino all Southwestern College

Woman and man working at table or bench left to right Jenille Heuneman, Hugh Menilly Finger Lakes Community College

Young woman in left corner Chona May dela Cruz Southwestern College

Two women in field left to right Kyle Hatcher, Jaime Meade Redlands Community College

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Undergraduate Research in Community Colleges

Preface

George R. Boggs
President and CEO, American Association of Community Colleges

Those who study American higher education often differentiate its largest sector, community colleges, from other colleges and universities, by defining them as teaching (and more recently learning) institutions. Community colleges exist to provide educational and training opportunities to students and to respond to the educational and workforce needs of local communities. They are not seen as institutions where faculty members and students are engaged in scholarly research and the production of knowledge. Adding to the limitations of the perceived mission of community colleges is the fact that their faculty members have the highest teaching loads in all of higher education and there are no graduate (and usually no upper-division undergraduate) students enrolled who could serve as teaching assistants. And the students who are enrolled are mostly part-time and often transient.

However, the authors of *Undergraduate Research in Community Colleges* point out that undergraduate research does occur in innovative community colleges, and that it has significant value to students and faculty members. The authors note ''research is teaching.'' I would add that research is also learning, and it may be one of the most effective ways to engage students in learning a discipline. If one considers what we know about student learning, undergraduate research can play an important role in increasing both student interest and success. We know that students build upon what they already know (or think they know). A research project provides an opportunity to challenge or build upon beliefs and knowledge. We know that engagement in the discipline is important to student persistence and success. What better way to engage students than to involve them in a research project?

We know that students are more successful if they have greater contact with faculty members and other students. Research projects require students to have frequent interactions with faculty mentors, and projects usually involve teams of students. We know that students who are taught critical-thinking skills are those who are most successful, not only in college but also in life beyond college. Involvement in a research

project almost forces students to think critically about a discipline. We know that engaging students in "real world" problems increases their motivation to learn. There can hardly be a better way to engage students in contemporary "real world" problems than by involving them in research projects.

While research is teaching for the faculty and learning for the students, it is also a motivator and a form of professional development for faculty members and potentially a source of recognition for the institution. The very best faculty members find ways to engage or re-engage in their disciplines. Leading students in a research project clearly is an effective way to remain engaged in a discipline. In his chapter, David Brown indicates that undergraduate research has been "one of the most fulfilling professional activities possible" for him.

In spite of the obstacles posed by lack of research funding and high teaching loads, this publication demonstrates that undergraduate research is being conducted in community colleges across the nation. I encourage college leaders to find ways to support the energetic faculty members who want to use research as a way to promote student learning. The reasons for supporting undergraduate research include a need to increase the number of students (especially minority students) majoring in science, technology, engineering, and math (STEM) fields; the need to promote better understanding of STEM fields; the need to improve student engagement and persistence in college; the need to assist people in becoming better consumers of research; the need to develop better understanding of the scientific method and research processes; and the potential for institutional recognition.

I appreciate the contributions of the authors in making *Undergraduate Research in Community Colleges* such an important resource for community college faculty members and administrators.

An Overview of Undergraduate Research in Community Colleges

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In 2006, the Council on Undergraduate Research (CUR) and the National Council of Instructional Administrators (NCIA) received a two-year planning grant from the Advanced Technological Education program (ATE award #0603119) of the National Science Foundation. The key component of this planning grant was a series of regional conversations about undergraduate research at community colleges. This chapter describes the process of conducting the conversations and provides a summary of those discussions.

The primary goal of our CUR/NCIA planning grant was to develop a basic understanding of the status of undergraduate research in community colleges. In the process of developing this understanding, we wanted to identify potential partners from community colleges, four-year colleges and universities, business and industry, government agencies, and non-profit organizations. We also wanted to develop resources that will broaden the involvement of community college students in undergraduate research. To accomplish our goal, we worked with a steering committee to organize and develop a series of regional conversations.

Six conversations were held between October 2006 and October 2007. In chronological order, discussions were convened at Harold Washington College (Chicago, IL), Georgia Perimeter College (Lawrenceville, GA), Mt. San Antonio College (Walnut, CA), Redlands Community College (El Reno, OK), North Seattle Community College (Seattle, WA), and Bunker Hill Community College (Boston, MA). For each conversation we identified a facilitator, an individual knowledgeable about undergraduate research, and a local contact—someone to assist with the identification of potential participants for the conversation, as well as the logistical aspects necessary to conduct it.

Our goal was to have between 20 and 25 individuals at each conversation. Within each group, the ideal was to include faculty members and administrators from at least four community colleges and two four-year institutions, as well as two ''outside''

individuals. The outside individuals were drawn from business and industry, governmental agencies, and other non-profit organizations such as museums. In total, the conversations involved participants from 27 community colleges, 13 four-year institutions, and 8 outside entities.

After each conversation, the facilitator, the local contact, the Executive Officer of CUR and the Executive Director of NCIA held a debriefing. As a result of the initial debriefings, we made a number of logistical changes. The initial conversations were two days in length, and a number of participants were not able to attend both days. As a result, we shortened the schedule for three of the conversations to facilitate attendance of the participants throughout the entire event. Based on feedback from the participants at the earlier events, we included in the final three conversations current or former community college students who had participated in research activities. In each instance, the students made brief presentations about their research and commented on the importance of participation in undergraduate research to their educational growth and development.

At each conversation, the facilitator guided large- and small-group discussions focusing on three broad questions related to student research:

- What is currently happening regarding undergraduate research at community colleges?
- In what kind of research activities would community colleges like to involve undergraduates?
- How could CUR and NCIA help community colleges realize their goals for students' participation in undergraduate research?

The facilitator summarized primary points from large-group discussions and gained consensus regarding the importance of these points among the participants. Recorders did the same for each small-group discussion, and a sharing session at the end of each small-group session created opportunities for expanded discussion among the total group of participants. All points were captured using laptop computers, and the files were then combined to prepare a report for each conversation. The participants received the report and had the opportunity to provide additional comments.

Initial Observations on Undergraduate Research at Community Colleges

It should be noted that we did not frame the conversations around the CUR definition of undergraduate research. Rather, we looked to the community college participants to identify research projects or research-like activities that involved the students attending their institutions. Based on the notes from the conversations, we have formulated four general observations about the status of undergraduate research at community colleges.

Like the multiple missions of this type of institution, definitions of such research vary and thus consensus regarding a single definition may not be possible. Some participants pointed to the developmental mission of the community college, stressing the importance of providing students with the opportunity to develop skills and abilities that would enable them to conduct independent research. Others pointed to the workforce and continuing education missions of community colleges and the importance of applied research (addressing a specific problem) to terminal associate degree and certificate programs, as well as to efforts to retrain displaced workers. And there were examples of community college students conducting investigations that made original intellectual contributions to the disciplines, most often among students who had transferred or planned to transfer to baccalaureate programs.

The variety of descriptions of undergraduate research illustrates our second observation. An overwhelming number of participants said that in the community college, undergraduate research was more of a curricular enhancement or a ''value added'' component of the curriculum than a component of a research agenda. Several faculty members at community colleges emphasized an underlying principle—that research is teaching. The evaluator of our grant pointed out that these arguments are similar to those made by proponents of problem-based learning or faculty members who incorporate case studies into the learning process. As regional, place-based institutions, community colleges' curricula reflect the needs of the region and the students who attend the institution. Students' descriptions of research in agricultural areas at the Oklahoma conversation, on wetlands in the Seattle area, and in medical studies in Boston support our observation and point to community colleges' mission of sustaining existing economic entities, as well as serving as a catalyst for entrepreneurial strategies.

A third observation is that community colleges do not always promote student activity as research. Faculty members shared examples of research activities that began or were components of community service or service learning programs. Others used terms such as ''projects'' or ''assignments,'' explaining that they feared the term ''research'' might scare some students away from participating. In a number of instances, the necessary skills to conduct research (e.g., developing a hypothesis, conducting a literature review, identifying appropriate statistical tests) have been included as components of various courses. In these instances, the students do not actually complete a research project, but the skills developed through a series of courses provide them with the capacity to conduct independent research.

Our final observation is that undergraduate research at community colleges is more commonly the result of the efforts of an individual or of a small group of faculty members than an institutionalized program that extends across the college. At colleges where both faculty members and the institution have made a commitment to undergraduate research, we contend that the activities appear to be sustainable and of a level comparable to such programs at four-year colleges and universities. There are, however, a number of places where undergraduate research would cease should a

particular faculty member or a supportive administrator leave the institution. It is safe to say that the greatest challenge facing undergraduate research in community colleges is institutionalizing comprehensive programs.

Categories of Undergraduate Research in Community Colleges

Based on the examples shared by participants in the conversations, we have developed four categories of undergraduate research at community colleges.

Incorporating research into the curriculum

We found three subcategories of activities in which community colleges and their faculty members are incorporating research into the curriculum. As noted, a number of instructors are revising their curricula to incorporate components of research into coursework. Examples range from using statistical software packages such as SPSS or SAS to writing literature reviews, developing research hypotheses, or formulating problem statements. Also included in this category are community colleges that have developed and implemented course offerings that ''mirror'' courses offered in undergraduate research programs at four-year institutions and that have developed articulation agreements to facilitate transfer of the course(s) from the community college to the senior institution. The third subcategory includes institutional efforts to include research as a value-added component of the educational program, requiring all students, not just ''volunteers,'' to complete a research activity or project.

Utilizing research activities in place of ''cookbook'' laboratories or assignments

As our funding was through the Advanced Technological Education program, a majority of the faculty participants were from disciplines in which courses commonly include both a lecture and a laboratory component. A number of faculty members indicated that they have begun to replace standard lab exercises with activities that focus on and develop research skills. In some instances, instructors are moving from holding labs that simply demonstrate that students can follow directions to asking students to develop an appropriate experiment or exercise that is directly related to the lecture. An additional approach in this category is the use of case studies that involve students in the development of a research study to address concepts or topics in a course.

Conducting applied research at the community college

We are defining applied research as activities designed to address practical problems. Examples of such research cited in our six conversations included increasing the amount of milk produced by animals and verifying predictive models for weather forecasting. We found examples of community college students conducting applied research on campus and at locations in the local communities. Although there were examples of four-year faculty members collaborating with community colleges on applied research, participants did not share any examples of applied research conducted by community college students at four-year colleges or universities.

Conducting basic research at the community college

We are defining basic research as activities that are designed to expand the knowledge of a scientific question. Examples of basic research by community college students that we encountered included examining how various strains of cells could be grown for research purposes and used in studying the genetic codes of insects. Many observers might think that true basic research does not occur at community colleges; however, one person commented that faculty members and students at community colleges can take more risks with their research because it is not typically part of the tenure and promotion process and expectations for results are much lower. We found examples of students conducting basic research at community colleges and at four-year colleges and universities, as well as with business, industry, and other external agencies. In some instances, research partnerships had been developed between faculty members from the two- and four-year institutions, providing the opportunity for both community college faculty members and students to participate in the research programs. In other instances, faculty members at four-year institutions are involving community college students in research programs. We did not find any instances in which faculty members at four-year institutions were involved in basic research projects with undergraduates at community college campuses.

What Research Activities are of Interest to Community Colleges

At each conversation, discussion concerning incorporating or expanding undergraduate research at community colleges turned towards challenges or barriers to such efforts. Participants indicated that the greatest challenge was funding. Mentioned most often was the fact that funding, and thus faculty compensation, at community colleges is driven by the credit hours generated. Developing mechanisms to enable faculty members to receive credit for guiding projects and mentoring students is important to institutionalizing an undergraduate research program. Mentioned almost as often was the fact that most community colleges lack the laboratory and research facilities necessary to provide opportunities for large numbers of students to participate in research. A close third was the cost of purchasing and maintaining state-of-the-art technology and equipment to support research activities. Several participants mentioned that teaching loads at community colleges were high, making it difficult for instructors to take on the additional responsibilities of mentoring undergraduate researchers. The typical characteristics of community college students as commuters, attending part-time, and having the outside demands of family and work were identified as additional problems in recruiting students for undergraduate research.

A number of participants noted that business and industry often utilize a ''team'' approach to research projects and questioned how important it was for community college students to complete applied or basic research on their own. In regard to career programs, one person stressed that community colleges were doing a disservice if they only prepared ''workers,'' arguing that the research activities important for

students in such programs were those that moved the students to the position of being considered as "a vital component of the research team."

At each of the conversations, the transfer of "research courses" to four-year institutions was identified as a barrier to promoting undergraduate research at community colleges. We did find a few examples of institutional articulation agreements, but no statewide approaches that would provide opportunities for transfer to any four-year institution. From the student perspective—credit for undergraduate research was problematic from two perspectives. First, the credits that students completed in such projects were most often accepted as "electives," rather than as credits towards a major. Second, students reported that they often had to enroll in particular courses or independent-study hours to participate in research, thus taking on additional tuition costs.

Although discussion on this question skewed to barriers and challenges, three specific purposes of undergraduate research in community colleges emerged from the conversations. Universally, the community college participants are interested in research activities that will contribute to their students becoming better consumers of research, enhancing both their professional and personal lives. Community college faculty members involved in workforce development, certificate, or terminal associate-degree programs are interested in research activities that meet the needs of the employers who will hire their students. Faculty members involved in transfer programs are interested in research activities that provide a seamless transition for their students into research programs at the receiving four-year institutions.

What can CUR and NCIA do to Facilitate Undergraduate Research?

The response from an overwhelming number of participants in our conversations was that there is an interest in expanded undergraduate research at community colleges and support for CUR and NCIA to continue efforts to facilitate such an expansion. Faculty participants included both individuals already engaged in undergraduate research and those interested but not yet engaged. Faculty who are "new" to undergraduate research are primarily interested in how community colleges have developed and implemented research activities. Faculty engaged in undergraduate research are interested in how community colleges have developed partnerships with four-year colleges and universities, business and industry, governmental agencies, and non-profit organizations. All faculty members are interested in ways to promote research to community college students. The participants suggested that CUR and NCIA facilitate the identification of funding sources and the development of grant-writing skills to help faculty members secure the necessary resources to conduct undergraduate research projects.

A number of community college administrators attended the conversations, and they also were in favor of CUR and NCIA continuing to facilitate undergraduate research. Foremost among their concerns was learning how community colleges "counted"

mentoring student researchers in faculty teaching loads. The second most common concern was securing the necessary funding to provide adequate facilities and equipment to conduct research, as well covering the ongoing expenses of maintaining laboratory facilities and providing supplies. Administrators also shared the faculty interests in learning how community colleges had developed and implemented activities and developed partnerships. Finally, community college administrators were concerned that not all of their faculty members would support attempts to implement an undergraduate research program and wanted to learn how other administrators had dealt with naysayers.

Summary

Evaluations of the conversations indicate that the events helped develop and expand networks among faculty members and administrators from community colleges, four-year institutions, governmental agencies, non-profit organizations, and business and industry. Moreover, the conversations sparked interest in developing research activities at institutions that have not fully incorporated the concept, as well as interest in additional activities at institutions where students have engaged in research. Through the networks developed in the project, CUR and NCIA are pleased to provide this monograph as a resource to those interested in undergraduate research in community colleges.

The Search for Synergy: Undergraduate Research at the Community College

James Hewlett
Professor of Biology, Finger Lakes Community College

Undergraduate research is not only the essential component of good teaching and effective learning, but also ... research with undergraduate students is in itself the purest form of teaching (Research Corporation and Doyle 2000).

The American Association of Community Colleges (AACC) reports that as of January 2007 an estimated 6.5 million students were enrolled at a community college (2.7 million full-time). Accounting for approximately half of the U.S. postsecondary population, these large enrollment numbers highlight the increasing impact that community colleges are having on postsecondary education in the United States. The impact is equally dramatic when considering the role that community colleges play in the education of students in science, technology, engineering and mathematics (STEM) disciplines. In 1999 and 2000, close to half of the more than 740,000 graduates earning bachelor's degrees in STEM disciplines had attended a community college (NSF/SRS 2004).

The role of community colleges in undergraduate education is even more prominent for students in specific underrepresented groups. More than half of Native American and Hispanic undergraduate students are enrolled in community colleges (NSF/SRS 2003). These statistics suggest that any broad-based plan to reform undergraduate science education must rely heavily on the capacity of community colleges to implement that reform. In order to realize progress, initiatives to increase the number of students from underrepresented groups pursuing advanced degrees in science and engineering must acknowledge the important role of community colleges.

Literature on the reform of undergraduate science education is extensive, and reports from a variety of organizations have focused on some common recommendations, including the importance of integrating inquiry-based methods of teaching and research experience into undergraduate education. Central to the reform movement is the idea that learning science should be an active endeavor that focuses on science as a process (NSTA, 1996). Conceptual understanding of scientific principles can be enhanced through inquiry-based instruction and problem-based learning strategies

(NRC, 2000). Reform should involve the integration of an undergraduate research experience as early as is practical in the education of STEM students (NRC, 2003b). In addition, the reform must include a well-defined strategy of assessment that involves evaluation tailored to the specific mission and student demographics of the institution (NRC, 2003a).

Taken together, the recommendations make clear that community colleges must take a leadership position in implementing reforms that involve the integration of inquiry-based instructional models and undergraduate research. While educators may agree on *why* this type of reform must occur, the significant challenges and barriers related to community colleges raise the essential question of *how* such reform will actually take place. Many of these barriers are unique to the community college as an institution, and effective models of integration and implementation are lacking. A review of the development of the undergraduate research program at Finger Lakes Community College (FLCC) in Canandaigua, NY, illustrates the challenge of implementing undergraduate research in community colleges. Our efforts had a modest beginning, and the story is full of serendipity, dead ends, naysayers, but, most importantly, examples of student success.

In 2001, Finger Lakes Community College began an Associate of Science Biotechnology Program in response to an increase in demand for high-tech employees from a growing biotechnology industry. While the program began with only five students, an investment in laboratory space and instrumentation soon followed and continued over the next few years with support from industry and funds from the National Science Foundation (NSF). While four-year colleges frequently rely on the research labs of their faculty members to support undergraduate research programs, community colleges are often asked to use teaching labs for undergraduates' research. In many cases, these labs are ill-equipped and over-utilized. Although not specifically designed to support an undergraduate research program, the investment in the biotechnology program at FLCC was the beginning of several years of important infrastructure and capacity building. The infrastructure associated with the new technical program was a key element in the ''butterfly effect'' that soon followed. However, it would be several more years before a formal undergraduate research program would be envisioned, based on the lessons learned during the early stages of this pedagogical journey. In hindsight, in fact, it is clear that undergraduate research at FLCC began as an alignment of several seemingly unrelated events.

Ironically, the beginnings of a formal undergraduate research program at FLCC can be traced to a scientific question exchanged during a chance encounter between two faculty members in 2001. Anne Schnell, associate professor of environmental conservation and a volunteer for Braddock Bay Raptor Research (BBRR), was wrestling with an important problem related to BBRR's raptor-banding program. Records sent to the Federal Bird Banding Laboratory on Red-tailed Hawks did not contain information on the sex of the individual birds released with bands. While most raptors are sexually dimorphic, the Red-tailed Hawks lack this characteristic.

Banders processing Red-tailed hawks in the field are forced to enter "unknown" in the sex field on the data records. Being familiar with the biotechnology program and its capabilities, Professor Schnell inquired about the ability to determine the sex of a bird from a blood sample. Within a few months, a protocol for determining sex from whole blood was developed, and faculty members and students began processing the more than 300 samples brought into the lab. Soon several novel research questions were developed, and students began participating in customized, credit-bearing, independent studies. Faculty members quickly recognized the transformative potential of immersing students in research experiences. The Red-Tailed hawk program at FLCC led to the institution's very first Barry Goldwater Scholar and also resulted in several undergraduate grant proposals receiving funding from the Rochester Academy of Sciences.

A year later, in fall 2002, Bruce Jackson, director of biotechnology at Massachusetts Bay Community College, announced that he was seeking student applicants from community colleges for a project funded by the NSF's Undergraduate Mentoring in Environmental Biology (UMEB) program. The project, Research Integrating Molecular and Environmental Science (RIMES), was established to increase the number of underrepresented minority and female investigators in the environmental sciences. Under RIMES, Dr. Jackson established an international environmental-research effort for undergraduates on the island of Montserrat, a British territory in the Lesser Antilles.

Montserrat is home to an active volcano, which began erupting in 1995. While the activity of the Soufrière Hills Volcano has been intermittent, several of the eruptions have produced widespread devastation, which led to two thirds of the island being restricted to an exclusion zone, barring all residents from entering. Repeated flows of fluidized hot rocks and gases have buried both the capital city of Plymouth and the international airport. RIMES scientists focus primarily on the effects of the volcanic activity on the various ecosystems and are actively involved in the restoration effort that continues to this day. Students selected to travel to Montserrat under the mentorship of a RIMES investigator receive up to two years of intensive, interdisciplinary research training from an international corps of researchers.

When faculty members at FLCC learned Dr. Jackson was seeking community college students, they were confident that students who had been actively involved in the Red-tail Hawk program would have both the maturity and skills to be very competitive applicants. Two FLCC students ultimately were selected and traveled to Montserrat in June 2003. Since this initial experience, FLCC faculty members and students have participated in five research expeditions to Montserrat. Collaboration with Dr. Jackson continued, and under the mentorship of RIMES investigators, a new research program was established at FLCC focusing on macro and molecular indicators of stress in coral reef ecosystems. In 2006 FLCC established a novel collaboration with Reef Check, the largest volunteer reef-monitoring program in the world. Reef Check collects survey data from over 80 different countries, and to date, every single piece

of Reef Check data generated from Montserrat was collected and submitted by students and faculty members at FLCC—a point of pride for students who have participated. The result of this activity was an expanded research portfolio that could be used to develop a formal undergraduate research program.

The expansion of research activities at FLCC quickly focused attention on one of the primary barriers community colleges face in their efforts to incorporate undergraduate research into their curricula: the ''research versus teaching debate.'' This debate combined with the stigma that community colleges' science faculty members often face in the research community, presents a challenging—and often insurmountable—problem. The challenge is getting a community of educators to see that the issue is not research *or* teaching, but the concept that research *is* teaching. Undergraduate research must be accepted by community colleges as a pedagogy and aligned with other widely accepted alternative teaching methodologies (such as collaborative learning, peer-led team learning, case studies, inquiry-based learning). Until this happens, research will always be seen by some community college faculty members and administrators as a scholarly activity with benefits that translate directly toward the field of study, with only limited capacity for extrapolation into the classroom.

As the RIMES collaboration continued to develop, faculty members at FLCC quickly realized that they lacked a model for integrating research into their science classrooms. The institution had been successful in its efforts to involve students and faculty in primary research, but had not taken on the challenge of ''institutionalizing'' the experience and employing it as a foundational teaching tool. This would change with the release of *BIO 2010: Transforming Undergraduate Education For Future Research Biologists* in 2003 by the National Academies of Science.

Since its publication, *BIO 2010* has been the topic of numerous articles and scientific and educational conferences, as well as the driving force behind countless curriculum reform projects. The study, sponsored by the National Institutes of Health (NIH) and the Howard Hughes Medical Institute (HHMI), focused on biomedical research, but contained recommendations that impact all of the scientific disciplines. The fifth recommendation in the report suggested that students should be encouraged to pursue independent research as early as possible in their education. For community colleges, this would mean in either the first or second science class of their postsecondary careers.

The *BIO 2010* report has had a transformative effect on a variety of institutions, but translating the recommendations into the FLCC science curriculum was clearly going to be a challenge. For two years, our efforts to achieve some level of integration of undergraduate research into early science courses met with limited success. While faculty members were united in their understanding of the need for curriculum reform, the application of theory to practice remained elusive.

A 2003 article in the journal *New Directions For Teaching And Learning* would help catalyze that reform. The article, by Jorge Perez of LaGuardia Community College, contained the results of a survey of 40 community colleges that did not offer undergraduate research experiences (Perez 2003). Respondents cited financial constraints and ill-prepared students as their primary reasons for not establishing a research program. The article sparked a self-study at FLCC using Root Cause Analysis (RCA) tools. RCA is often associated with the analysis of accidents or problems in industrial settings, but the tools used for RCA are robust and applicable to a variety of problem-solving scenarios. The problem was simple: With the release of *BIO 2010,* faculty members at FLCC were aware of *what* should be done, but were unaware of *why* reform efforts were falling short. Using RCA on this problem led to some very interesting outcomes that were not associated with financial barriers or the ill-prepared student. The RCA results focused around five central themes that were then used by FLCC faculty members as they moved toward integrating undergraduate research into the curriculum. The results suggested that such an integration could be facilitated by:

- Developing a compatible community college faculty model;
- Aligning the research experience with other widely accepted instructional pedagogies, including case-based and problem-based learning;
- Establishing a faculty development program to build a platform of research skills;
- Creating a collaborative of community college and four-year college researchers to expand access to primary research questions and build a network of mentors;
- Disseminating curriculum reform recommendations and efforts to community college administrators and leaders.

The Root Cause Analysis of the barriers preventing the successful establishment of an undergraduate research program at FLCC led to construction of a testable model of integration. The case study method (CSM) of teaching was an instructional methodology employed by several FLCC science faculty members and was seen as potential source of synergy. A plan was hatched to develop novel case studies around research questions being explored within RIMES and the two research programs under way at FLCC. The case studies would be aligned with current freshman biology syllabi and employed in the classroom. The classroom activity would introduce students to the core research questions, and an associated laboratory activity would then be created to expose students to the research methods associated with answering those questions. The primary goal of this part of the model was to engage students and begin the process of introducing process-thinking skills in the context of an authentic research question.

A sophomore-level course would then be created to provide students with an opportunity to further explore the research questions they encountered in the freshman-level course in an independent way. The course would also include instructional elements designed to train students in basic research skills (experimental design, data analysis, etc.). In 2005, a proposal to support the development of this model was submitted to the Course Curriculum and Laboratory Improvement program at NSF. The

proposal included a collaboration of representatives of three community colleges (Finger Lakes Community College, Monroe Community College, and Genesee Community College), one four-year school (Rochester Institute of Technology), two established NSF programs (Research Integrating Molecular and Environmental Science and the National Center for Case Study Teaching in Science), and two environmental organizations (Reef Check and Braddock Bay Raptor Research).

The award supported faculty training in the case study method, a field methods workshop, development of the sophomore research course, and the ongoing RIMES and Red-Tail research. Lessons learned from this pilot study were used in an expanded Phase II proposal in 2008 that included two additional community colleges (Tompkins-Cortland Community College and Delaware Technical and Community College), an additional ongoing NSF project (Taking Delaware's Biotechnology Education to the Next Level), a state government agency (New York State Department of Environmental Conservation), and two additional environmental research organizations (The Nevis Biodiversity Project and The Terramar Foundation). The Phase II proposal included support for an extensive evaluation of the project's goals, and it is anticipated that formative and summative data will begin to become available in 2010—a twist not lost on the stakeholders in the project.

The Phase II proposal addressed one of the core themes that had emerged from the Root Cause Analysis, namely the need for a compatible community college faculty model. On July 19th, 2007, the National Science Foundation convened a "conversation in the sciences" with professionals from across the country, titled "Vision and Change in Biology Undergraduate Education, A View for the 21st Century." Included in the conversation were the presidents of the National Academy of Sciences, university deans, program directors from the Howard Hughes Medical Institute and the National Institutes of Health, senior faculty members from major research institutions (Georgetown, Columbia, Duke, North Carolina, Michigan), and program officers from every area of the NSF's Division of Biological Sciences. Of the 50 individuals invited to the summit, only three were from Community Colleges, and Finger Lakes Community College was at the table. During the meeting, Peter Bruns, vice president for Grants and Special Programs at the Howard Hughes Medical Institute, said that "at the core of biology education reform is the undergraduate research experience, which must be integrated as early and as often as possible. What is lacking is a good model for this level of integration." A discussion regarding the role of community colleges ensued, and the issue of teaching load was addressed. In the end, the conclusion was that the current community college faculty model was not compatible with sustaining a long-term undergraduate research program.

The typical teaching load for science faculty members at Finger Lakes Community College is 20 to 25 contact hours per week, with some faculty members carrying as many as 30 contact hours in a given semester—a load that certainly is not conducive to maintaining a research program. One solution is to issue temporary "release time" in order to help faculty members establish projects, but this quickly raises questions

of sustainability. What is required is a merger of teaching responsibilities with the undergraduate research initiative. The development of the sophomore-level Research Methods course is one solution to this problem. Students exposed to projects in the freshman biology courses via realistic laboratory experiences and inquiry-based curriculum modules could further explore their research questions by enrolling in this sophomore-level course. Faculty members teaching this course would then have the contact hours become part of their teaching load.

This model, however, is not fully sustainable as an institutional effort to reform the curriculum using undergraduate project-based learning. At issue are the number of faculty members able to teach the course during any given academic year and the amount of work faculty members and students would have to undertake outside of this course. Liberal-arts colleges and research universities solve this problem by limiting teaching loads for their science faculty members (6 to 10 contact hours per semester). These institutions then require their faculty members to actively engage in primary research, and these faculty members make efforts to incorporate undergraduates into their labs. What is needed at the community college is a similar model that focuses on the primary mission of teaching and instruction, but encourages the development of research programs and undergraduate research projects for the purpose of teaching biology.

Our proposal to NSF in 2008 involved maintaining the current minimum teaching load of 17 contact hours for FLCC science faculty members, but redefining five of those hours for faculty members actively engaged in research involving undergraduates. It was felt that while four-year schools often have a nebulous definition of ''active,'' a community college would require a more detailed description to ensure that the research was being utilized primarily as a teaching tool. The goal was then to work with faculty members and administrators to refine this definition, with the goal of eventually institutionalizing a version of the faculty model. The model was included in the NSF proposal in an effort to solve two problems often cited regarding proposals from community colleges. The first problem involves NSF officials' concern that the faculty cannot sustain an active research program outside of its heavy teaching load. The second issue is that general institutional ''buy-in'' is often lacking in such proposals.

Defining the five hours of active research and instruction was complicated and involved input from the faculty, administrators, and the current literature on reform of science curricula. Everyone involved agreed that several iterations would be required before any true consensus was achieved. The model would need to simultaneously capture the mission of the institution, meet the needs of the students, and give faculty members incentives to join the effort. The first iteration of the model emerged in 2007 and was included in the 2008 proposal. In the initial pilot of the model, five hours of the faculty load would involve ''active'' research with undergraduates. In order to meet this definition, the individual faculty member would be required to:

- Submit an annual report to demonstrate engagement in primary research;
- Incorporate his or her project/research into the freshman biology curriculum as both a classroom curriculum module and a laboratory experience;
- Participate as an instructor in an annual professional development workshop where training on the classroom and laboratory activities would take place for all biology faculty members (both full and part-time);
- Demonstrate either an inter- or intra-departmental collaboration;
- Team teach the Research Methods course and mentor students who enroll in the course to explore questions related to the faculty project;
- Demonstrate that, as a teaching tool, the project includes both a math and a writing component;
- Develop and demonstrate the use of assessment tools based on the General Education Criteria for the Natural Sciences at FLCC.

The sustainability of research programs and project-based curricula at community colleges was an issue that required attention from the very beginning. The Root Cause Analysis had revealed that at the core of the issue for community colleges is a lack of access to a community of researchers at both the two-year and four-year levels. These networks will be a critical component of any program to sustain undergraduate research at the community college level. They provide access to novel research projects, lead to sharing of resources and best practices, encourage collaboration on projects, and help in creating opportunities for students at community colleges to transfer to four-year institutions.

In 1998, the National Science Foundation surveyed students who had attended a community college before going on to graduate with a bachelor's or master's degree in a science or engineering field. The most important reason respondents cited for attending a community college was to complete credits toward a bachelor's degree (NSF/SRS 2004). As other community colleges develop undergraduate research programs, they will need to connect these programs to the four-year schools to which their students traditionally transfer. With respect to curriculum development, courses that rely on project-based learning need to be constructed so that students at the community college receive credit that applies toward their two-year degree and also transfers to a four-year institution. To ensure the proper development of a sophomore-level advanced research course, faculty members from two- and four-year schools need to collaborate to construct the course's pedagogy and framework.

A traditional method for developing research skills in science students at community colleges is to connect those students with active research programs at four-year institutions using internship programs. The curriculum reform model described here strives to keep the research experience in the community college while maintaining the essential connection to the four-year institution. Faculty members in the Environmental Science Program at Rochester Institute of Technology (RIT) were approached early in the development of our model in order to begin developing a regional network. Faculty members from RIT and FLCC are working together to identify research

questions that can be adopted and adapted to the program at FLCC—an effort that includes the development of novel case studies for use in the freshman biology course. This will help build a more diverse project portfolio at FLCC and establish important collaboration between the two institutions. As faculty members identify areas of collaboration, opportunities for students to collaborate on research projects begin to emerge. The resulting connection provides the two-year college student with another level of mentorship and strengthens the pathway for transfer to the four-year institution. The connection is further strengthened by the fact that students who transfer from FLCC to RIT will be able to take their research questions with them. In addition, students who transfer to RIT will be recruited back to FLCC as leaders of peer-led teams to mentor freshmen entering the FLCC research program. These students will receive payment from a peer-tutoring fund or academic credits from RIT (or a combination of both). Peer-led team learning is an instructional methodology used widely at both RIT and FLCC, and combining it with the case study method has been shown to be a highly effective strategy (Hewlett, 2004). Transfer students recruited back to FLCC will lead case study discussions in freshman biology courses, mentor sophomore research students, and collaborate with FLCC and RIT faculty members on novel research projects as part of their undergraduate science education.

Network building must also involve an invitation to other community colleges to begin developing their own programs. As a leader in the reform effort, FLCC is working with faculty members at Tompkins-Cortland Community College (Ithaca, NY), Genesee Community College (Batavia, NY), Monroe Community College (Rochester, NY), and Delaware Community and Technical College (Newark, DE). As community college research programs mature, networks can become useful tools in the construction of regional project portfolios. These portfolios can then be used by faculty members at community colleges to collaborate on a variety of levels as they build their programs. With the primary focus on undergraduate education, an atmosphere of sharing and mentorship will lead to benefits that the entire network can tap into. There are many barriers and challenges associated with integrating undergraduate research into community college curricula, and a network can act as a clearinghouse for best practices and provide opportunities for resource sharing.

Dissemination of a model for integrating undergraduate research at a community college will be the primary focus of future efforts at FLCC. Testing, evaluating, and refining the model and its various elements is the current priority. Synergy was sought from the outset. Successful pedagogical tools were already being employed in the classroom, and several faculty members had already begun to develop research programs in which students were engaged. Student-transfer opportunities had been established, and mature faculty collaborations were operating in support of other projects. The model needed to bring these elements together in a way that not only supported research by undergraduates, but also helped reshape the culture at FLCC.

References

Bransford JD, Brown AL, and Cocking RR (eds.) and Committee on Learning Research and Educational Practice. M.S. Donovan, J.D. Bransford, and J.W. Pellegrino (Eds.) (2001).

Commission on Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.

Hewlett J. 2004. In Search of Synergy: Combining Peer-Led Team Learning with the Case Study Method. *Journal of College Science Teaching.* 2004;33(4): 28–31.

NRC, *How people learn: Brain, mind, experience and school: Expanded edition.* Committee on Developments in the Science of Learning. Washington, DC: National Academy Press, 2000.

NRC, *Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics.* Washington, DC: National Academy Press, 2003a.

NRC, *BIO 2010: Transforming Undergraduate Education For Future Research Biologists.* Washington, DC: National Academy Press, 2003b.

NSF/SRS (National Science Foundation, Division of Science Resources Statistics). *Women, Minorities and Persons With Disabilities in Science and Engineering 2002.* NSF 03–312. Arlington, VA, 2003.

NSF/SRS (National Science Foundation, Division of Science Resources Statistics. *The Role of Community Colleges in the Education of Recent Science and Engineering Graduates 2004.* NSF 04–315. Arlington, VA, 2004.

NSTA (National Science Teachers Association). *NSTA Pathways to the Science Standards.* Arlington, Va.: NSTA Press, 1996.

Perez J. Undergraduate Research at Two-Year Colleges. In Kinkead J. ed New Directions For Teaching And Learning; no. 93, Spring 2003.

Research Corporation and Doyle, M.P. (eds.) *Academic Excellence: The Role of Research in the Physical Sciences at Undergraduate Institutions.* Tucson, AZ: Research Corporation, 2000.

A Model of Interdisciplinary Undergraduate Research Experiences at a Community College

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In response to the clear need for authentic, engaging research experiences for undergraduates early in their academic careers, North Seattle Community College (NSCC) has designed and implemented a model that provides rich interdisciplinary research experiences for its students. Conducting student-centered research in the unique setting of a community college has provided both unexpected challenges and rewards, and the experience clearly illustrates the importance of strong institutional support and rich collaborations between both faculty members and outside experts.

Introduction

At North Seattle Community College (NSCC), we are in our third year of creating powerful, embedded, basic research experiences for our first- and second-year science students. We have embarked on this effort to address several critical areas of concern among science faculty members at community colleges: recruiting and retaining more science majors, providing meaningful and accessible learning experiences for a diverse student population, and providing opportunities for pre-teachers to engage in learning experiences that reflect current philosophies in the teaching and learning arena. We also have inadvertently discovered that the creation and implementation of these programs can provide a powerful opportunity for a community of faculty members and students to come together and advance their understanding of science, teaching, and learning.

Students who enter college with the intent of pursuing a science major often change their minds, citing disinterest during introductory courses as their primary reason (Seymour & Hewitt, 1997). In addition to difficulties in retaining science majors, pre-service K-12 teachers often take only freshman- and sophomore-level science courses. Thus it follows that K-12 science education cannot be improved until 100- and 200-level science courses at colleges are restructured (NRC, 1996). This is particularly important at community colleges, where the education of many of our future scientists

and K-12 teachers begins. In fact, 44 percent of all recent STEM graduates nationwide have attended a community college (Kincaid, et al, 2007).

Participation in undergraduate research has been linked to greater gains in learning, increased retention, greater participation in campus activities, and integration into the culture and profession of the discipline. These research experiences also foster interaction between students and faculty and strengthen peer groups, both of which have been shown to positively affect cognitive and behavioral development (Astin, 1993). Thus, engaging students in a meaningful research experience early in their academic careers can have lasting implications for both initial student success and long-term development of a community of innovative, enthusiastic teachers and scientists.

The community college setting, where faculty members are not expected to conduct research and where financial support for research is limited, creates an opportunity to rethink the role of undergraduate research in teaching and learning. This represents a fundamental paradigm shift in which the student's research is no longer a piece of some larger question or study; the student experience is itself the final outcome. This liberating shift in thinking allows us to focus on creating meaningful experiences for our students that will empower and inspire them as they move forward in their science education.

Our setting also provides unique challenges, as there are no ongoing research projects for our students to simply "plug into." Thus, the research questions themselves can and must be deliberately designed for the benefit of student learning. As our undergraduate research experience is closely tied to an interdisciplinary science program that integrates chemistry and biology, we want to engage our students in research questions that require them to incorporate critical concepts from both disciplines and to engage them in real-world problems. Our initial theme, described in more detail below, was the carbon cycle, a complex system requiring an understanding of both critical biological and chemical concepts. In addition to the need to move fluidly between disciplines, this theme also forced our students to think about research on both global and local scales.

Adapting global research to a local scale is attractive in multiple ways. It allows students to see immediate connections between their work and the larger body of knowledge; they thus begin to see themselves as contributing members of a scientific community. Situating the research experience in the students' immediate environment is logistically much simpler, and, more importantly, it helps them connect classroom theory to local contexts. As many local environments have not been heavily studied, a local emphasis also provides the opportunity for students to do authentic, basic research and contribute to the body of knowledge on carbon cycling.

As neither of us had extensively studied the carbon cycle, we sought an outside collaborator with recent research experience in this area. We were fortunate to quickly

partner with a graduate student, Sonya Remington, at a nearby research university. The collaboration greatly contributed to the design of the research experience and also added to the interdisciplinary nature of our program. Initially borrowing, and eventually purchasing, a single critical instrument allowed us to generate large amounts of data from a nearby, unstudied wetland. Thus, our students were able to generate novel data that contributed to the body of knowledge on carbon cycling while working closely with both their faculty members and an expert in the field. As we expand our collaborative model, this use of outside experts with an interest in fostering rich educational experiences continues to play a pivotal role.

In the sections that follow, we provide a more detailed account of our model for embedding undergraduate research experiences early in the academic careers of the diverse set of students who start their development as teachers, scientists, and citizens at community colleges. We believe this model provides a powerful means to engage our students and spark their interest in science early. In addition, it fosters the critical thinking skills and close bonds with peers and faculty members that facilitate success in future academic pursuits.

Background

NSCC was established in 1970 as a two-year public college, one of 34 community and technical colleges in Washington State. It is part of the Seattle Community College District, which also includes Seattle Central and South Seattle Community Colleges. NSCC is a commuter college with an enrollment of approximately 6,000. The student population has an average age of 30, and 62 percent are women. Many of the students at NSCC work full-time, and many others receive financial aid as a means to fund their education. One important goal of our science division is to prepare students to successfully and confidently transfer to four-year universities with the knowledge, skills, and values to be ready for the upper-level coursework in their major. It is well known that when community college students transfer to four-year institutions, they tend to lack knowledge of research-related opportunities that are typical stepping stones to graduate school and beyond. Community colleges have an opportunity to bridge this gap and move these typically non-traditional students one step forward in their quest to pursue advanced degrees in the sciences.

NSCC is well known for its vibrant, liberal-arts style Integrated Studies Program, which offers interdisciplinary learning experiences primarily for students in the humanities and social sciences. This student-centered program provides the opportunity to be more engaged with classroom-based activities that involve exploration of complex questions, problems, and or issues that are often too broad to be adequately studied within a single discipline. In 2004 we decided to create similar interdisciplinary opportunities for science majors, adding biology and chemistry to the disciplines represented. The initial goal was to design project-based and interdisciplinary modules that engaged students in problem solving at the interface between the two disciplines. The long-term goal was to develop a year-long sequence (the first at NSCC) in which

the entire first year of science majors' chemistry and biology coursework would be taught in an interdisciplinary and research-based context.

In addition to NSCC's Integrated Studies Program, the chemistry department had already begun developing both research-based lab activities and inquiry-based classroom activities. The department was committed to more deeply engaging students in the co-construction of knowledge, developing their awareness as reflective learners, and helping them take responsibility for their own learning. As the curriculum development process continued, opening up the program to undergraduate research activities was part of a natural progression toward an increasingly more student-centered approach to education.

While NSCC is an urban college, it is fortunate to have recently restored wetlands on campus. These wetlands provide critical habitat for some of the area's largest breeding populations of native amphibians and provide critical flood- and water-quality protection for the Thornton Creek watershed. NSCC's biology program has a long history of using the wetlands as both a teaching tool and an opportunity for students to conduct service learning; extending its use to undergraduate research was a natural next step. These campus wetlands consist of multiple permanent and ephemeral ponds, providing an immediately accessible, diverse set of conditions in which to investigate a variety of scientific questions, including how carbon moves through a wetland system.

The final factor that played a pivotal role in the initiation of undergraduate research at NSCC came directly from the students themselves. The more responsibility faculty members gave students, the further students pushed towards independent investigation of their own questions. This process continued until ultimately it led to ongoing and extended student efforts to produce results that could be presented at undergraduate research conferences. The factors involved in initiating research by students at NSCC can therefore be summarized as a combination of forward-thinking faculty members, motivated students, and creative curriculum design that has been a part of NSCC culture for 30 years.

How Students Participate in Research Activities

At NSCC, undergraduate research currently is under way in three disciplines—psychology, chemistry, and biology. Here we focus on the research conducted in the later two disciplines. Since our students' research in the sciences grew out of our rich tradition of interdisciplinary studies, the initial pilot was an integrated studies program known as Atoms to Ecosystems. This program operated for two years as a "soft link" between a section of cellular and molecular biology (the first quarter of our three-quarter series for biology majors) and the second quarter of first-year chemistry.

In the integrated studies program, the curriculum of both the separate courses was restructured to better reflect the connections between the two disciplines. In addition,

students could opt to enroll in an additional two credits of independent study. In classes ranging from 24 to 32 students, 6 to 9 students would typically opt for the additional credit. These students met for an additional two hours, one afternoon per week. Their work in this section was initially focused on reading and interpreting papers relating to our theme for the quarter, global carbon cycling. As the quarter progressed and the students became more skilled with the instrumentation used to measure carbon dioxide exchange, they began to generate hypotheses about the movement of carbon dioxide through wetlands and to design experiments to test their hypotheses. In both the years in which we ran this "soft link," a subset of these students (4 to 7) chose to continue their research into the following quarter, eventually completing a project they could write up and present at several undergraduate research symposia. Thus, the initial experimental design was conducted in class, but the data collection occurred largely outside of class time. These students met regularly with one or both of the faculty members involved, and one or both faculty members were typically present with the students during their data collection. Preparing the data and writing up the research for presentation was also done in a collaborative fashion, with groups of students and faculty members meeting for several hours at a time to create the final product. In this pilot effort, the modest set of laboratory supplies needed by the students was obtained through the lab fees they paid when enrolling in the program.

Because of the clear value of both the research experience and the integrated format for student learning, the integrated studies approach was expanded to become a fully coordinated, year-long experience for science majors. In this new format, a single cohort of students completed their entire year of chemistry and biology in an interdisciplinary manner, with faculty members from both disciplines present during all classes. The large number of contact hours for the program (16 hours per week) and the long duration (three quarters) created a strong context for embedding undergraduate research in the curriculum. In this embedded model, students gained the necessary skills and discipline-specific grounding during their first quarter, designed and began their research projects during the second quarter, and finished their data collection, analyzed their results, and presented their work during the third quarter.

The goal of this embedded model was to successfully engage the entire cohort of 40 freshmen and sophomores in meaningful, authentic, student-driven research projects that could ultimately be presented at an undergraduate research symposium hosted by a nearby four-year institution. Students were introduced to a reasonably broad range of research topics that were feasible at our institution based on available resources, and they were then free to form their own groups based on their interests. As in previous years, the carbon cycle played a large role, with our unique instrumentation and access to a local expert providing the foundation for the research of approximately half of the student groups. In addition, we also partnered with a chemist from Central Washington University (CWU), Anne Johansen. In this partnership, NSCC provided the space and modest facilities required for the CWU group to install an ultrafine particle collector on campus. Our students could then help collect these

particles and conduct their own analysis of several of the size fractions using an on-campus GC-MS. The research opportunities available to our students also expanded when an NSCC faculty member in microbiology, Suzanne Schlador, volunteered her time as a consultant to two of the student groups.

Based on these resources, the individual student groups developed their research question around the available technologies, equipment, and expertise. To manage the large number of student research groups, we established rigid deadlines for structured proposals, timelines, and progress reports. The submission and feedback of these various components were managed electronically through the use of an e-portfolio system. Groups were given some class time to conduct research and meet with their faculty mentors, but most experimentation and data collection were conducted outside of class time. Thus, support from our laboratory staff was critical in allowing students access to lab space and equipment when faculty mentors were unavailable. As before, modest amounts of supplies for student projects were paid for by students' lab fees. For the research projects related to this year-long sequence, students were asked to turn in a list of needed supplies and justification for them that faculty members could review before materials were ordered. Students conducted their research either in the field or, largely, in classroom labs when classes were not in session. The one exception to this was the use of a small, dedicated room by the students conducting molecular biology experiments. This space provided both a darkroom and a more isolated environment for the handling of toxic chemicals, thus minimizing any inadvertent contamination of teaching labs. Students conducting this work were trained and supervised by the faculty mentors.

As our first year in this fully integrated, year-long model drew to a close, 32 students from our initial cohort of 40 had completed their research projects and presented them at both our own "Day of Learning" and at the undergraduate research symposium held by a nearby four-year institution. Currently, we are conducting assessment projects to evaluate the impact of this experience on student learning and confidence. We also have begun to recruit the next cohort of students and are revising the curriculum to better meet student needs involving both the interdisciplinary focus of the course and the embedded research experience.

Work Processes and Resources

Central to the success of developing a meaningful undergraduate research program was our initial partnership between three faculty members from the University of Washington (UW) School of Oceanography and our own campus. This three-way collaboration included the biogeochemistry graduate student from UW, Sonya Remington, and the authors of this chapter—a biologist who has been teaching at NSCC for many years and a chemist who also teaches at NSCC and brings a background in educational research to the partnership. NSCC's location near the university was ideal for creating this collaboration rich in scientific, teaching, and educational research expertise.

This partnership grew out of an inquiry about teaching opportunities made by Sonya Remington, the UW graduate student, to the science faculty at North Seattle Community College. She was interested in participating in a teaching-related project that went beyond the walls of the classroom. The timing was extraordinary, since we had just begun to create the interdisciplinary experience for science majors described earlier and were in the process of designing multi-week interdisciplinary and research-based lab projects. Remington was pursuing a PhD in oceanography with a focus on the ecology of tropical river systems. Her work provided an ideal platform for students to engage in original research related to the global carbon cycle and global warming. Much of her research was conducted in Brazil and was occurring as the students pursued similar work in the NSCC campus wetlands. Remington won the UW Huckabay Teaching Fellowship in May 2005 to complete this work. She was funded to develop a three-week interdisciplinary, research-based module (CO_2 Flux in Aquatic Ecosystems) centered on climate change, her primary dissertation research topic. She also was interested in gaining experience in curriculum design and teaching with a diverse student population. She contributed her scientific expertise pertaining to cutting-edge interdisciplinary research, while at the same time gaining valuable experience and mentoring in curriculum development, teaching, and conducting educational research about student learning.

The initial stages of our undergraduate research program began in chemistry and biology courses as embedded research experiences and as a part of a seminar course that was newly developed and taught by two NSCC faculty members on their own time. As an introduction to the CO_2 Flux in Aquatic Ecosystems module, chemistry students read primary literature on carbon cycling (Richey et al, 2001) in preparation for a two-hour class session in which they learned about the graduate student's ongoing, inherently interdisciplinary carbon-cycling research in the Amazon River basin (Remington, et al, 2007). In laboratory and field sessions, students learned techniques that were common practice in Remington's oceanography research group, such as Winkler titrations to measure dissolved O_2 concentrations and aquatic respiration rates (Wetzel and Likens, 1991) and how to use a CO_2 Flux Dome to quantify the influx or outflux of CO_2 from aquatic ecosystems (Alin et al, 2006). As a result of this successful project for our general chemistry and biology students, North Seattle Community College obtained the funds (from NSCC's internal Universal Technology Fee Granting Program) to purchase a CO_2 Flux Dome identical to the instrument used in the Amazon River basin. The third year of the program brought some support from the institution in the form of an agreement to offer the fully coordinated chemistry and biology year-long program for science majors, and thus credit the embedded research experience towards the faculty members' teaching load. We will continue with our year-long, interdisciplinary program for academic 2008-09; however the research component still has been primarily driven by the two faculty members involved with its initiation.

Attributes and Problems in Development and Implementation

The development and implementation of the undergraduate research program at NSCC has brought both growth and success, as well as unexpected challenges and

barriers. The organic nature of the program's initiation provided the college with immediate success, but left the faculty members involved wondering how to build a program that is sustainable and attractive to students, faculty members, and the college's administration.

At the heart of the current success with the design and implementation of this research program is the great benefit that results from a collaboration that is mutually beneficial. It is well known that when diverse perspectives are brought to a project, the possibilities for innovation and unique creation expand and deepen. The initial collaboration among a chemist, a biologist, and a biogeochemist was an example of coordinated efforts and expertise that led down a path of rich opportunities for both learners and teachers. The collaboration fostered a creative process that was friendly, exciting, and meaningful. Ideas brought to the table were listened to, respected, and worked into the curriculum or future plans for expanding the program. This faculty team was especially interested in gaining a richer understanding of students' learning as undergraduates engaged in sustained scientific inquiry. The team shared ideas, strategies, student learning data, and provided feedback for team members every step of the way. The team became acutely aware of the power of open-ended, inquiry-based experiences for students and had the opportunity to use these moments of awareness as inspiration for moving forward with their own understanding of teaching and learning. The graduate student involved is well on her way toward an academic career in interdisciplinary research, curriculum design, and study of student learning in a research context. The NSCC faculty continue to co-create innovative learning experiences for students and share their experiences with other faculty members across the state.

The creation of new relationships served to enrich the experience for all involved. Students formed close working relationships with their peers and with their faculty mentors, which turned out to be a highlight of the experience. Reports from students indicate that their connection to the research mentors was a primary motivator when it came to sustaining their efforts in their coursework, research projects, and future educational progress (i.e. selecting a major and/or a university to attend). All former research students continue to check in with faculty mentors on a regular basis, and semi-structured interviews with the students one and two years after their research experience continue to shed light on the positive and long-lasting impacts the experience has had on their lives.

Another compelling benefit for both students and faculty members during the implementation process emerged from the practice of viewing everyone involved as both learners and teachers. The content areas covered in research investigations were often outside faculty members' expertise, yet regular, ongoing discussions of results and next steps occurred throughout the implementation of the program. Students independently mined the primary literature for background information as a springboard for the next research steps, which served to bring faculty members up to date with current research trends and approaches. Students found it compelling to be in a

position to update their faculty mentors with knowledge and/or expertise. The interdisciplinary nature of the projects also allowed students to view how one mentor's expertise played a specific role in moving the research forward, while the other mentor participated as a learner along with the students. It was also true that as students became increasingly comfortable, they shared ideas about issues related to teaching and learning, as well as personal information, all of which helped faculty members better understand the challenges and issues facing a wide range of the student population.

In addition to the benefits to students and faculty members, several college staff members invested their time and energy in helping students successfully carry out their projects. In fact, the entire staff of science technicians became key players in moving students forward with their work. They provided after-hours access and supervision, knowledge and training on instrumentation, and creative troubleshooting when it came to modification of tools and procedures. Not only did students benefit from this relationship, but reports from staff members indicated that these activities also were exciting and rewarding for them, particularly when the students went off to prestigious symposia to present their projects. Interacting with students daily created a connection between the important work that goes on behind the scenes in a science department and the frontline work that occurs at the interface of teaching and learning.

The challenges involved with the initial phase of providing opportunities for undergraduate research centered on the typical shortage of time and resources. Community colleges are not traditionally prepared to handle the structures needed to successfully carry out research projects. This may include a lack of facilities or instrumentation, mechanisms to reward and motivate both faculty members and students who participate, and funding for supplies. It is also important that the college leadership develop a clear understanding of both the possibilities and limitations of undergraduate research programs. At NSCC, science faculty members have struggled to gain recognition for the work they do with students in a research context, particularly in having this research component applied towards their teaching loads. This will perhaps always be a challenge when budgets are tight, because creating meaningful research experiences and mentoring a variety of student projects clearly requires a smaller class size and more contact time, and therefore more expense, than a traditional lecture course. While the college administration would like to embrace undergraduate research, we, as a college, lack a sustainable model to support the current level of activity. Increased communication and creative thinking are needed to help all parties become aware of the challenges and opportunities that lay ahead.

Another challenge came in the third year of our program when we began to require students to conduct research as a part of the year-long interdisciplinary program, as opposed to letting students decide whether to conduct research. Requiring students to participate clearly changed the dynamic of several of the student research groups and, in some cases, diminished the enthusiasm that we had encountered in previous

years. Requiring students to participate also meant that the program became much larger in a very short period of time, while the number of mentors remained the same. As we attempt to make our model sustainable and attractive to other faculty members, we envision moving more towards a system that allows students to self-select for the research experience. Sadly, this process of self-selection will inevitably leave out some students who have been most profoundly affected by the experience. But clearly, creating a sustainable model for institutionalizing undergraduate research will require balancing the needs of students, faculty members, and the institution.

Applicability

Our model for undergraduate research at a community college has broad applicability as other institutions begin to recognize the value of creating research experiences for science students early in their academic careers. This early experience is especially critical for recruitment and retention of students in STEM fields, but it creates the additional challenge of developing meaningful projects with students who have very little academic grounding. Our mandate as a community college also requires a fundamental paradigm shift towards viewing research strictly as a pedagogical tool. Other institutions will undoubtedly struggle with many of the same issues of resources, time, and student preparation.

We are in the early stages of disseminating our model and have been presenting both our model and results at regional conferences. One method for disseminating our model for undergraduate research involves collecting and sharing evidence of student learning in a research context. More specifically, we have developed a method to capture student progress through video-documentation of students as they participate in a classroom-based learning group seeking an understanding of an interdisciplinary, complex problem that is directly related to their research projects. The learning-group curriculum is designed to actively engage participants in co-construction of scientific concepts, drawing as a means to represent and debate theories, and applying newly constructed knowledge to more complex problem solving and explanation of ''real world'' phenomena. The video-taped dialogue is then transcribed and imported into a PowerPoint presentation along with still images of students working in their learning groups. One key feature of this method is to slow down the exchange to allow for deep listening and reflection by active viewers, including the students, educational researchers, administrators, and others. We hope this work will provide the bulk of evidence needed to iteratively redesign our research program, make claims about the ''leverage'' that students gain as a result of research-based learning, provide a means for dissemination, and provide the justification needed to institutionalize research-based interdisciplinary opportunities for community college science students.

Future Status

The tremendous amount of work involved in effectively mentoring so many student groups has compelled us to revisit and revise our model for undergraduate research.

We are firmly convinced that a successful model must first be invigorating and manageable for faculty members (and students) before the practice can be truly institutionalized. While we clearly see the benefits of requiring all students in our program to complete a research project, engaging those students who lack the time or motivation to successfully complete such a project consumes a disproportionate amount of time. Thus we intend to shift towards a model in which multi-week, research-based activities are embedded in the curriculum of our science majors. This, we believe, will give students the practical experience of designing, conducting, and presenting their own experiments, in addition to generating the increased confidence and enthusiasm we have seen in the students who have completed research projects over the last three years.

In this new model, students who have successfully completed the first year will be eligible to enroll in a newly developed research course. In it, they will design, conduct, and present truly original research under the close mentoring of both a faculty member and former students. This inclusion of former students as peer mentors is a critical element, and one we hope will prove rewarding for the student mentors and provide a critical time-saving component for the faculty member. In addition, placing the research in a separate course allows the college to generate limited revenue (in the form of tuition) and the faculty members to have their efforts in supporting undergraduate research recognized as part of their annual teaching load. This shift to a deliberately designed research course will also facilitate the implementation of research experiences by other faculty members throughout the district.

With the obstacles reduced, we hope to encourage other faculty members to begin mentoring students in research projects. Our college continues to expand its annual Making Learning Visible event, a day-long celebration of learning across all divisions on the campus. This event provides a unique opportunity for both students and faculty members to see directly the high-quality research being conducted on our campus and the clear benefits to the student presenters. We are hopeful that undergraduate research on our campus will continue to grow in a sustainable manner as both faculty members and students become more aware of the benefits and possibilities of this powerful pedagogical tool.

Rewards and Lessons Learned

NSCC's undergraduate research program is clearly in its infancy, yet the rewards for students, faculty members, and the college have surpassed all expectations. Each year for the past three years, a new cohort of NSCC students have presented their research projects at the University of Washington Undergraduate Research Symposium. The number of students participating steadily increased from four students in 2006, to seven students in 2007, to 32 students in 2008. Upon completion of a second year of research, the first cohort of students was selected to present its research in Washington, D.C., at the CUR-sponsored Posters on the Hill Symposium. Students not only

presented their work at the poster symposium, but also met with state Congressional members to discuss the benefits of conducting research early in the college experience.

The rewards for students reach far beyond symposium presentations. Anecdotal reports indicate that major transformations occur that involve altering and solidifying educational and career goals and students' viewing themselves as competent and capable participants in the scientific community. Students have reported immediately pursuing research experiences when they transfer to four-year institutions and doing so with confidence and knowledge of the process from beginning to end. Students also report the benefits and joy that accompany working as a part of a community and building lasting friendships and working relationships with peers. These peer groups tend to remain cohesive into a second year at NSCC and, in some cases, well beyond their time at the college.

The rewards for faculty members are centered on their growth as mentors and teachers, as well as the energizing spirit derived from open-ended and inquiry-based investigations that are new and interesting to all parties involved. Due to the nature of NSCC's collaborative approach, faculty members work closely with each other to create possibilities for students. Co-creating these possibilities for communities of learners brings an aesthetic to the teaching profession that is difficult to reproduce outside of this context. Faculty members are also driven by deep feelings of satisfaction when students quickly transform into critical, responsible, and reflective thinkers who successfully function within the scientific community. In short, faculty members have the opportunity to work closely with colleagues and students in a learning environment that fosters creative and critical thinking, and ultimately pushes everyone involved to a new level.

Although it is early in our progression towards institutionalizing undergraduate research, the benefits to the college are becoming increasingly clear. The Atoms to Ecosystems program helped the college to be recognized by the state and obtain additional "high profile" STEM funding. Our undergraduate research program was also recognized by CUR as a regional leader in providing such opportunities for community college students. NSCC was accepted into CUR's Regional Workshop Program on Institutionalizing Undergraduate Research and has hosted a regional meeting to foster these same partnerships amongst other interested community colleges. Participation in these programs has allowed faculty members and administrators to form relationships with other institutions and gain much-needed perspective on the challenges and opportunities involved in creating and nurturing undergraduate research programs.

Our program at NSCC has progressed quickly to involve more than 30 students. Although this progress appears to be a success story, the college continues to struggle with how to sustain and then expand the program to include even more faculty members and students. We believe that it is vital, as the program moves through this period of growth, that the focus remain on student learning, not on a faculty research

agenda or college priorities. We also believe that working with college leadership on issues of teaching load, resources, and time commitments should occur early in the process and that laboratory staff should be included in all discussions during the planning phase. Continual assessment of student gains and perceptions of learning should be embedded in any undergraduate research program, providing a powerful tool to bring together faculty members and other key participants for rich conversations about student learning. The unique challenges of the community college setting require that research programs be student-focused and centered on available resources. This represents both a challenge and an opportunity for interested faculty members to involve outside experts and stakeholders in creating mutually beneficial relationships that both expand and deepen the research experience for students. The creation of these deep, meaningful experiences takes time, energy, and vision. Faculty members interested in developing an undergraduate research program should look to their colleagues, students, administrators, staff, and community to find allies with whom to create rich, synergistic partnerships around student learning, thus expanding the tremendous benefits to be had from authentic, student-centered research experiences early in the academic careers of science students.

References

Alin S, Salimon C, Richey J., Krusche A, Holtgrieve G, Neu V. Carbon Dioxide Flux and Transfer Velocity Measurements in the Amazon (Brazil) and Mekong (Southeast Asia) River Basins. *Eos Trans. AGU, 87(52), Fall Meet. Suppl., Abstract.* 2006: B31C-1135.

Astin AW. *What Matters in College?* San Fransisco, CA: Jossey-Bass, 1993.

Kincaid WB, Narum J, Keoupelis T, Shriner W, Adams-Curtis L, Agwu N, Dorland L, Figueroa D, Fletcher L, Guertin L, Higginbotham C, Higgins T, Lewis E, Oakes J, Sharma JC, Shih S. 2007. *Bringing Community College Faculty to the Table to Improve Science Education for All.* PKAL Volume IV: What works, what matters, what lasts. 2007.

National Research Council (NRC). National science education standards. Washington, DC: National Academy Press, 1996.

Remington S M, Strahm B D, Neu V, Richey JE, Brandao da Cunha H. The role of sorption in control of riverine dissolved organic carbon concentrations by riparian zone soils in the Amazon basin. *Soil Science*. 2007(172): 279–291.

Richey J E, Melack JM, Aufdenkampe AK, Ballester VM, Hess LL. Outgassing from Amazonian rivers and wetlands as a large tropical source of atmospheric CO_2. *Nature*. 2002 (416): 617–620.

Seymour E. Hewitt N. *Talking About Leaving: Why Undergraduates Leave the Sciences*. Boulder, CO: Westview Press, 1997.

Wetzel RG. Likens GE. *Limnological Analyses.* New York, NY: Springer-Verlag, 1991.

Institutionalizing Applied Research at Redlands Community College

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This chapter describes the efforts to institutionalize applied research at Redlands Community College (Redlands) in Oklahoma. Redlands is a comprehensive community college. Its mission is teaching, and applied research augments this mission, adds to the students' academic and skill-building experiences, and clearly promotes a *research is teaching* model.

Introduction

Redlands Community College in El Reno, Oklahoma, is incorporating applied research into the curriculum of several academic programs. Currently, the programs most actively involved in applied research are located in the math and science and agriculture departments. An important aspect of our efforts is that the faculty members who have introduced research into their classes are following the philosophy that research is teaching. Our initial efforts indicate that one of the greatest values to undergraduate research is the students' engagement. While there may be some exceptions, the vast majority of students who participate in research activities take ownership of their projects, often doing more than is required and frequently leading their instructors into new avenues of inquiry. In applied research, students are not passive learners; they become actively engaged in the learning process.

Background

The State of Oklahoma introduced a strong research initiative as we entered the 21st century. Beginning in 2000, significant research funds were made available for this initiative, but none were awarded to community colleges. Clearly, if our students were to compete successfully with those who attended four-year institutions, they needed to overcome this disadvantage. Redlands students needed to be able to do more than understand the research process, and our administration realized the importance of engaging our students in research.

Larry Devane, president of Redlands Community College, has long had a vision of undergraduate research. Without a doubt, his support and leadership have greatly

contributed to the extent that applied research has become institutionalized in the curriculum. When the college acquired its first agriculture site in 2000, President Devane named the site The Redlands Community College Agriculture Education and Applied Research Center. However, his vision would take a few more years to become reality.

The site had been unused and not maintained for several years. Buildings were in disrepair, and the weeds had grown so high some buildings were "discovered" as the mowing began. The center is now a showcase for agricultural education and applied research. Thanks to a statewide capital bond issue, public/private partnerships, and several large and small grants, the center is now home to a meat-goat demonstration laboratory, a grade A goat dairy, and a state-of-the-art artificial insemination laboratory. These programs all involve applied research, and students are involved in all research activities.

Prior to the state-wide initiative, Redlands had participated in two major activities that introduced our students to research. Since 2001, the college has been part of the IDeA Network of Biomedical Research Excellence (INBRE). This network, funded through the National Institutes of Health's Institutional Development Award (IDeA) Program, provides funds for regional universities and community colleges to engage students in research projects. Oklahoma students participate in learning and training opportunities throughout the year and may participate in ongoing research projects in the state during the summer. Redlands students most often choose to join summer projects at the U. S. Department of Agriculture Research Services (USDA-ARS) facility located in El Reno. The research facility is less than five miles from the site of the Redlands Applied Research Center and is home to the Grazinglands Research Laboratory. Redlands's INBRE activities are coordinated by Reonna Slagell-Gossen, one of our biology instructors. Mrs. Slagell-Gossen helps identify students for participation, represents the college at INBRE meetings, monitors student progress throughout the academic year and during the summer program, and generally serves as the academic and career counselor for INBRE students. Redlands students have participated in INBRE each year, with as many as 10 students participating in a given year.

The second research activity, which also began in 2001, is the Bridges to the Baccalaureate Program (Bridges). This program is expressly designed to help minority students, underrepresented in the sciences, transition from a two-year college to a four-year college. Redlands is one of several community colleges in the program that partner with East Central University (ECU) in Ada, Oklahoma. At the university, Terry Cluck and Charles Biles are responsible for securing the funding that supports Bridges, through a grant from the National Institutes of General Medical Sciences, one of the National Institutes of Health. The Bridges coordinator at Redlands is David Dalbow, a biology instructor.

Bridges Scholars are urged to become acquainted with faculty members and laboratory practices by working as an hourly paid aide during the regular semesters. Scholars attend four colloquia during the year, where they learn from researchers in various academic fields and participate in field trips to Oklahoma research facilities, including the Oklahoma Medical Research Foundation and the Oklahoma Heart Institute. Scholars are involved in a program-wide research project during the regular academic year; they meet weekly to collect, analyze, and report data on the current research project. The project in 2007-2008 for all Bridges Scholars was to collect data on airborne fungi in various parts of Oklahoma. Bridges Scholars from several different community colleges throughout the state and at ECU jointly prepare an article for publication in an undergraduate research journal.

Since Redlands's involvement in this program, 14 students from groups underrepresented in the sciences have participated, representing Native American, African American, and Hispanic populations. Twelve of these students have conducted their own research and made presentations at national conferences in New Orleans, Los Angeles, and Austin. While most students have found it convenient to work with the scientists at the USDA Grazinglands Research Laboratory in El Reno, Bridges Scholars have also participated in research at the Oklahoma Medical Research Foundation, the Noble Foundation, the University of New Mexico, the University of Oklahoma, and East Central University. These projects contributed greatly to developing the model for undergraduate applied research opportunities at Redlands and led the way for Redlands to become actively involved in applied research. Although community colleges in Oklahoma are still not participating at the rate of four-year and research institutions in the statewide initiative's research funding, Redlands and others are developing their own opportunities, gaining very small pieces of the funding pie. Redlands has been creative in identifying external support for some applied research projects and has moved forward with projects even though funding is not available. Redlands relies heavily on public/private partnerships, in-kind donations from agencies and industries, and expert guidance from research facilities. Contributions may be as small as bags of feed for animal research activities or as large as equipment for the dairy, such as a large donation from the DeLaval Corporation.

In 2004, Redlands was designated by the Oklahoma State Regents for Higher Education (OSRHE) as a Center of Excellence in Agriculture. This designation provided funds to support student scholarships, internships for applied research, and study-abroad opportunities. Additionally, Redlands prepared a number of grant proposals through the Oklahoma Center for the Advancement of Science and Technology (OCAST). We have been successful in securing funding through the OCAST competition for three applied research projects. Each OCAST grant funds two student internships for work on research projects. The vast majority of applied research projects at Redlands are funded through external sources, including grants and contracts, with minimal institutional expenditures.

How Redlands Students Participate in Research Activities

At Redlands Community College, students are active partners with their faculty mentors from the beginning to the end of classroom research projects. Research projects to date have largely been conducted in two departments at the college, the Mathematics and Science Department and the Agriculture and Equine Department. Both departments are rich in research possibilities, and faculty members in these departments are eager to assist in finding funding for the projects and funds to involve their students in research activities. Indeed, the entire success of undergraduate research at Redlands Community College is due to our faculty and our students. Each success brings more ideas, provides evidence that contributes to efforts to secure additional funding, and further institutionalizes our undergraduate research initiative.

At Redlands we apply a *research is teaching* model. Through the creativity of our faculty members and division chairs, each research project relates directly to course content. Although the research has an applied focus, each project also develops techniques and strategies applicable to basic research, including data collection, data analysis, preparing a literature review, technical writing, and oral and written presentations. Most projects include preparation of posters for presentations at state and national research conferences.

At these conferences, our students and faculty members are typically the only community college participants. We have become accustomed to this and are very proud to be noted as the "only community college" in the competitions and presentations. Recently, one of our freshmen, Katlyn Weathers, and her research mentor/instructor, Sam Nusz, a faculty member in the Agriculture and Equine Department, were invited to present their research project on ruminant feeding observations at a national conference; their results will be published in the journal of the Southern Association of Agriculture Research. Again, Redlands was the first community college represented at the conference. This project is also an example of partnership and cooperation. The research was conducted at the USDA research center just five miles from the Redlands Agriculture Education and Applied Research Center, and it was part of a larger research project conducted with Elizabeth Walker, a member of the graduate faculty at Missouri State University and a nationally recognized agricultural researcher.

We can also cite examples of partnerships with business and industry. Ed Zweiacher, an agriculture faculty member at Redlands, has been instrumental in forming a valuable partnership with Martin Bio-Chem, Inc., a company that has supported undergraduate research projects on several occasions. Mr. Zweiacher has designed research projects involving applications of the company's non-chemical crop stimulatant. These projects have brought Redlands new opportunities with OCAST, funding for research internships for six Redlands students over the past three years. Mr. Zweiacher's research interns are known statewide for their knowledge of the product, its applications, and research results. Students involved in this project have presented

at almost every research and student agricultural conference in the state. Under Mr. Zweiacher's mentorship, students majoring in agriculture have also had the opportunity to participate in out-of-state conferences and prepare articles for publication in agricultural journals. It is also important to note that he has provided students with these opportunities without tapping institutional budgets. More important, however, are the outcomes of his efforts. Students who admit that they had no idea what research was about, are now looking forward to continuing their education (some have expressed interest in graduate school) or have found new energy and interest in applying research to their own businesses and to their future careers.

The *research is teaching model* emphasizes the goals of improving teaching and providing expanded learning opportunities. We have achieved results we could not have imagined when we set out on this journey. Of course, we have seen small research projects brought to conclusion with suggested future research activities and projects, but most importantly we have seen students grow in confidence and express the desire to continue their education beyond the associate degree and even consider graduate school. We have seen students from small rural high schools and communities grow into accomplished presenters, teaching others about their research and mentoring other students. Students who were afraid of math and science are actively involved, eager to learn more, and to participate more fully. Students who typically fall asleep in lectures are found in the fields and in the labs from early morning to late at night working on research projects. At Redlands our research activities are not designed to compete with large research universities; they are designed to help our students be successful. Research as teaching is working well at Redlands, and we have our faculty members and our students to thank for our successes.

Work Processes and Resources

The work processes for undergraduates' applied research at Redlands are very informal at this point. Although all faculty members are encouraged to participate with their students in research projects, faculty members are also responsible for formulating the research idea and design and identifying potential funding for each project. Redlands is not a large institution (with approximately 1,500 students per year) and has very limited fiscal resources. The idea of developing an institutional research program came from faculty members who sought to engage students in practical applications for classroom lectures and assignments. Faculty members who led the way had a desire to get their students out of the classroom and into projects that reflected actual workplace experiences that applied what students were learning in the classroom. Funding opportunities to support research activities are announced campus-wide, and faculty members are encouraged to present ideas for projects that might be appropriate for these opportunities.

Faculty members who present ideas for research projects work with the Redlands Grants Development Office to try to identify external funding for their project. Unfortunately, funding opportunities often do not exist, but every attempt is made

to proceed with the research project through redesigning the project, identifying internal resources, and creativity. There is no formal application to do a research project at Redlands at this time. Some faculty members present projects that can be accomplished with no external funding, utilizing the equipment and physical resources available at the college or within the department. In such instances, there is simply an institutional commitment to help faculty members and students participate in undergraduate research. Once the project is designed, the faculty member who will mentor the project selects student participants based upon their interest and their ability to participate.

In order to help faculty members further research initiatives, applied research was added to my portfolio in 2004 and my title became vice president for Grants Development and Applied Research. I work with faculty members to identify the goals of each research project and assist with finding and/or designing financial support for each research project. The combination of grants development with applied research reflects the college's need to seek external funding for research projects, but also demonstrates the administration's commitment to provide as much support for undergraduate research as possible.

Attributes and Problems in Development and Implementation

Although there are many positive attributes associated with undergraduate research at Redlands, the most outstanding is the involvement of faculty members and students. Our faculty members are creative, accustomed to accomplishing goals and objectives with limited financial resources. Of course, there are faculty members who have no interest in research, and these individuals are not pressed to participate. Interested faculty members participate voluntarily. This process, while born out of necessity, provides a strong and supportive cadre of individuals who are actively engaged in research activities. They participate because they want to, not because they expect any financial reward or out of a need to conduct research for promotion or tenure. Their only reward is working with students on a new level and integrating new activities and concepts into their teaching portfolios. Faculty members' involvement by choice is a real asset to undergraduate research at Redlands and sustains the projects.

The limited financial resources I have discussed will, of course, not come as a surprise to other community colleges. Our projects are limited in depth and duration only by the lack of funding available. Unfortunately, there is no easy answer to this challenge, so we attempt to meet this challenge in diverse ways. Where possible, we ask partners to provide support for projects. These requests often result in in-kind contributions of supplies needed for the project. When funding opportunities arise, we attempt to match projects of interest with the funding source and compete for funding dollars. Fortunately, we have more successes than failures in securing grants or contracts, but the competition is becoming more and more rigorous. Future funding of this

type is dependent upon each project's success, placing the burden of continuation on the faculty members and students participating in each project.

Applicability

Undergraduate research is not exclusive to Redlands Community College, of course. Many community colleges in Oklahoma are actively involved in undergraduate research at varying levels. Oklahoma City Community College, under the guidance of Charlotte Mulvahill, has been actively involved in applied research in biotechnology with freshman and sophomore students. Their projects have received funds from the National Science Foundation and the statewide INBRE resources. Dr. Mulvahill has indeed led the way for community college research activities in Oklahoma. There is an emerging interest to add undergraduate research to the Special Interest Groups associated with the Oklahoma Association of Community Colleges. At Redlands we believe that research activities are very applicable to a community college's mission, and we continue to encourage our colleagues to seek ways they too can integrate the basic principles of research into a variety of classroom experiences.

Future Status

Undergraduate research becomes more institutionalized at Redlands as funding and additional research ideas become available. We hope to expand research activities beyond the math, science, and agriculture areas. In fall 2008, we planned to start an informal research study group of faculty members interested in integrating research activities into their classes. The proposed working name, the Undergraduate Research Support Group, will be charged with encouraging and supporting faculty members interested in models of research as teaching.

Undergraduate applied research is a part of Redlands Community College now, and although it may take on a variety of forms and functions, we believe it will be sustained within the mission of the college.

Rewards and Lessons Learned

We are still learning about the benefits and responsibilities of research at the community college. According to Amanda Evert, Agriculture and Equine Division Director, ''There is a lot of undiscovered territory between a high school science fair project and a master's thesis.'' Evert highlights some of the rewards and lessons learned from the Redlands' agriculture students who have participated in research projects throughout the past four years. According to Evert, ''Student researchers have overwhelmingly reported a high level of satisfaction with their projects. All of the student researchers to date have completed their associate's degree with above a 3.0 GPA. In focus groups held after the final presentations, students unanimously reported an interest in continuing their education at the university level. Sixty percent of students who completed applied research projects indicated an interest in earning a master's

degree and continuing to conduct agricultural research. Faculty members involved in the projects also report a high level of satisfaction. They have had the opportunity to travel to national conferences to present findings from their experiences, received technology and tools to improve the academic experiences in their classes, and published their findings in journals, magazines, and conference publications. The college has benefited from the student projects with increased support from public and private entities impressed with the quality of undergraduate applied research projects conducted by freshman and sophomore students at Redlands Community College."

The greatest reward a faculty member and a college can receive is the knowledge that their students are actively engaged in learning and are succeeding in their academic pursuits. These rewards are being realized at Redlands Community College where *research is teaching*!

Engaging Undergraduates in Chemical Research at Southwestern College

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This chapter provides an account of the establishment and expansion of an undergraduate research program in the Department of Chemistry at Southwestern College. Faculty members and students engage primarily in basic research, applying spectroscopic methods to analyze and characterize various materials, ranging from human cells to metal oxide powders to amorphous glasses.

Introduction

Southwestern College (SWC), one of the 110 California community colleges, represents the only institution of higher education in south San Diego County and enrolls approximately 19,000 students. SWC is a minority-serving institution with a student demographic that includes 60 percent Hispanic, 13 percent Filipino, and 5 percent African-American students. It sits in a bi-national and bi-cultural region, eight miles from the international border with Mexico.

The Department of Chemistry at SWC currently employs four full-time faculty members and, depending on staffing needs, between six and 10 part-time faculty members. The department serves approximately 500 students across the chemistry curriculum each semester. Students in the Department of Chemistry at SWC have been offered opportunities to engage in undergraduate research since early 1999, shortly after the author joined the full-time faculty.

As do many two-year college students, through internships and fellowships SWC students engage in research activities at four-year institutions and corporate and government laboratories. Efforts to send SWC students to these laboratories have been supported through federal funds from the National Science Foundation (NSF) Advanced Technological Education (ATE) program and the Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP), as well as the National Institutes of Health's Bridges to the Future program. Further, since 2006 annual donations totaling $120,000 from the Dr. David W. Lipp Foundation have supported opportunities for SWC student scholars to engage in research activities; the donations also have provided scholarships and contributed to a growing endowment.

While these off-campus research experiences are valuable, can be quite meaningful, and will always be an important part of the campus culture, I will focus here on *resident* undergraduate research, undertaken on the SWC campus. Students who engage in research conducted on-site at SWC are provided an experience that is typically of significantly greater depth than their counterparts who participate in off-campus opportunities. On-campus research projects at SWC are ongoing, year-round. While six to eight weeks of summer undergraduate research off campus are surely valuable and enriching, when the students return to SWC in the fall semester, their connection to a research mentor is significantly reduced or possibly even terminated.

Undergraduate research has an inherently high pedagogical value and serves to enrich the environment of an institution regardless of the academic setting in which it is undertaken. It is possible that undergraduate research may provide a more meaningful experience at a community college, where it is not a part of the historical culture of the institution and where many of the students are from lower socio-economic backgrounds and often are the first in their families to attend a postsecondary institution. Undergraduate research has unquestionably had a significant transformative impact on the SWC students who have been able to participate. These experiences ultimately have prepared them better for transfer to four-year institutions, including eventual graduate studies. They also have made them stronger applicants for scholarships and internships and have increased their ability to secure employment in local industries.

Background

Two primary factors facilitated the initiation of resident undergraduate research activities in chemistry at SWC. They were the addition of a faculty member (the author) who had an interest in directing undergraduate research and the receipt of a National Science Foundation (NSF) award (DUE #9850951) that provided for the acquisition of an extensive collection of analytical instruments. The equipment acquired through the NSF grant includes Nuclear Magnetic Resonance (NMR), Fourier Transform Infrared (FTIR), Ultraviolet-Visible (UV-Vis) spectrometers and Gas Chromatography/Mass Spectrometry (GC/MS) and High Performance Liquid Chromatography (HPLC) systems. The department has since added an Electron Paramagnetic Resonance (EPR) spectrometer to the assortment of analytical and spectroscopic instruments. These various instruments permit students to obtain information pertaining to the structures of molecules, separate and isolate individual components from mixtures, and measure the concentrations of specific substances in mixtures.

The instrumentation obtained with the funds from the NSF grant was primarily intended for use in laboratory courses across the curriculum, and it is indeed used in General Chemistry, Organic Chemistry, and Analytical Chemistry. However, in addition to strengthening the content of the formal teaching curriculum, possessing

a wide-ranging assortment of instruments opened the door to establishing a research program at SWC.

Researchers at SWC primarily engage in basic research, with a strong emphasis on molecular spectroscopy as applied to materials characterization. The types of systems investigated have varied widely and have fit well with the interests of students, who have a similarly wide range of educational and career goals. Systems investigated have ranged from human cells that have been genetically engineered to tolerate desiccation, to luminescent rare-earth oxide powders, to samples of silica-based glass doped with nano-clusters of differing index of refraction that function as volume holographic gratings (VHGs).

How Students Participate in Research Activities

SWC students must be selected as undergraduate research assistants in order to participate in research activities. I select the research assistants, sometimes upon the recommendation of other professors, and serve as a research mentor. Often recommendations come from faculty members who have had the students in a chemistry class. At any given time, the typical research group contains three or four students, primarily chemistry, chemical technology, or chemical engineering majors, often at various stages in their curricula. One of the most significant challenges associated with supporting undergraduate research at a community college is the recruitment of qualified students. There are factors related to this component of developing a research program that are unique to community colleges. First, a relatively rapid rate of student turnover is inherent in the nature of community colleges. A second issue, strongly linked to the first, is that students are typically less prepared, having had fewer courses in their academic discipline, compared with undergraduate researchers in four-year institutions.

These aspects of undergraduate research at community colleges require thoughtful and judicious efforts in recruitment and preparation of student research assistants. Moreover, the nature of the work assigned to the students must be commensurate with their level of experience and understanding. One way to handle this is to assemble a research group composed of students whose experiences span various levels of courses. In this way, a ''mentoring cascade'' can be developed, with more-advanced students assisting the students with less experience. This enhances the continuity of the research group, because, as semesters pass and students advance through their curricula, the more senior students can help to foster development of more recent, less-experienced additions to the group.

Due to a variety of factors, it is rare that a student in the chemical sciences would complete his or her studies at SWC (or at most community colleges) within the ideal time frame of two years. Therefore, it is not uncommon to have a student who has completed a course in analytical chemistry and at least one semester of organic chemistry available to serve as the leading student member of a research group. This

extra coursework produces student researchers who possess a deeper knowledge of the chemical principles and who have had a richer experience with analytical instruments. They can then be offered a more profound glimpse into the scientific basis and interpretation of the research activities and can also serve as a conduit for transferring their understanding to the less-experienced members of the research group.

Students are involved in nearly all aspects of research activities. At the beginning, they typically are provided with resources in the form of textbooks, articles, primers, and Web sites where they can explore background information about the research. Moreover, they are required to read the manufacturer's user manuals for both software and hardware associated with the instrument(s) they will be using. This background reading is supplemented with lectures on basic principles and details on how those principles apply to the specific project at hand; demonstrations of the use of the instrumentation also are provided.

As a great deal of the effort associated with the research at SWC involves molecular spectroscopy, the early training activities include a great deal of hands-on experience to learn how to use spectrometers and how to apply spectroscopic methods. Student researchers are put through a "boot camp" of sorts, given samples of known composition to analyze, which allows them to check the accuracy of their results. This training is typically accomplished with a more experienced member or even a former member of the research group working with the new member(s) on the instrumentation, collecting data from samples that are simple to interpret. Not only does this method of information-transfer benefit the newcomer, but it also promotes an even deeper understanding of the spectroscopic techniques for the veteran students by providing them an opportunity to serve as instructors.

When a specific research project commences, undergraduates are included in discussions about the nature and scope of the project and the planning of experimental activities. They assist in sample preparation, if necessary, and data collection. Based on the analysis of data acquired, their insight and input are valuable in the redesign of experimental conditions and parameters.

Usually more than one unique research project is under way at any given time in the group. Each student is given ownership—and the accompanying responsibility and accountability—for a specific project or a particular element of a project. However, while one individual may bear the majority of the load for a given project, all of the students are kept apprised of the activities connected to the various projects in the group. This is accomplished informally by simple discussion carried out when students are working in the lab at the same time or more formally during student presentations in research group meetings or at meetings and conferences external to the group.

Work Processes and Resources

As I noted, one of the critical factors that facilitated the establishment of a research program in the SWC Department of Chemistry was a grant from the NSF Instrumentation and Laboratory Improvement (ILI) program. With the support and encouragement of departmental colleagues and the dean of the School of Mathematics, Science and Engineering, in 1997 during my second year on the full-time faculty at SWC, I submitted the proposal to the NSF ILI program. The NSF award of $73,400 was matched by an equivalent amount from SWC. These grant funds made it possible to acquire the instrumentation necessary to develop the research program commensurate with my expertise and interests. This NSF-funded project was unquestionably the key resource that ultimately permitted SWC undergraduates and faculty members to engage in chemical research.

Through prior connections established with individuals at four-year institutions, the acquisition of the analytical instruments paved the way to create inter-campus collaborations. These early collaborative efforts with researchers at the University of California, San Diego (UCSD) and the University of Nevada, Reno (UNR) were essentially not funded for SWC personnel, and students simply volunteered to participate. The UCSD collaboration was a well-defined project with a specific purpose. This particular group's need for consultation and spectroscopic capabilities was limited to one instance. The UNR collaboration, however, has been and continues to be an ongoing partnership. While the professor involved at UNR surely values the experimental results provided through work performed at SWC, she also recognizes the benefit of involving community college students in research activities. Therefore she chooses to collaborate with us, rather than seeking access to the same type of data from other sources.

The UCSD project involved developing a technique for measuring water levels in various cell lines of human fibroblasts using FTIR spectroscopy. The cells were genetically engineered by researchers at the UCSD School of Medicine to express high levels of the disaccharide trehalose, which is known to confer desiccation tolerance in a variety of species. The human cells were completely dried in an oven, rehydrated, and then their viability was assessed upon rehydration. The contribution made by SWC researchers was important as the water measurements were a critical aspect to this research. This work led to two publications in peer-reviewed research journals (Guo, et al, 2000; Puhlev, et al, 2001).

The research with the UNR group involves the analysis of various oxide powders, produced by reverse micelle and combustion syntheses, for the presence of trace impurities. These powders perform as luminescent phosphors, and magnetic and refractory materials. The goal is to identify synthetic pathways that result in the least amount of impurities of reagents used in the syntheses. Once again FTIR spectroscopy is employed to analyze the powders and identify the presence of organic impurities. As the optical character of the powders is not conducive to traditional transmission

infrared methods, an Attenuated Total Reflectance (ATR) accessory is employed to make the measurements. The ATR accessory was purchased with the funds provided by the original NSF ILI grant. Results from the UNR collaboration have been published in a peer-reviewed journal (Graeve, et al, 2006), presented at a national meeting, and contributed to the master's thesis of a UNR graduate student (Corral, 2004).

Early in 2006, the NSF Division of Industrial Innovation and Partnerships (IIP) announced a new supplemental program within the Small Business Innovative Research/Small Business Technology Transfer (SBIR/STTR) program. Created to support community college research teams, this initiative, the SBIR/STTR Phase IICC program, a collaboration with the ATE program, provides supplemental awards to small businesses that are current Phase II SBIR or STTR grantees. Supplements have a maximum value of $40,000, and no less than 75 percent of the funds must be allocated for the community college team.

In 2007 the SWC research team established a collaboration with Ondax, Incorporated, a small business in Monrovia, California, that was an SBIR Phase II grantee and that produces VHGs for use in lasers and devices that utilize lasers. The collaborative research was funded with two SBIR Phase IICC supplements, with a combined amount of $60,000 for SWC, to support two individual research projects to investigate properties and characteristics of Ondax materials. One project was to explore the optical properties of the VHG materials outside of the range of wavelengths for which they are intended to function, namely the mid-infrared range. The other project was an investigation of the possibility of nanofabricating optical structures in the materials by exploiting differential chemical etching rates between the bulk glass and the imbedded nano-clusters. This collaboration with Ondax is still in progress as of this writing, but research results have been presented at several meetings and conferences, including the 2007 NSF ATE Principal Investigators Conference and 2008 CUR Posters on the Hill event in Washington, D.C.

Organizational Structure

Chemistry is one of several disciplines in the School of Mathematics, Science and Engineering at SWC. While research currently undertaken on the SWC campus occurs solely within the Department of Chemistry, there is a desire to expand research activities to other disciplines within the school and, eventually, for undergraduate research to become institutionalized across SWC. Of course this is a long-term goal, and a successful model developed in the Department of Chemistry could serve as a template for application in other disciplines.

As a means to promote cohesion among the various academic disciplines within the School of Mathematics, Science, and Engineering, to increase visibility of SWC research endeavors to outside entities, and to facilitate institutionalization of undergraduate research activities, the SWC Governing Board approved the creation of the

Mathematics, Science and Engineering Research and Training Institute (RTI) in October of 2006. The detailed memorandum of understanding, that established the RTI was crafted by the school's dean and the college's president, with generous input and feedback from key faculty leaders. The RTI creates no additional fiscal burden on the college, as all funds channeled through it are obtained from external sources. Furthermore, it creates a multi-disciplinary collaboration allowing for the efficient management of important campus initiatives such as undergraduate research. Therefore, its establishment was well-received and unanimously approved by the Governing Board.

Key aspects and responsibilities of RTI include:

- Serving as a vehicle for providing funds for student scholarships and research assistantships.
- Functioning as a clearinghouse to disseminate research and funding opportunities to SWC students and faculty members and increasing the number of students to whom research opportunities are made available.
- Pooling resources and expertise to connect projects with appropriate personnel and provide oversight of health and safety matters.

The RTI's director is the dean of the School of Mathematics, Science and Engineering, who is assisted by an Oversight Committee composed of key faculty members from the school.

Positive Attributes and Problems Encountered in Implementation

As with nearly all endeavors that explore relatively uncharted academic territory, involving community college students in research activities is simultaneously rewarding and challenging. The idea of engaging students in chemical research at SWC came about as a consequence of receiving the NSF ILI grant, and there was no history or institutional memory to draw upon in order to establish and develop a research program. Thus, the initiation of undergraduate research at SWC was inherently a process of trial and error.

Three chief factors posed the greatest challenges to establishing a research program. Sustaining a research group requires continual attention to these same issues. These challenges are creating an appropriate environment (supplies, equipment, and facilities) in which to undertake research, making time to direct and engage in research endeavors, and acknowledging and working with the diverse academic preparation and life circumstances of typical community college students.

Among the most significant challenges to supporting undergraduate research in community college settings is finding the necessary resources and facilities to carry out the research. Depending upon the nature of the research interests of the investigator, this could be a formidable, perhaps prohibitive, challenge. Similar to chemistry departments in the majority of community colleges, ours at SWC was designed solely to

function in a traditional instructional mode, having laboratories, equipment, and supplies to support instruction but not necessarily research activities. Furthermore, depending on the type of research to be carried out, departmental supply budgets most often are not sufficient to promote, support, and sustain the needs of extensive research projects.

In most circumstances, including those at SWC, external support in the form of grants and/or donations is crucial to acquiring the additional equipment and supplies necessary to create an environment conducive to undergraduate research. Once again, it was the NSF ILI grant awarded to SWC that provided the initial foundation on which the chemical research program was built. Also, in 2001, SWC was awarded an NSF ATE grant (DUE #0101729) to establish a program in chemical technology, formally known as Pharmaceutical and Laboratory Science (PLS).

Each vocational program at SWC, including the technician education programs funded with ATE grants, is eligible to receive an equal share of the annual grant received under the federal Carl D. Perkins Vocational and Technical Education Act (VTEA). This annual allocation of funds creates a mechanism to purchase equipment and supplies for instruction in courses required for the PLS program. Often these equipment and supplies can also be applied to research activities, thereby amplifying the impact of the VTEA funds.

For nearly all community college faculty members, instruction is the primary focus of their employment and the bulk of the effort expected by their institutions. At SWC the teaching load required for a full-time faculty member is 15 units each semester. An inequity exists between the rate at which lecture and laboratory hours are counted toward a teaching load, with a laboratory hour counting as 0.8 of a lecture hour. For those who teach chemistry courses with laboratory components, this can translate into a weekly assignment of 18 student contact hours. Of course, this does not include the expenditure of time for preparation and grading, all of which are done without the luxury of teaching assistants, which are not part of the community college landscape.

SWC does not provide faculty members with reassigned time for engaging in research activities. Recognizing the amount of time already required to fulfill the full-time commitment to the institution, faculty members realize that investing a great deal of additional time to direct undergraduate research can become a significant challenge. During the first several years of involving SWC undergraduates in chemical research, I volunteered many hours to oversee research projects. This investment of time is made worthwhile by witnessing and appreciating the positive impact research has on the students. Nonetheless, it can become genuinely burdensome when combined with an already considerable teaching load.

In 2005, our collaborator at UNR received a grant that included a month of summer faculty salary for SWC's contribution to the collaborative research project, which

was a welcome step forward. The budget for the 2007 SBIR Phase IICC supplements awarded to the SWC/Ondax collaboration included funds for a faculty member's salary during both the academic year and the summer. This was a major milestone in the efforts to build a more complete and comprehensive research program at SWC.

SWC students are diverse, coming from all walks of life, ethnicity, age, economic status, prior academic preparation, and family situation. This diversity makes the college environment very interesting and stimulating, but it also increases the challenge of creating and sustaining an effective research group. More often than not, students at SWC are employed and pay their own expenses. Many earn money to contribute to their family's household or are heads of households themselves. This need to earn money to support themselves and others, in addition to carrying the traditionally heavy course load of a science or engineering major, limits how involved a student may become in research.

Given many students' need to earn money, we need to understand and respect how limited students' time may be to engage in a research project, and we need to be flexible in scheduling their participation. Secondly, we need to seek ways to pay undergraduate researchers for the time spent working on research projects.

The ability to pay undergraduate research assistants at SWC is a relatively recent phenomenon, commencing in 2006. Prior to that time, students simply volunteered to participate in research projects, recognizing the valuable return on their investment of time. Beginning with the first donation from the Dr. David W. Lipp Foundation in 2006, funds were made available to compensate student assistants for work in the chemistry research group. In that year, less than 15 percent of the Lipp Foundation donation was set aside to support students in the on-campus chemical research projects. In 2007, with the advent of the NSF SBIR Phase IICC funds and a subsequent Lipp Foundation donation, support to compensate student time increased 450 percent.

Applicability

The activities that have taken place at SWC to establish and develop a chemical research program are certainly transferable and applicable to nearly any other community college where a desire exists to participate in faculty-directed undergraduate research. The same mechanisms and resources that made it possible to involve SWC undergraduates in research projects are available to any public community college where faculty members are willing to make the effort and sacrifice necessary to write and submit grant proposals and carry out the tasks set forth in the projects proposed. Of course, this assumes the presence of a supportive campus administration that also sees and embraces the value of offering on-campus research experiences to students. The support of campus administrators is vital in such an undertaking.

Future Status

The ideal future of undergraduate research at SWC would be one in which students in disciplines across the campus would be afforded opportunities to be involved in research projects. However, in order to attain that ideal, the traditional paradigm by which the community college functions would have to undergo a great deal of change. Fiscal resources to support campus-wide research activities would need to be increased, and the formula by which full-time service to the college is defined would need to be altered. This would be essential to free up more time for faculty members who choose to involve themselves in directing undergraduate research projects.

Rewards and Lessons Learned

In my experience, being a research mentor to students at a community college is one of the most fulfilling professional activities possible. Although a research experience may be short-lived or the depth of the student's investigation may be somewhat lessened due to limited academic preparation, the transformative impact of a research experience is not diminished. To witness a scientific "coming of age" take place when a student begins to grasp the power and beauty of inquiry is a remarkably gratifying reward.

Working with students at a community college brings with it a need to be flexible and compassionate about their life situations. Students at SWC are often parents and spouses with the many responsibilities and demands that come with those roles. To help students offer their best efforts, a research mentor to students in such situations must balance the structure, guidance, and discipline necessary to bring research projects to fruition with a keen recognition, understanding, and support of the factors the students face in their everyday lives.

The groups and individuals who support undergraduate research at a community college such as SWC (funding agencies, research partners, and campus administrators) have the opportunity to contribute significantly to the development of an important pool of talent for the high-technology workforce. The life-altering impact of being involved in undergraduate research isn't restricted to the students. The funding agencies, through their investment in traditionally overlooked and under-supported populations, benefit by being able to assess the impact of novel initiatives. A case in point is the NSF SBIR/STTR Phase IICC program, which has already had a major impact on SWC students. The work supported by this program has been disseminated by students at meetings and conferences from coast to coast. Collaborative partners at four-year institutions and small businesses have benefitted by having expanded research groups at their disposal. Campus administrators enjoy the reward of knowing they are part of a venture that offers SWC students the highest-quality learning experience possible, while also supporting an initiative that is important to the educational landscape.

With the sheer number of undergraduates who attend community colleges and the growing need for a talented, well-prepared workforce to propel the high-technology economy of the United States, offering research experiences to community college students is not simply a novel idea. It is an imperative matter of the highest priority. Success stories, such as ours in SWC's chemistry department, should become common and widespread.

References

Alingog M, Solano H-EM, Brown DR, Steckman GJ, Moser, C. Characterization of Glass Volume Holographic Gratings in the Mid-Infrared Range with Attenuated Total Reflectance Measurements, Student Poster Presentation at ACS Western Regional Meeting, San Diego, CA, October 2007.

Alingog M, Solano H-EM, Brown DR. Mid-Infrared Characterization of Volume Holographic Gratings and Nanofabrication of Optical Structures. Student Oral Presentation at 180th Conference of the Two-Year College Chemistry Consortium, Baton Rouge, LA, April 2008.

Alingog M, Solano H-EM, Brown DR, Setckman GJ, Moser C. Mid-Infrared Characterization of Volume Holographic Gratings and Nanofabrication of Optical Structures. Student Poster Presentation at National Meeting of the American Chemical Society, New Orleans, LA, April 2008.

Alingog M, Solano H-EM, Brown DR, Steckman GJ, Moser C. Mid-Infrared Characterization of Volume Holographic Gratings and Nanofabrication of Optical Structures. Council on Undergraduate Research Posters on the Hill, Washington, DC, April 2008.

Corral JO, Preparation of Rare-Earth (Eu^{3+}, Tb^{3+}, Tm^{3+}, and Yb^{3+}) Doped Y_2O_3 Luminescent Ceramics by the Use of Reverse Micelles, Thesis for M.S. in Metallurgical Engineering, University of Nevada Reno, 2004.

Graeve OA, Varma S, Rojas-George G, Brown DR, López E. Lope Synthesis and Characterization of Luminescent Yttrium Oxide Doped with Tm and Yb, *Journal of the American Ceramic Society,* **89** [3], 926 (2006).

Guo N, Puhlev I, Brown DR, Mansbridge J. Trehalose Expression Confers Desiccation Tolerance on Human Cells, *Nature Biotechnology* **18**, 168 (2000).

Hensel N, Wesemann J, Brown DR, Alingog M.Undergraduate Research - Discovering the Role of Community Colleges. Discussion Session at NSF ATE Principal Investigators Conference, Washington, D.C., October 2007.

http://www.swccd.edu/~rti

López E, Corral J, Vázquez R, Rebolledo O, Graeve OA, Brown DR. Analysis of Infrared Spectra of Ethanol and Diethyl Ether Trapped in Yttria Powders Doped with Rare Earth Ions, 229th ACS National Meeting, San Diego, CA, March 2005.

NSF Award DUE 9850951 - http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=9850951

NSF Award DUE 0101729 - http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0101729

Puhlev N, Brown DR, Levine F. Desiccation Tolerance in Human Cells, I. Puhlev, N. Guo, D.R. Brown, and F. Levine, *Cryobiology* **42**, 207, 2001.

Resources Available In Support of Undergraduate Research at Community Colleges

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This chapter reviews some of the many resources that are available in support of undergraduate research efforts with community college students. Included in the chapter are resources that are specific to community colleges as well as information focused on undergraduate research at universities and four-year colleges.

Until recently, much of the efforts and resources in support of undergraduate research (UR) have been focused on research universities and baccalaureate colleges. Admittedly, four-year colleges have different academic missions and serve different student populations compared to those at two-year colleges. There is, however, a great deal of similarity between two- and four-year colleges. Both institutional types are focused on the mission of teaching and on the education of undergraduates. Community college faculty may also benefit from partnerships with UR efforts taking place at research universities. These institutions have faculty, facilities, instrumentation, and other resources that may be useful to community colleges that desire to offer UR experiences to their students.

It is also important to recognize that, until recently, undergraduate research was primarily conducted in the science, technology, engineering, and mathematical (STEM) disciplines. Even today much of what we know about undergraduate research, many of undergraduate research programs, and the bulk of the external funding available in support of UR has resulted from work in the STEM disciplines. Although there is a growing UR movement among faculty in the humanities and social sciences at many community colleges, this monograph focuses on examples from STEM disciplines; thus, the resources are targeted to those disciplines. Readers are strongly encouraged to examine each of the previous chapters for examples of placing the resources into action and to be creative and to think "outside the box" in terms of how to leverage the information and resources listed in support of UR efforts.

Models for UR at Community Colleges

There are many models for undergraduate research. One of the more familiar is the single investigator driven research program model in which students assist faculty on the faculty's research project. In this model, the faculty advisor guides the student through the research process. However, there are many models worthy of investigation. Research Corporation's "Academic Excellence" edited by Michael P. Doyle (Doyle, 2000) is an invaluable resource for faculty considering starting their own individual undergraduate research programs or for departments or institutions considering developing such programs. The book discusses the value of research in an undergraduate education and gives examples of different approaches to undergraduate research. The examples are heavily focused on efforts in the chemical sciences but the information will be valuable to anyone interested in undergraduate research. If there are not adequate resources to support UR on campus, faculty may wish to consider partnering with faculty or researchers that have similar research interests at neighboring colleges, universities, or companies.

Increasingly, due to the complexity of the research problems tackled, a collaborative model that brings together technical experts from several disciplines is appropriate. This model may be advantageous for community college faculty at institutions that lack the needed culture and infrastructure (e.g., bibliographic, safety - chemical, radioactive, biological, institutional review board for human subjects research, research space, materials, equipment, instrumentation, etc.) to support the type of research the faculty member and his/her undergraduate research students wish to pursue. Raymond Turner, formerly at Roxbury Community College, developed a community-based, culturally sensitive (to students of color), collaborative environmental sciences program nicknamed FUSION (Facilitating Urban Science Initiatives by Organizational Networking) (Turner, 2004) in partnership with researchers at nearby Northeastern University and the Harvard School of Public Health. According to Turner, benefits of his model include increased recruitment and retention of students in the sciences. Another fine example of a collaborative UR effort involving community colleges is the Jet Propulsion Laboratory's Community College Consortium (JPL CCC; avail. URL: http://jplccc.jpl.nasa.gov/index.cfm and also see URL: http://protostar.calstatela.edu/cure/). The Consortium, which began in 1999, is a collaboration between the California State University of Los Angeles (CSLA), the Jet Propulsion Laboratory (JPL) and four nearby community colleges, specifically, Los Angeles City College, East Los Angeles College, Los Angeles Southwest College, and Pasadena City College. JPL CCC runs a year-round community-based National Science Foundation (NSF)-funded Research Experiences for Undergraduates (REU) program (Award No. 0139675) in astronomy and astrophysics referred to as the Consortium for Undergraduate Research Experience (CURE) Program.

General Resources for Faculty on Starting an Undergraduate Research Program

The Council on Undergraduate Research (CUR) published a series of "How to" booklets providing guidance on different aspects of undergraduate research. "How

to Get Started in Research''(Goodwin, et al, 1999) gives an overview of the key issues involved in starting a single-investigator driven research program. The book also contains an appendix on proposal writing and provides a useful though somewhat dated list of potential funding sources primarily in the STEM disciplines. Other booklets in this series likely to be of interest to individual faculty, departments and institutions seeking to initiate undergraduate research efforts include ''How to Mentor Undergraduates'', (Merkel, et al, 2002) and ''How to Develop and Administer Institutional Undergraduate Research Programs'', a practical guide for departments and institutions seeking to develop undergraduate research efforts.(Hakim, 2000)

The module ''Developing a Thriving Research Program'' (avail. URL: http://serc.carleton.edu/NAGTWorkshops/earlycareer/research/index.html), part of a larger web-based resource entitled ''On the Cutting Edge: Professional Development for Geoscience Faculty'', is an excellent collection of information and resources that any faculty member in the STEM disciplines will appreciate. Included are sections on developing a research program, funding research, collaborating with students, and carving out time. The website also includes advice and information for faculty teaching at two-year colleges and examples of successful grant applications submitted to a number of different grant programs at the National Science Foundation, the American Chemical Society Petroleum Research Fund, NASA, etc.

Financing Undergraduate Research

Conducting UR in a specific discipline may require additional financial resources in order to provide student stipends; to pay for materials, supplies, and/or instrumentation; to cover institutional access to resources (administrative support); or for travel to conferences by the mentor and his/her undergraduate protégés. Grant opportunities available through any federal agency are listed on the website ''Grants.gov'' (avail. URL: http://www.grants.gov/). After registering on the website, one can search the listings for grant opportunities, sign up for email notification of any new grant opportunities that become available in various research areas, submit grant applications, and track submissions.

At present there are no funding programs targeted specifically to support undergraduate research at community colleges. The Division of Chemistry at the National Science Foundation recently experimented with an initiative entitled the Undergraduate Research Collaboratives (URC) Program. However, this program is closed and no longer active. The goal of URC was to investigate the development of new models and partnerships that engage college students earlier in their education, specifically during the first two years and increase the diversity of the talent pool in the STEM disciplines. Several of the URC programs (NSF Award Nos. 0539816 and 0629174) involved collaborations with two-year colleges and sought to investigate collaborative approaches that would support the participation of faculty and their students in authentic research experiences. Another program that can be leveraged to provide support for undergraduate research in the STEM disciplines at community colleges

is the Advanced Technological Education Program (ATE) (avail. URL: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5464) which is sponsored through the National Science Foundation's Division of Undergraduate Education (DUE). The focus of ATE is improvement of the education of science and engineering technicians at two-year colleges. An important element of the program is development of partnerships between two-year colleges and four-year colleges, universities, secondary schools, business, industry, and/or government which will train technicians to meet the needs of today's workplace.

In the STEM disciplines, the National Institutes of Health (NIH) and NSF represent the two principal sources of external funding to which faculty turn for support of their research programs. Both NIH (avail. URL: http://grants.nih.gov/grants/seminars.htm) and NSF (avail. URL: http://www.nsf.gov/bfa/dias/policy/outreach.jsp) offer regional workshops each year for current and prospective researchers describing their missions, funding programs, as well as the application and review process. The author has participated in several of these meetings and found that they provide invaluable opportunities to meet with program officers, learn about new and existing funding opportunities, and to network with other researchers. Based on her experiences, the author strongly encourages community college faculty to attend a regional workshop if they plan to seek federal funding.

An NSF-wide initiative, the Research in Undergraduate Initiatives (RUI) program (see URL: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5518), provides an umbrella for support of undergraduate research at predominately undergraduate institutions including community colleges. The RUI announcement describes how individual investigators as well as teams of investigators from undergraduate institutions can apply for support for their research programs or needed research instrumentation. The collaborative efforts can involve several faculty at one or more community colleges or partnerships between investigators at different types of academic institutions. Community college faculty that collaborate with NSF-funded investigators at a graduate research university are eligible for NSF Research Opportunity Award (ROA) that can be used to apply for a supplement of up to $25k on an existing NSF award to support faculty at predominately undergraduate institutions.

Another important NSF-wide funding program supporting undergraduate research is the National Science Foundation's Research Experiences for Undergraduates (NSF REU) Program. There are two variants of this program (avail. URL: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5517&from=fund), site awards and supplemental requests. Site award grants provide funding for a summer research program administered by an academic department or research center typically for a three-year period. Support usually covers stipends for the undergraduate researchers as well as their travel, housing, subsistence, and some structured programming. Typically these REU programs run for a period of approximately ten weeks during the summer months. Some funded REU programs specifically target women, underrepresented minorities and community college students. While the majority of REU

programs have been funded at four-year colleges and universities, several awards have been made to community colleges. For example, a recent collaboration between Delaware State University, Delaware Technical & Community College, Wesley College and the Delaware Biotechnology Institute hosted a summer undergraduate research program in molecular biology and genomics (NSF Award No. 0648740). The other type of REU award is the supplemental request. Any principal investigator with active NSF funding can apply for funds to support an undergraduate research student from any two- or four-year college or university. As with any federally funded program, however, it is important to note that student participation is necessarily limited to U.S. citizens and permanent residents of the United States. A fully searchable listing of currently funded REU programs at can be found at URL: http://www.nsf.gov/crssprgm/reu/reu_search.cfm

At the NSF, there are additional programs beyond those listed above that support research efforts at community colleges. A comprehensive list of these programs can be found on the NSF website (avail. URL: http://www.nsf.gov) as well as a list of program officers that can address questions about NSF programs. For example, faculty at historically Black, Hispanic-serving, and Tribal community colleges that partner with small businesses on actively funded (Phase II) Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) research projects, which could lead to commercial products and processes, can apply for supplemental awards (see URL: http://www.nsf.gov/pubs/2006/nsf06008/nsf06008.jsp) of up to $40k, 75% of which must be used by the participating community college research team.

At present, there are no funding programs at the NIH for faculty doing research at community colleges. However, this doesn't prevent community college faculty from partnering with faculty at four-year colleges or research universities in order to apply for funding for collaborative efforts. The review system at NIH (avail. URL: http://grants.nih.gov/grants/peer_review_process.htm; also streaming video avail. URL: http://cms.csr.nih.gov/ResourcesforApplicants/InsidetheNIHGrantReviewProcessVideo.htm) is very different from that at NSF. Panels of expert reviewers, which are commonly referred to as ''study sections'', initially review all proposals. The membership of study sections in each institute is posted by NIH and reviewers tend to serve on study sections for several years.

There are several federal programs that provide support for community college faculty and/or student internship opportunities in the STEM disciplines. The U.S. Department of Energy's Community College Institute (CCI; avail. URL: http://www.scied.science.doe.gov/scied/CCI/about.html) offers a ten week summer internship program specifically for community college students that places students in paid internships at one of the national research laboratories (Argonne, Brookhaven, Lawrence Berkeley, Lawrence Livermore, Oakridge or Pacific Northwest) where the students partner with government scientists and engineers on a research project related to the mission of the laboratory. A faculty member in the STEM disciplines who

wants to initiate a research program in an area of interest to the Department of Energy, then the Faculty and Student Teams (FaST; avail. URL: http://www.scied.science.doe.gov/scied/fast/about.html) Program, a cooperative effort between the Department of Energy (DOE) Office of Science and NSF, might be a useful mechanism. FaST provides hands-on research opportunities in participating DOE laboratories during the summer to faculty and student teams from institutions with limited research facilities and those that have significant number of women and underrepresented minorities.

Resources on Proposal Writing

The Council on Undergraduate Research (CUR) offers an annual Institute for faculty and administrators focused on proposal writing. Participants work individually with a mentor and in groups to hone their proposal writing skills with the goal of applying them subsequently to an actual research proposal. The CUR Quarterly is another terrific resource for information on proposal preparation. Over the years there have been many excellent articles and even complete issues providing advice on grant submissions to the NSF RUI program (see the December 2004 issue), the NSF REU Program (see the June 2003 and September 2003 issues), the NSF Course Curriculum and Laboratory Improvement (CCLI) Program (see the March 2002 issue), and the NSF Major Research Instrumentation (MRI) Program (see the December 2002 issue). Especially noteworthy is the fact that NSF program officers have authored a number of these articles.

As the National Science Foundation has a federal mandate to serve the nation, they seek a cross section of reviewers diverse in gender and ethnicity, representing all academic ranks, funded and unfunded, tenured and un-tenured from public and private two- and four-year colleges and universities across the nation. By participating in the review of proposals, faculty have an invaluable opportunity to network with their peers in the research community and gain first hand insight into what makes a grant proposal successful. The first step in becoming a reviewer is to visit the National Science Foundation homepage (URL: www.nsf.gov) and complete the reviewer expertise form. This places your name on the list of potential reviewers from which NSF program officers will identify proposal reviewers. Depending on the specific funding program, you may be asked to review a single research proposal or to serve on a panel and review several proposals submitted for consideration of funding by a specific program.

Community college faculty and administrators that seek funding from NSF or NIH will find Liane Reif-Lehrer's "Grant Application Writer's Handbook" (Reif-Lehrer, 2005) (now in its fourth edition) an invaluable resource. Her book takes the reader literally step-by-step through the process of planning, writing, and submitting a grant application. There are two other noteworthy resources for grant writers. John Schwaub and Jean Chin's chapter in Research Corporation's "Academic Excellence"(Doyle, 2000) provides a succinct overview of the process and requirements

for individuals seeking funding from the NIH for their research. The CUR booklet, ''How to Get Started in Research''(Goodwin, et al, 1999), also includes a succinct summary of advice on proposal writing.

Selecting UR Projects and Recruiting Students

A series of articles (Brown, 2006; Ealy, et al, 2006; Gaglione, 2005; Perez, 2003) in the *Journal of Chemical Education* describes successful UR programs at community colleges. These articles provide useful listings of the projects the students' undertook as well as the outcomes. Julie Ealy and Veronica Kvarta's JCE article (Ealy, et al, 2006) is particularly noteworthy as it details the mentoring of one community college student on a year-long research project in organic chemistry that ultimately culminated in a successful presentation by the student of her research findings at a regional American Chemical Society Meeting. Based on the author's experiences, most students become involved in UR because a faculty member approached them not because they sought out a faculty member. (Mabrouk, et al, 2000)

Mentoring Resources

A number of excellent resources describe different approaches to mentoring undergraduate research students. The National Academies booklet, ''Adviser, Teacher, Role Model, Friend'' (avail. URL: http://www.nap.edu/readingroom/books/mentor/), discusses the ethical considerations of being a faculty mentor. The Council on Undergraduate Research booklet, ''How to Mentor Undergraduate Researchers'' (Merkel, et al, 2002) , is aimed at faculty that are new to undergraduate research focusing on the practical aspects of mentoring undergraduates through the research process. Several good articles (Kurdziel, et al, 2002; Mabrouk, et al, 2000; Shellito, et al, 2001) also offer faculty advice on how to be better mentors. Two of these articles (Mabrouk, et al, 2000; Shellito, et al, 2001) are based on surveys of undergraduate researchers in an effort to learn what faculty can do to be more effective research mentors. If you are thinking about UR in a collaborative venture with partners from a research university, it is important to recognize that graduate and/or post doctoral students often supervise undergraduate researchers on a day-to-day basis. Handlesman developed a mentoring program ''Entering Mentoring''(Handelsman, et al, 2005) intended for use by graduate and postdoctoral students who often find themselves supervising undergraduate research students in the biological sciences. The goal of the program is to develop effective mentors and as such the materials and suggested activities will be useful not only to UR efforts that use graduate and post doctoral students as research mentors but to anyone interested in improving their own mentoring skills.

Resources to Guide UR

An excellent resource for students and faculty with less experience in empirical research is Mildred L. Patten's book, ''Proposing Empirical Research: A Guide to

the Fundamentals''(Patten, 2000). Patten takes students by the hand and leads them through the design and execution of an effective empirical research study. She discusses problem selection and how this relates to the selection of an appropriate experimental approach (qualitative, survey, correlational, etc.), the literature review, sampling, instrumentation selection, data analysis, and data reporting. In the author's opinion, this resource is particularly noteworthy for the thoughtfully embedded introduction to and discussion of research ethics that permeates the text as well as the end-of-chapter exercises. Mabrouk (Mabrouk, et al, 2007) have developed an interactive, web-based, student-centered resource intended to assist undergraduates in navigating the hurdles of an undergraduate research experience. Nicknamed webGURU (avail. URL: http://www.webguru.neu.edu), the web-based Guide to Research for Undergraduates, includes fully-searchable program listings for UR opportunities, UR grants and fellowships in support of UR experiences, meeting opportunities, a growing collection of researcher profiles, and peer reviewed technical information on all aspects of the undergraduate research experience.

Organizations that support UR

The Council on Undergraduate Research (CUR) is a non-profit professional organization of faculty from a wide array of academic disciplines (including the humanities and social sciences). Although CUR membership is primarily from four-year colleges, there is a growing number of community college faculty that belong and a limited number of community colleges now hold institutional memberships. In the author's opinion, CUR has much to offer community college faculty. The organization hosts workshops on grant writing and mentoring undergraduate researchers, publishes a quarterly journal (*The CUR Quarterly*) and numerous written resources in support of undergraduate research programs, and conducts a notable biennial national conference (the 2010 CUR National Conference will take place at Weber State University in Ogden, Utah). Additional information on the programs and services that CUR provides can be found at http://www.cur.org. The Undergraduate Research Community for the Human Sciences (avail. URL: http://www.kon.org/urc/undergrad_research.html) is an initiative sponsored by Kappa Omicron Nu Leadership Academy and other organizations in support of undergraduate research in the ''human sciences.'' The organization publishes a journal, hosts a conference for undergraduate research in the human sciences, and the website provides links to a number of useful resources for faculty engaged in undergraduate research in these disciplines.

Undergraduate Research Conferences

There are several national conferences where undergraduates can present their research. The most well known and respected is the National Conferences on Undergraduate Research (NCUR) (http://www.ncur.org/), which was established in 1987. More than 2,000 students and their research advisors from colleges and universities across the U.S. come together each year to present their undergraduate research, scholarship, and creative activity in all fields of study using a variety of forms including

posters, oral presentations, visual arts and performances. Student presenters at NCUR have the opportunity to publish their work in the NCUR Conference Proceedings, edited and published annually by the University of North Carolina at Asheville and distributed nationally. Another excellent venue for undergraduates from all disciplines to share their research is the Council on Undergraduate Research's annual "Posters on the Hill" event (avail. URL: http://www.cur.org/postersession.html). Held in late March/early April every year, this event provides an opportunity for sixty competitively selected student/faculty teams to present posters on their undergraduate research at the U.S. Capitol and meet with their Representatives and Senators. Students from Southwestern College and North Seattle Community College presented posters at Posters on the Hill in 2006 and 2007.

Most of the other national conferences are discipline-based. Sigma Xi, the national honor society in the sciences, holds an undergraduate research conference (avail. URL: http://www.sigmaxi.org/meetings/annual/index.shtml) for students (members and non-members can participate) at the same time as its annual research meeting. Other professional meetings specifically designate certain sessions for undergraduates. For example, at the annual National American Chemical Society meeting the Division of Chemical Education organizes a series of poster sessions for undergraduate research with more than 100 undergraduates participating.

Journals about UR

The CUR Quarterly (http://www.cur.org/Publications/Quarterlies.html) is an excellent resource for any faculty member or administrator interested in undergraduate research. The journal publishes articles on a wide range of topics, including undergraduate research in community colleges. The table of contents for issues published after June 1998 and selected articles can be viewed online and searched by author, title, or subject. Other journals that include articles on undergraduate research include *Science Education*, the *Journal of College Science Teaching*, the *Journal of Research in Science Teaching, Life Science Education, Cell Biology Education*, and the *Journal of Chemical Education*.

In recent years, a number of journals that publish undergraduate research have also been launched. *The Journal of Young Investigators* (http://www.jyi.org/) is a student-led, peer-reviewed, web-based undergraduate research journal focused on undergraduate research in the STEM disciplines and the social sciences. JYI is quite unique in that undergraduates participate in all aspects of the publication process. The journal, now ten years old, enjoys support from the National Science Foundation, the Burroughs Wellcome Fund, Glaxo Wellcome Inc., the American Association for the Advancement of Science (AAAS), and a number of colleges and universities. Psi Chi, the National Honor Society in Psychology, publishes a nationally, reviewed quarterly focused on undergraduate research in psychology, the *Psi Chi Journal of Undergraduate Research* (http://www.psichi.org/pubs/journal/home.asp). *A* final example from the human sciences is the *Undergraduate Research Journal for the Human Sciences*

(http://www.kon.org/urc/undergrad_research.html). The Undergraduate Research Community initiated this reviewed (two professionals and one peer) online journal for undergraduate research in the human sciences in 2002.

Resources on Research Ethics

Resources regarding research ethics exist in a number of formats. Three books discuss ethical theory, ethical decision making, and the fundamental issues related to ethics in the conduct of research: Jeffrey Kovac's "The Ethical Chemist", (Kovac, 2003) Dore Beach's "The Responsible Conduct of Research," (Beach, 1996) and the seminal "Scientific Integrity" by Francis L. Macrina (Macrina, 2005). All use a case study approach as a springboard for active learning. Kovac's book is geared toward chemists. Beach's book was written in response to the National Institutes of Health mandate for ethics training as an element of training grants. Consequently this book will be most useful as a resource to those faculty involved in NIH funded research efforts. Macrina's book is targeted toward biomedical research. An excellent resource with a broader disciplinary appeal is Robin Levin Penslar's "Research Ethics: Cases and Materials."(Penslar, 1995) This book is unique in that it thoughtfully discusses some of the challenges in teaching research ethics and some possible solutions to those problems. A concise introduction to ethical theory is presented and followed by a case-based approach to issues faced by researchers in a wide range of disciplines including the natural sciences (biology), the behavioral sciences (psychology), and the humanities (history). Also extremely useful are the instructional notes provided for the in-chapter case studies and the annotated bibliography that provides information on additional resources in support of the issues and cases presented in the text. Joan E Sieber's book "Planning Ethically Responsible Research: A Guide for Students and Internal Review Boards"(Sieber, 1992) is a valuable resource for faculty and students undertaking research projects using human subjects. The book discusses the ethics of research on humans, the role of the internal review board and research protocols, and the central issues including risk, consent, privacy, and vulnerable populations.

Two smaller booklets provide more succinct information on research ethics. "On Being a Scientist"(Committee on Science, 1995) by the Committee on Science, Engineering, and Public Policy at the National Academies of Science, Engineering, and Medicine is a 29-page downloadable (pdf) containing information regarding data analysis, conflicts of interest, openness, allocation of credit, error, and misconduct. Particularly useful to faculty and students are the brief, ambiguous, open-ended case studies that accompany the discourse on each topic and the appendix that highlights the relevant issues in each case. Sigma Xi, the National Honor Society in the Sciences and Engineering, published a 64-page booklet "The Responsible Researcher: Paths and Pitfalls"(*The Responsible Researcher: Paths and Pitfalls*, 1999). This booklet is intended to serve a wide audience including undergraduate, graduate and postdoctoral students, and academic faculty and administrators, as well as scientists and engineers and their managers working in government and the private sector.

"The Online Ethics Center at the National Academy of Engineering" (National Academy for Engineering, 2006) is a web resource that contains case studies, articles and essays and other materials instructors can use in discussing ethics in research, issues related to employment, safety, and the environment. WebGURU, discussed earlier, also has an extensive section on research integrity that identifies and discusses some of the most common ethical challenges undergraduates encounter during the research process including plagiarism, assignment of credit, confidentiality, openness, and personal misrepresentation. Finally, the American Association for the Advancement of Science (AAAS) produced and markets a series of five video resources ("Integrity in Scientific Research - the Videos,") as part of a larger project, the Integrity in Scientific Research Program, in ethics training in the sciences. The videos feature vignettes on a wide range of issues that allow students and faculty to identify the issues, discuss possible options and the implications associated with those decisions.

It is increasingly common to find all types of academic institutions thinking deeply about and crafting policies concerning intellectual property ownership. The United States Patent and Trademark Office (http://www.uspto.gov/) has a series of web-based resources faculty and administrators will find useful in educating their undergraduate research students as well as themselves concerning issues related to copyright, trademarks and patents. Faculty should also be aware that the USPTO website offers *gratis* a fully searchable database of all the patent applications and patents issued in the United States since 1790. The United States Copyright Office (http://www.copyright.gov/) provides extensive information on copyrights and a free fully searchable on-line database for all the copyrights filed and issued by the Office since 1978. "Patents and Trademarks Plain & Simple"(Jester, 2004) written by patent attorney Michael H. Jester is a resource on patents and trademarks that faculty and undergraduates will find interesting and accessible.

In summary, there are many resources available in support of undergraduate research efforts involving community college faculty and students. Some are specific to community colleges but there are many resources that can also be leveraged by community colleges which were developed for undergraduate research at universities and four-year colleges.

References

Beach, D. *The Responsible Conduct of Research*. Weinheim: VCH, 1996.

Brown, D. R. Undertaking Chemical Research at a Community College. *Journal of Chemical Education, 83*(7), 970–972, 2006.

Committee on Science, Engineering, and Public Policy. *On Being a Scientist: Responsible Conduct in Research*. Washington, D.C.: National Academy Press, 1995.

Doyle, M. P. (Ed.). *Academic Excellence: The Role of Research in the Physical Sciences at Undergraduate Institutions*. Tucson: Research Corporation, 2000.

Ealy, J. B., & Kvarta, V. Mentoring an Undergraduate Research Student in the Structural and Nonstructural Properties of Drugs. *Journal of Chemical Education, 83*, 1779–1783, 2006.

Gaglione, O. Underground Existence of Research in Chemistry in Two-Year College Programs. *Journal of Chemical Education, 82*(11), 1613–1614, 2005.

Goodwin, T., & Holmes, B. *How to Get Started in Research*. Washington, D.C.: Council on Undergraduate Research, 1999.

Hakim, T. M. *How to Develop and Administer Institutional Undergraduate Research Programs*. Washington, D.C.: Council on Undergraduate Research, 2000.

Handelsman, J., Pfund, C., Lauffer, S. M., & Pribbenow, C. M. *Entering Mentoring*. Madison: University of Wisconsin, 2005.

Integrity in Scientific Research - the Videos. Retrieved May 31, 2008, from http://www.aaas.org/spp/video/thevideos.htm

Jester, M. H. *Patents and Trademarks Plain & Simple*. Franklin Lakes: The Career Press, Inc., 2004.

Kovac, J. *The Ethical Chemist*. Upper Saddle River, NY: Prentice Hall, 2003.

Kurdziel, J. P., & Libarkin, J. C. Research Methodologies in Science Education: Undergraduate Research Mentoring, Teacher Workshops, and K-12 Outreach Activities. *Journal of Geoscience Education, 50*(5), 602–609, 2002.

Mabrouk, P., McIntyre, R., Virrankoski, M., & Jeliffe, K. WebGURU: The Web-Based Guide to Research for Undergraduates. *Journal of College Science Teaching, 36*(7), 18–13, 2007.

Mabrouk, P. A., & Peters, K. Student Perspectives on Undergraduate Research Experiences in Chemistry and Biology. *CUR Quarterly*(September), 25–33, 2000.

Macrina, F. L. *Scientific Integrity: Text and Cases in Responsible Conduct of Research* (third ed.). Washington, D.C.: ASM Press, 2005.

Merkel, C. A., & Baker, S. M. *How to Mentor Undergraduate Researchers*. Washington, D.C.: Council on Undergraduate Research, 2002.

National Academy for Engineering. The Online Ethics Center at the National Academy for Engineering. from http://www.onlineethics.org/, 2006.

Patten, M. L. *Proposing Empirical Research: A Guide to the Fundamentals*. Los Angeles: Pyrczak Publishing, 2000.

Penslar, R. L. *Research Ethics: Cases and Materials*. Bloomington: Indiana University Press, 1995.

Perez, J. A. Undergraduate Research at Two-Year Colleges. *New Directions for Teaching and Learning, 93*, 69–78, 2003.

Pfund, C., Pribbenow, C. M., Branchaw, J., Lauffer, S. M., & Handelsman, J. The Merits of Training Mentors. *Science (Washington, D. C., 1883-), 311*(5760), 473–474, 2006.

Reif-Lehrer, L. *Grant Application Writer's Handbook* (fourth ed.). Boston: Jones and Bartlett Publishers, Inc., 2005.

The Responsible Researcher: Paths and Pitfalls. Research Triangle Park, NC: Sigma Xi, The Scientific Research Society, 1999.

Shellito, C., Shea, K., Weissmann, G., Mueller-Solger, A., & Davis, W. Successful Mentoring of Undergraduate Researchers. *Journal of College Science Teaching, 30*(May), 460–464, 2001.

Sieber, J. E. *Planning Ethically Responsible Research: A Guide for Students and Internal Review Boards* (Vol. 31). Newbury Park, NY: SAGE Publications, 1992.

Turner, R. E. Spinning ATOMS Draws Energy from FUSION. *Journal of Chemical Education, 81*(9), 1246–1250, 2004.

Context, Implications, and Recommendations

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Context

Scientific progress is the hallmark of a dynamic society, and the United States leads the world in scientific discoveries. Recently, however, the U. S. Congress, the National Academies of Science, the Business Roundtable and other organizations (Business Roundtable, 2005; National Academies of Science, 2007; America Competes, 2007) have expressed serious concerns about the ability of the American scientific community to retain its world leadership role in innovation and technological development. An important aspect of scientific progress is the education of future scientists. American universities have seen a decline in the number of American-born science graduates at the same time that these universities are experiencing a decline in admissions of foreign students (National Academies of Science, 2007). Recent reports have called for increased support for science education at the K-12, baccalaureate, and graduate levels (National Academies of Science, 2007). Improvements in science curricula, particularly changes that engage students in the process of research and discovery, have become a focal point for attracting more students into science. Undergraduate research is a significant strategy for improving undergraduate science education.

While undergraduate research has been a part of undergraduate education since at least the time of Isaac Newton, it has only been in recent years that undergraduate research has become a movement (Blanton, 2008). The Council on Undergraduate Research (CUR) began in1978 with a small group of chemists from private liberal-arts colleges who believed that faculty members at such colleges could engage in substantive research and, further, that they could involve students in such research. Since that time CUR has expanded to include all disciplines and all baccalaureate institutions in its efforts to foster undergraduate research as a powerful learning paradigm. It is only recently, however, that CUR has become involved in working with community colleges. As Hewlett points out in chapter two, community colleges must be included in efforts to reform science education. Community colleges prepare students who will transfer to four-year colleges and technicians who will become a part of research efforts. Further, they play a significant role in the preparation of underrepresented groups in science. CUR recognized the significant role that community colleges play in the preparation of future scientists and technicians when

it suggested a partnership with the National Council on Instructional Administrators and submitted a proposal to explore undergraduate research at community colleges to the National Science Foundation.

Community colleges have long recognized the importance of mentoring students and have a history of success in educating underrepresented students, as well as underprepared students, for successful scientific careers. Community colleges play an important role in workforce development in their states and local communities. Industry frequently looks to community colleges to provide an educated and technologically up-to-date workforce. What has not been a part of the community college mission is research and the creation of new knowledge. Incorporating research into the traditional teaching mission of the community college is a relatively new and, to some, a controversial expansion of the mission. A recent view of community college faculty members suggests they can be "agents of knowledge dissemination and participants in a socially and personally transformative process, and as workers, facilitators of postindustrial production (p.133,Levin, Kater, Wagoner, 2006)." If faculty members are to achieve this new vision of their role, they will surely need to incorporate undergraduate research into the curriculum and their teaching. The authors included in this monograph have shown how they have been able to successfully become part of the process of knowledge development and dissemination on their campuses. Each author has demonstrated that engaging students in authentic research is in fact an enhancement of the teaching and learning process.

Participants in the regional conversations pointed out that the definition of undergraduate research and the ways in which campuses incorporate undergraduate research differ widely. All participants seemed to agree that teaching is research and that research can be effectively built into the community college curriculum and teaching mission.

Finger Lakes Community College has addressed the teaching versus research controversy head on. Faculty members have experimented with ways to deeply embed undergraduate research into the curriculum while also engaging students in authentic primary research. James Hewlett, his colleagues, and students are well on their way to developing a sustainable undergraduate research program at a community college. They are also beginning to share what they have learned with faculty members from other community colleges.

Kalyn Owens and Ann Murkowski at North Seattle Community College have engaged students in interdisciplinary basic research by incorporating research into coursework. To accomplish their goals, they also involved experts beyond their own campus community. Owens and Murkowski discussed the challenges of conducting research at a community college, but they also found that the significant gains in student learning were deeply satisfying to the faculty.

Redlands Community College (RCC) provides excellent examples of applied research and the role such research can play in the economic development of a state. RCC has developed a partnership with a corporation for agricultural research that assists both regional agriculture and the company's product development. Redlands has also done work in developing viticulture and enology programs that have led to an emerging Oklahoma wine industry, and many of RCC's students have developed their own wineries and businesses.

Southwestern College, through its partnership with Ondax, Inc., is engaged in basic research that may have far reaching benefits. The explorations of David Brown and his students in the fabrication of nano-structures within materials that can be used to control and manipulate the propagation of light, could lead to replacing electricity with light in applications that are typically done with silicon chips and other semiconductor materials. Southwestern College also provides examples of partnerships with other colleges and industry.

Implications

Our review of the role of undergraduate research in community colleges suggests that this movement will have significant implications for institutions, faculties, and students. Each group clearly must make adjustments to their traditional way of doing things.

The community college must weigh the consequences for its traditional mission of introducing undergraduate research into its curriculum. That is, how can this new approach be used to further the mission of the organization without resulting in unsustainable added costs and burdens? Participants in our regional conversations talked extensively about the teaching mission of the community college and how many faculty members and administrators saw the introduction of research as a distraction from teaching. Those who had engaged in undergraduate research were convinced that involving students in authentic, hands-on research is teaching. Even when an institution embraces the concept of research as teaching, however, many challenges must be addressed.

Curricular revision may be the first challenge. Faculty members will need to carefully review their courses to see how research skills, methodology, and activities can be incorporated into existing courses. This will have the added benefit of better preparing students for transfer to four-year institutions or preparing future technicians to be contributing members of a research team.

Teaching load is perhaps the most difficult challenge. Finger Lakes Community College has begun to address this challenge by allotting five hours of the faculty teaching load to research for faculty members who want to do research. Four-year colleges, with a longer history of undergraduate research, have allowed faculty to

"bank" work with students on research and receive reassigned time at a later date. They have also designed research courses for which students receive course credit.

The faculty must also weigh its commitment to such a program in terms of the time, energy, and resources required. That is, how much added preparation will be necessary, how much additional time and energy will be required? Will the new commitment become overly burdensome? And will the institution provide offsets in terms of teaching load and other requirements? These are real challenges and must be considered.

Community colleges are now hiring more faculty members with PhD's, many of whom wish to continue their involvement with research. They have chosen community colleges, however, because they value the teaching role and feel a personal satisfaction when they see their contributions to student success. They may also have a special commitment to the underrepresented populations at community colleges. For these reasons, many faculty members at community colleges are willing to assume the extra commitment of undergraduate research. Recognition of their work, however, will help to sustain that effort. Recognition might take the form of support for writing research proposals, funds for travel to conferences, and when possible, policies regarding teaching load and tenure and promotion that take supervision of undergraduate research into account.

Like the faculty, students must weigh the existing burdens, as well as those that a new commitment will require, that is, what will be the student expectations for the undergraduate research experience? Will it require additional time and resources and most important of all, will the benefits exceed the costs to the student? Community college students often have part-time or full-time jobs that make extra curricular activities difficult. Many community college students may also have family responsibilities that further reduce time available for study and for academic activities outside the classroom.

Community college students are also highly motivated and want to be adequately prepared for their future careers or for transfer to a baccalaureate program. Undergraduate research will enhance their preparation and help them to achieve their goals. When they understand the importance of undergraduate research to their ability to transfer to a four-year college or to be successful in their careers, they are more likely to seek out undergraduate-research experiences. Faculty members and student-development personnel need to explain the benefits of undergraduate research to students and help them to understand the positive impact it can have on achieving their career goals. Professors also need to plan research experiences that take into account the time constraints facing students.

In short, attempting to expand undergraduate research will have important systemic implications that have to be taken into consideration. The essays in this book attempt to outline the dilemma.

Recommendations

If undergraduate research is to expand and thrive on community college campuses, several steps must be taken:

- Boards of trustees need to recognize that engaging students in research is a legitimate and powerful teaching strategy. Boards need to affirm the interests of faculty members in engaging in research and support the efforts of students to do so.
- State legislators must provide the financial support to meet community colleges' infrastructure needs for up-to-date buildings, laboratories, and equipment so that faculty members can engage in developmentally appropriate collaborative research with their students.
- Community college administrators need to support and encourage faculty members' involvement in their disciplinary or professional organizations so that professors can remain current in their fields and be aware of future directions.
- Community college administrators also need to find ways of supporting faculty members for outside-the-classroom mentoring of students engaged in collaborative research.
- Faculty members need to consider ways in which the development of research skills can be incorporated into the curriculum.
- Student-affairs personnel at community colleges need to recognize the importance of undergraduate research for students' transfer and career opportunities and encourage students to participate in research activities.
- Local employers need to provide research opportunities for community college students as well as students from four-year institutions.
- Community college administrators need to provide support for faculty members to write proposals for external funding.
- Community colleges should expand their partnerships with nearby four-year colleges, local industries, and local government and non-profit agencies to provide additional research opportunities for students.

Bibliography

The America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education and Science Act, HR 2272, August 9, 2007

Blanton, RL. A Brief History of Undergraduate Research, with Consideration of its Alternative Futures In: Taraban R and Blanton RL, eds. *Creating Effective Undergraduate Research Programs in Science.*

The Business Roundtable. *Tapping America's Potential: the Education for Innovation Initiative.* The Business Roundtable, Washington, DC: 2005.

Levin JS, Kater S, Wagoner RL. *Community College Faculty: At Work in the New Economy.* New York: Palgrave Macmillan, 2006.

National Academies of Science. *Rising Above the Gathering Storm: Energizing And Employing America for a Brighter Economic Future by Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology.* Washington DC: National Academy of Sciences, National Academy of Engineering, and Institutes of Medicine, 2007.

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David R. Brown holds a B.A. in Chemistry from Southern Illinois University Edwardsville, a Ph.D. in Physical Chemistry from the University of Illinois at Urbana-Champaign and undertook postdoctoral research at UC San Diego. In 1996 he joined the faculty at Southwestern College, where he has mentored more than two dozen undergraduate researchers. He was the recipient of the 2007 Stanley C. Israel Regional Award for Advancing Diversity in the Chemical Sciences from the American Chemical Society's Western Region.

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Penny Coggins holds an MS and PhD in Adult and Continuing Education from Kansas State University and has been working in community colleges for over 25 years. Coggins is Vice President for Grants Development and Applied Research at Redlands Community College in El Reno, Oklahoma. She assisted in securing funding for the RCC Center of Excellence in Agriculture and has presented workshops and discussions involving undergraduate research at national and state conferences including the American Association for Community Colleges and the Oklahoma Association of Community Colleges. Coggins and her colleagues are helping establish RCC as an emerging undergraduate research institution, focusing on the overarching philosophy that "*Research is Teaching*".

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James Hewlett is Professor of Biology at Finger Lakes Community College. His research interests include the use of the Case Study Method of teaching science and integrated Project-based learning. Professor Hewlett's active areas of scientific

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Patricia Ann Mabrouk is Professor of Chemistry and Chemical Biology at Northeastern University (Boston, MA). Her research interests are in chemical education (active learning methods, pedagogy of graduate education and undergraduate research), green chemistry, and electroanalytical chemistry. She is passionate about undergraduate research. Over the past nineteen years she has partnered with 50 students (61% women, 18% underrepresented minorities) from a wide range of academic disciplines. Nearly one-third of her nearly 50 peer-reviewed publications have been co-authored by undergraduates.

Ann J. Murkowski, M.S., is an instructor of biology at North Seattle Community College. She has a deep interest in designing curriculum that encourages an active approach to learning biology and maintains a strong interest in documenting student learning. She has worked collaboratively with a variety of colleagues to develop interdisciplinary courses across the curriculum. Ann is also passionate about creating authentic field-based research experiences for her students, especially around issues of sustainability.

Kalyn Shea Owens, Ph.D., is an instructor of chemistry at North Seattle Community College where she has been involved in innovative course design and research around student learning. Her research focuses on the design of interdisciplinary, community-based curriculum for science majors that weaves chemistry, biology and undergraduate research into a year-long program. Dr. Owens also has a deep interest in documenting students as they socially construct and represent their scientific thinking in a classroom.


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