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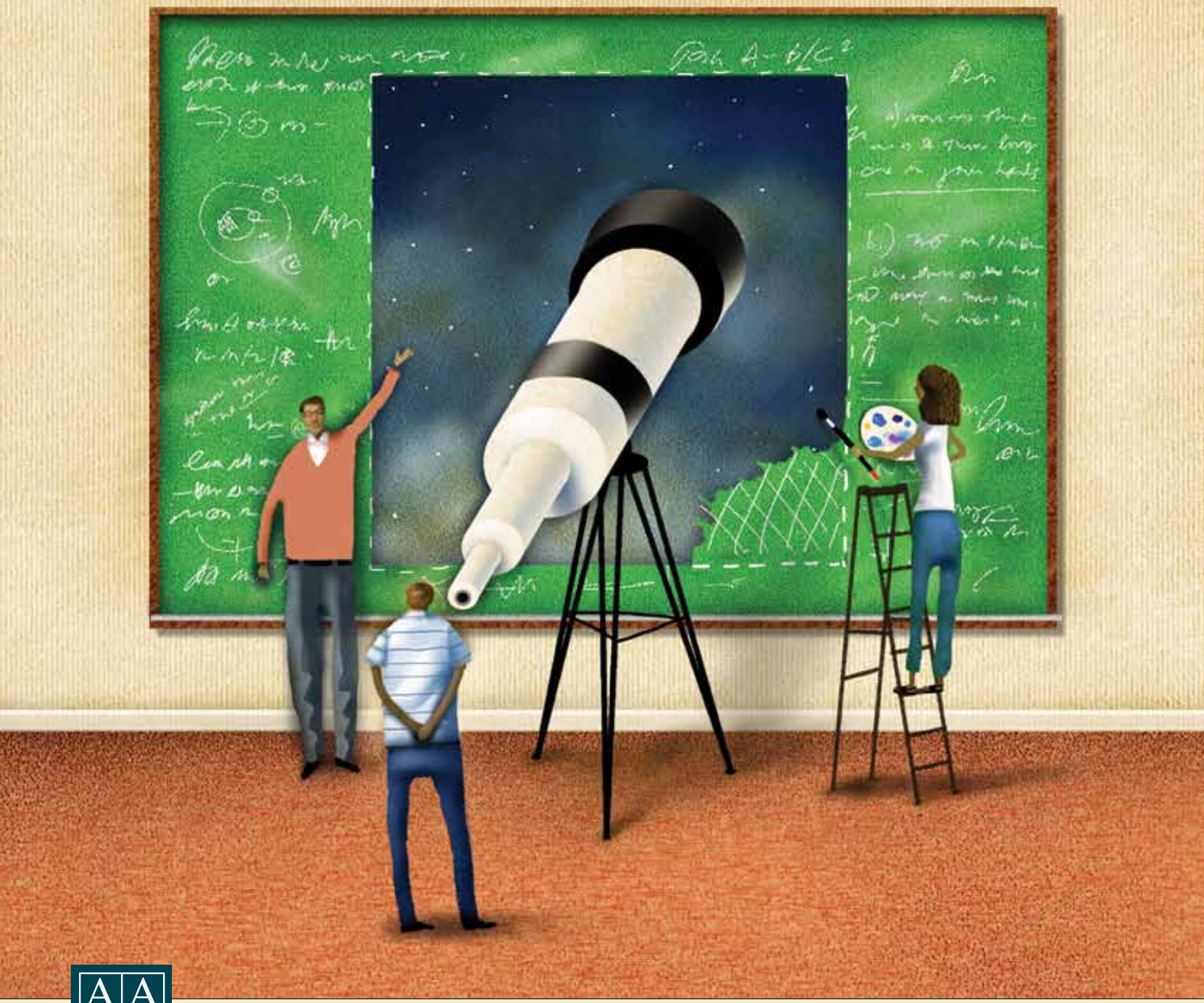
peerReview

EMERGING TRENDS AND KEY DEBATES IN UNDERGRADUATE EDUCATION

Undergraduate Research



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Studies have demonstrated the positive effect of student participation in undergraduate research. In fact, the Association of American Colleges and Universities (AAC&U) has identified it as one of ten "high-impact practices" highlighted in various reports from the LEAP Initiative. In their forthcoming AAC&U report, *The Impact of Engaged Educational Practices: What Research Shows About Learning Outcomes, Completion, and Quality,* authors Jayne Brownell and Lynn Swaner note that undergraduate research is the most frequently and effectively used high-impact practice for underrepresented students in higher education. The authors also cite Ernest Pascarella and Patrick Terenzini's 2005 meta analysis of higher education research, in which they report that undergraduate research has a "positive influence" on "persistence and degree completion," and "elevates degree aspirations…and the likelihood of enrolling in graduate school."

And although undergraduate research requires a significant time commitment from faculty, this practice is being embraced by institutions across the country. In response to a question on the 2009 Faculty Survey on Student Engagement that asked, How important is it to you that undergraduates at your institution work on a research project with a faculty member outside of course or program requirements?, 56 percent of respondents answered "important" or "very important."

As I planned this issue, I wondered if any colleges in the Gulf Coast area were involving their students in undergraduate research projects related to the ongoing oil spill crisis. I contacted Xavier University of Louisiana and learned about Anil Kukreja, a professor and chair of the school's business department, who is mentoring two students participating in a collaborative research project involving Xavier and Seedco Financial, a nonprofit community development lending group that has established a fisheries assistance center to serve local commercial fishermen in the region. The initial goal of the project was to provide loans and grants to local fishermen and other small businesses that were affected by Hurricane Katrina. The partnership between Xavier and Seedco Financial started in September 2008 with funds from the National Oceanic and Atmospheric Administration, and was designed to support the Southeast Louisiana Fisheries Recovery Resource Center over a two-year period. As Kukreja explains, "The recent oil spill in the Gulf has changed the focus of the project, as many of the fishermen are now not able to conduct their businesses."

Sondra Willis, a senior management major who plans to go to law school when she completes her coursework at the university, and Brianna Bell, a junior sales and marketing major who hopes to become an entrepreneur after graduation, are the two students working with Kukreja and Seedco. The students' tasks include interviewing fishermen and other small business owners, gathering and analyzing data, and creating a process flowchart that will help Seedco in managing its resources more effectively. "The situation here is very fluid and we are working closely with Seedco in making sure that we do what is best toward achieving project goals," Kukreja reports.

When I asked Brianna and Sondra about their work, they described the challenge that comes from learning in a real-world setting. As they explained in their e-mail message, "Most fishermen really aren't accessible because a lot of them don't have technology (such as e-mail, computers, and cell phones). Most just have a home number and [they] aren't home a lot. Also, some information that we are asking for might be hard for them to attain and/or understand." These students, however, feel that many of their classes have helped prepare them to respond to Seedco's needs. They are putting into practice skills learned, for instance, in their statistics and service management classes. "We feel that [working on this project] will help us to reflect on endeavors or jobs that we might take in the future." This is but one example of the kinds of rich learning environments that undergraduate research can provide.

Learning to deal with the unscripted problems presented by the Gulf oil spill has been challenging for the most experienced politicians and scientists, so Brianna and Sondra's project is providing a learning experiences that will be particularly meaningful in their future endeavors. In a forward George D. Kuh has written for *The Impact of Engaged Educational Practices*, he notes that, "High-impact practices are developmentally powerful because they harness and concentrate empirically validated good practices in education. These practices are at the heart of a liberal education. Equally important, all the evidence so far suggests they benefit all students." Engagement with high-impact practices such as undergraduate research gives students the opportunity to test and build on their classroom learning, which will prepare them to make good decisions for an ever-evolving and complex world.

—SHELLEY JOHNSON CAREY

Research and Discovery Across the Curriculum

▸ **Susan Elrod,** Executive Director, Project Kaleidoscope (PKAL)
Diane Husic, President, Council on Undergraduate Research (CUR)
Jillian Kinzie, Associate Director, Center for Postsecondary Research and NSSE Institute

The national conversation on undergraduate research is gaining momentum, in part because of its identification as one of the ten high-impact educational practices identified in an analysis of data from the National Survey of Student Engagement (NSSE), published by the Association of American Colleges and Universities (Kuh 2008). However, the trend is not new; the Council on Undergraduate Research (CUR) has been a leading proponent of undergraduate research for the past thirty years. According to CUR, undergraduate research is "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline." Ramirez and Hoagland (2003) state that faculty and students should be encouraged to

> …collaborate as partners in their explorations of uncharted intellectual terrain. The symbiosis established between the faculty member and undergraduate collaborator energizes and informs the faculty member's teaching and research while simultaneously introducing the student to the joys of discovery as well as to lessons in persistence, problem-solving and critical thinking.

Thus, it is as much a matter of effective teaching and learning as it is a matter of research and scholarship. In STEM (science, technology, engineering, and mathematics) disciplines, Project Kaleidoscope, working over the past twenty years to advance effective STEM education, has also played a role. The National Science Foundation's Research Experience for Undergraduates (REU) and Research in Undergraduate Institutions (RUI) programs and various scientific societies have also helped to promote, support, and highlight the work of undergraduate researchers. Many funding agencies, philanthropic foundations and other organizations have also touted and supported the educational benefits of undergraduate research across all disciplines for decades, including the National Humanities Alliance, which holds an annual Humanities Advocacy Day. Undergraduate research experiences are also held in high regard by faculty members: more than 50 percent of faculty members reported on the Faculty Survey of Student Engagement (FSSE) that participation in a research project with a faculty member is important for students (National Survey of Student Engagement 2008). Students in all disciplines are also increasingly calling for such experiences (Society of Physics Students 2008). In this article, we provide an analysis of the value of undergraduate research and suggest that its essence be used to infuse a pedagogy of research and discovery into courses across the curriculum for a more relevant, real-world, research-rich educational experience.

WHAT MAKES UNDERGRADUATE RESEARCH VALUABLE?

Undergraduate research is associated with a wide range of positive benefits for students. A series of studies summarized on the CUR Web site highlights the critical role undergraduate research plays in advancing student learning (Kardash 2000; Lopatto 2003; Seymour et al. 2004), in increasing the likelihood of earning a degree, and specifically in retaining diverse students in fields in which they are historically underrepresented (Nagda et al. 1998), and in increasing students' pursuit of advanced education (Bauer and Bennett 2003; Hathaway, Nagda, and Gergerman 2002; Kremer and Bringle 1990). These studies bolster the assertion in the Boyer Commission on Educating Undergraduates in the Research University report (1998), which emphasized the benefits

of inquiry-based learning experiences and the recommendation that a supervised research project be incorporated into the undergraduate program.

Recent reports using data from the National Survey of Student Engagement (NSSE) and assessment studies, such as those led by Elaine Seymour and David Lopatto, reinforce findings of the *educational* value of undergraduate research and focus attention on the importance of assessing the nature and quality of undergraduate research experiences. These projects also provide an opportunity to distinguish the features that make undergraduate research so effective. NSSE results featured in the AAC&U publication *High-Impact Educational Practices* (Kuh 2008) were used to explore the effects of six high-impact activities, including undergraduate research, on first-year and senior student self-reported gains in three clusters of learning and personal development outcomes, and in engaging in deep approaches to learning. Results showed positive associations between high-impact activities and all gains and deep approaches to learning. In addition, students who have these experiences are also more engaged overall in the NSSE clusters of effective educational practice. Although it's likely that certain specific features of high-impact practices exert a significant influence on learning gains, it is notable that these practices are effective because they are clearly marked by six hallmarks of high-impact practices that put students in circumstances that demand meaningful faculty and peer interaction; help students connect their learning to real-world settings; occur in the context of a coherent and challenging curriculum; provide students with frequent feedback; require time on task; and challenge students to think in new ways and respond to novel situations. Moreover, they suggest the features that should be carefully crafted into undergraduate research experiences.

Additional features of undergraduate research and what students gain from the experience were explored more fully via a set of NSSE items. Results based on 2,674 students from a variety of major fields at sixty-three baccalaureate institutions showed that doing research with faculty was positively associated with deep approaches to learning and gains in general education, personal and social development, and practical competencies (NSSE 2007). Students reported a range of contributions to the research project, including designing the study, reviewing literature, collecting data, and presenting findings. Although most of these practices were positively related to educational gains, the activities with the strongest association were reviewing literature and interpreting findings. The advantage of doing research with a faculty member is that students are able to spend time in the company of a professional researcher and learn firsthand how he or she thinks and deals with the challenges of research. Also, these interactions make students more likely to receive feedback during or after their project and to report more supportive relationships with faculty members. Finally, the more time students spent on the research project, the better they came to understand the inquiry process and the more they gained overall.

LEVELS OF PARTICIPATION VARY

One additional conclusion from NSSE's examination of undergraduate research is that these experiences are not as widely reported by students as we would hope, given their educational value. Of the seniors at more than six hundred baccalaureate-granting colleges and universities that completed NSSE in spring 2009, only about one-fifth participated in an undergraduate research experience (NSSE 2009). First-year students' plans to do research seem realistic, with about one-third indicating that they "plan to do" research at some point in their undergraduate careers. Interestingly, some institutions stand out for their high levels of undergraduate research. As many as half or more of the seniors at some engineering and technical universities, and 40 percent or more at about forty-five small private liberal arts colleges, report involvement in undergraduate research. About two dozen doctoral research universities stand out among their peer institutions with 40 percent of seniors reporting research experiences with faculty. Results on levels of participation suggest that it would be worthwhile to characterize the research experiences going on at the institutions with high scores, but the average participation levels reveal the gaps that must be addressed to make this practice more widely available.

ESSENTIAL FEATURES OF UNDERGRADUATE RESEARCH

Lopatto (2003) reports several essential features of undergraduate research, as identified by faculty members. These encompass reading the literature, designing some aspect of the project, feeling ownership of the project with an increasing independence over time, using careful and reproducible lab techniques (and even mastering some), striving to produce a significant finding, and presenting results in both oral and written communication formats. In *Science in Solution* (2009), Lopatto writes

> Undergraduate research, done well, engages multiple dimensions of a student's cognitive, behavioral, and attitudinal skills. Task-specific learning about instruments and methods cascades into active hypothesizing and procedural troubleshooting that result in the accumulation of self-confidence and independence that help shape the student's vision of her future. The whirlpool of outcomes mixes value added with value expressed, that is, mixes the guided

acquisition of expertise with the discarding of the fear of expressing ideas and hypotheses.

As this eloquent passage suggests, undergraduate research experiences benefit students in ways that transcend mastering disciplinary knowledge or helping students obtain a more professional orientation (Lopatto writes more about this later in this issue). Many of the benefits of undergraduate research are aligned with three of the essential learning outcomes espoused by AAC&U's LEAP campaign—intellectual and practical skills, personal and social responsibility, and integrative and applied learning. It is these kinds of experiences that have the potential to transform the way students perceive and understand what they are learning and how it is applied in authentic, real-world situations.

Besides contributing to an individual student's professional development, undergraduate research can and should also result in contributions to the discipline or to community or to solving even larger societal problems. While the contributions to a discipline by any single student might be small, they contribute to a larger body of collaborative work done by other students and a faculty mentor over time. Some undergraduate research projects can be categorized as transformative—a term defined by the National Science Board (NSF 2007) as research driven by ideas that have the potential to radically change our understanding of an important existing concept or leading to the creation of a new paradigm. Over the past year, CUR engaged in a study of transformative research that was recently published (Karukstis and Hensel 2010). Many examples of undergraduates participating in transformative research were found, such as students at the University of Central Florida and Davidson College collaborating with industry to develop or screen new chemicals for agriculture and medicine.

Undergraduate student participation in research is now also seen by many as a way of developing leaders for the twenty-first century. By presenting their research to campuswide audiences, to peers at national conferences such as the National Conferences on Undergraduate Research (NCUR), to scientists at disciplinary society meetings, and to legislators at the state and national level, students learn to communicate at a variety of levels—including to "non-expert" audiences (in

terms of scientific literacy). More institutions are providing avenues on campus to showcase students' creative work. In 2010, Grand Valley State University hosted its fifteenth annual Student Scholar Day to celebrate the faculty-mentored student research and creative work presented by more than six hundred students. And the University of Maine–Farmington sponsored its fifth symposium, a university-wide day of presentations of outstanding student scholarship and creative achievements across academic disciplines. These events also attract members of the surrounding communities. Because a growing number of undergraduate research projects have significance to the local community, events like these increase the chances for researchers to interact directly with the public and use the projects as an opportunity to educate a general audience about science. Besides enhancing students' communication skills, all of these dissemination activities also enhance public understanding of science and allow our students to become ambassadors for illustrating the importance of science and research in society.

PKAL and CUR have long advocated for making research-rich experiences available to students early in the curriculum, integrating inquiry and analysis into coursework, and giving students the chance to use problem-based learning to apply their knowledge, to use case studies of scientific data, and to collect primary data in the field or as part of a larger research collective. For example, Cleveland State University's undergraduate research learning community (described later in this issue) provides first-year students in any major the opportunity to work on their own original research, develop a faculty-guided proposal, and conclude the semester with a presentation. The courses provide the framework for the creative research activity, but it's the interaction with faculty that provides new students with active, inquiry-based learning experiences with a faculty mentor. And at Grinnell College, the biology department has "inverted" the curriculum so that first-year students with interests that span the disciplines engage in "doing science" right away, as opposed to saving the excitement of real investigation for upper-division biology majors (Lindgren 2010). Lindgren notes that teaching in this way is "painfully authentic," meaning that students discover that experiments don't always work or yield clear results, as often shown in their

textbooks. But, perhaps teaching real science requires us to take a kind of "tough love" approach in order to help students understand the true nature of science, including its limitations. Russell, Hancock, and McCullough (2007) argue for earlier involvement in research for students in STEM disciplines, based on their study of the educational benefits of research and its influence on STEM career choice.

INFUSING A PEDAGOGY OF RESEARCH AND DISCOVERY ACROSS THE CURRICULUM

While the ideal undergraduate research experience is one in which students work closely with faculty members on a high-quality, original research project, high costs and personnel limitations make it difficult to provide the ideal mentored experience to all students. However, by understanding the essence of what makes undergraduate research such a valuable experience and then applying these principles more widely in courses and programs across the curriculum, we can provide opportunities for more undergraduates to experience similar benefits. Expanding meaningful research experiences to more students is particularly relevant in the face of increasingly frequent conversations about the need for a citizenry that can engage in evidence-based reasoning to deal with this century's complex and global challenges—such as climate change, energy use, water resources, and world health—that involve multidisciplinary perspectives. All students should have a personal experience with the complexity and interrelatedness of the issues facing our global society in order to be competent consumers, communicators, decision makers, teachers (see article by Baker and Keller later in this issue), and professionals in this new global century.

A number of grand challenges in engineering, the environment, and global health have been identified (National Academy of Engineers 2009; National Research Council 2001; Bill and Melinda Gates Foundation 2008). These range from the need to develop a better understanding of biological diversity, ecosystem functioning, climate variability, and hydrologic forecasting; to finding renewable, clean energy solutions or "greener" materials that lessen our dependence on diminishing natural resources; to global health issues including the development of new vaccines or novel ways to control infectious disease. A recent report from the National Research Council (2009) entitled, "A New Biology for the 21st Century," responded to the following question: How can a fundamental understanding of living systems reduce uncertainty about the future of life on earth, improve human health and welfare, and lead to the wise stewardship of our planet? The report findings assert that the new biology must be more integrative—not only across the field of biology, but across other disciplines—if we are to take full advantage of the power of science to address the complex societal problems we face. Key global research issues identified in this report are those surrounding health, the environment, energy and water. The United Nations Millennium Development Goals (such as ending hunger, improving maternal and child health, combating HIV/AIDS, and environmental sustainability) will also require great advances from the scientific community working closely with our colleagues in the arts and humanities. These reports, as well as others that address the sciences more broadly, suggest an increasing convergence leading undergraduate education in more interdisciplinary and integrative directions (Labov, Reid, and Yamamoto 2010). All types of perspectives, talents, and skills will be required.

Applying evidence-based reasoning to solve complex societal problems is certainly not a new educational goal, but what is new is the urgency with which some of these problems need attention. Lessons from studies about what makes undergraduate research effective provide a fresh perspective for considering a twenty-first-century framework for a pedagogy of discovery, inquiry, and analysis in undergraduate education. The research highlighted in this paper suggests that these opportunities must be designed to:

- Challenge students to confront novel ideas
- Engage students in the collection and analysis of original data
- Emphasize opportunities for applying research to real contexts or solving real problems
- Increase the time students dedicate to the project
- Maximize opportunities for students and faculty to interact and engage in substantive matters
- Be relevant and interesting to students, and influenced by their ideas to maximize engagement and learning
- Provide opportunities for students to receive frequent and meaningful feedback about their work
- Increase students ownership of the project over time
- Provide an occasion for students to present their work in oral and written formats
- Allow students to work in teams

A number of colleges engage students in research related to environmentally contaminated industrial sites in their neighborhoods. This work is often interdisciplinary and integrated with coursework, but students are also performing important monitoring studies, examining the flow of contaminants through water systems or food chains, and developing management protocols to minimize public health and environmental risks. At Moravian College, students are involved in a Superfund site revitalization project that has received national recognition for its success in turning a heavily contaminated

moonscape into a thriving grassland and wildlife refuge. Besides conducting a range of scientific studies, students are engaged with state and federal agencies in developing adaptive management protocols for the site. One student's project led to the creation of a searchable annotated bibliography with close to five hundred different references, including federal reports, abstracts, journal articles, books, theses, Web sites, fact sheets, magazines, newspaper articles, PowerPoint presentations, letters, videos, maps, photographs, and more, which was used by researchers, the EPA, the regional library (which houses many of the public documents and historical materials from the zinc smelter company responsible for both creating the town and the Superfund site) and the general public.

EDUCATION THAT TRANSCENDS THE CLASSROOM

Over the past year, there have been a number of editorials that have rehashed the false dichotomy between teaching and research, claiming that faculty (especially those working with undergraduate students) should focus on teaching so as not to "lose sight of the educational mission" (Jones 2010). However, our educational missions involve more than teaching in traditional classroom settings. Learning occurs in a variety of situations, both inside and outside the classroom, and in a variety of ways, as the *High-Impact Educational Practices* report (Kuh 2008) highlights. Education in the twenty-first century must have a view that transcends the classroom and engages students in the grand challenges and complex problems facing our society, and what better way to do this than to involve them in the pursuit of a relevant, real-world problem? A white paper published by the Teagle Foundation Working Group on the Teacher–Scholar (2007) provides a concise argument for the robust connections and synergy between teaching and scholarship at both undergraduate institutions and research universities. Fully embracing a pedagogy of discovery, inquiry, and analysis suggests integration of teaching with research as opposed to separation. Certainly financial considerations must be taken into account, but already many institutions are succeeding and there are many examples across the institutional spectrum of models that incorporate research-rich experiences into courses across the curriculum to engage more students in the core aspects of this high-impact practice. Campus leadership will be required to foster a continued vision for engaging students in undergraduate research experiences and research-rich courses in these challenging economic times and beyond. But for the future of our world, it will be worth the effort. ▪

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The Integrity and Integrality of Student Research at a Liberal Arts College

▸ **Greg Weight,** coordinator of student fellowships and scholarships, Ursinus College

In these pages some four years ago, authors from the Council on Undergraduate Research argued that undergraduate student research "speaks to some of our most fundamental educational objectives by providing a personalized education, exemplifying engaged pedagogy, and promoting students' intellectual independence and maturation" (Elgren and Hensel 2006). In the time since, the Association of American Colleges and Universities (AAC&U) has championed student research as one of the "high-impact practices" that can transform students' lives as it "involve[s] students with actively contested questions, empirical observation, cutting-edge technologies, and the sense of excitement that comes from working to answer important questions" (Kuh 2008). And, it almost goes without saying that the independent research experience adheres to the LEAP Principles of Excellence, as students learn the "arts of inquiry and innovation" to "engage the big questions" as they pursue their research principles. Student research is fundamental, exciting, and engaging.

THE ROLE OF THE STUDENT RESEARCHER

Student research at a small liberal arts college can reflect all of those superlatives, but student research in such an institution can also be constrained by a number of factors. Since they are often "small," relative to those at larger research universities, liberal arts college departments may lack both the breadth of coverage and the resources to respond to the variety of student research interests. At such institutions, the emphasis is on teaching, and taking on a student researcher for an independent study or an honors or senior thesis can be an unrecognized strain on a potentially heavy teaching load. As Kuh notes, student research "has been most prominently used in science disciplines," potentially preventing whole swaths of students from engaging in research (2008). Certainly faculty in the STEM disciplines welcome student researchers into their labs to work on their projects, but faculty outside of these disciplines can find it difficult to determine how a student researcher would help them in their own research. Should their duties include simple tasks such as getting books from the library, making copies of articles, and proofreading documents? Such work hardly constitutes research as we would ideally conceive of it, and in neither context would it be considered the kind of independent research that would develop the core skills which liberal arts colleges pride themselves on imparting, like critical thinking and the ability to synthesize.

And yet the academic skills and ideals that liberal arts colleges impart are exactly why student research at such institutions can flourish. In developing a research question, establishing a framework for the project, and analyzing data or texts, students necessarily sharpen their critical thinking skills. The breadth of knowledge they gain through exposure to a variety of disciplines and approaches—and the increasing emphasis on interdisciplinarity—helps to shape a project that perhaps has more nuance and even applicability. The close student–faculty interaction that almost naturally occurs in a small college can provide students with the opportunity to see first-hand what the life of a scholar is like—and inspire them to try their hand at it. With this encouragement, the independent spirit that marks so many liberal arts colleges can empower the student to ask his or her own questions about a discipline and then translate that experience to a lifelong thirst for inquiry and learning.

For student research to succeed at a liberal arts college, it requires a strong commitment from every facet of the college community: from the administration, philosophical and monetary support that conceptually and concretely secures student research as a worthwhile endeavor for every student at the institution; from the

faculty, the flexibility, openness, creativity, and even faith to believe that students *can* conduct independent research in any discipline, and that the benefits to both student and mentor can be surprising, transformative, and integral to the "normal" work of the college; and from the student, the diligence and bravery to ask the difficult questions and do the hard work to create something that is their own but also becomes a piece of the larger work of the academic community. Out of this network of support, students, faculty, and an entire college can be changed in surprising and enlightening ways.

TRANSFORMATIVE STUDENT RESEARCH AT URSINUS COLLEGE

In 1991, Ursinus College started a summer science research program after receiving a grant from the Howard Hughes Medical Institute (HHMI) for that purpose. The end of the grant coincided with the beginning of President John Strassburger's tenure. As one of his goals was to reaffirm Ursinus's commitment to a liberal education, President Strassburger and Vice President of Academic Affairs Judith Levy spearheaded an effort to expand the parameters of the HHMI program to fund student research in all disciplines; thus, the Summer Fellows program was born. Using college funds supplemented by faculty grants, the program funds upward of ninety students to conduct research for eight weeks during the summer in every discipline from anthropology to theater. Students are provided with a stipend and a room on campus; their faculty mentors are also provided with a stipend for their work as guides through the research process. The summer opens with students sharing summaries of their research plans to begin the process of becoming a community of scholars; weekly talks from faculty from Ursinus and beyond provide insight into what shapes research can take—and the effects on the researcher and the outside world that such work can have. The program closes with a research symposium, during which students present the work they have accomplished in front of an audience of peers, mentors, and visitors. I could gush at length about the benefits of this program to everyone involved—how the vast majority of students in survey responses reported receiving "great" or "good" gains in their understanding of the relevance of research to coursework and the connections among disciplines, as well as confidence to do well in future courses and in their ability to contribute to their discipline. However, a recent student project will better illustrate how transformative student research can be to both students and faculty.

In the fall of her junior year, Amanda Leatherman took a course on media and society with Lynne Edwards, associate professor of media and communication studies. Amanda was perhaps a model liberal arts student: a double major in media and communication studies and neuroscience, she planned on becoming a lawyer. For her final project in media and society, she wanted to delve deeper into trying to understand the criminal mind and try to trap those out to ensnare and exploit children online by posing as a thirteen-year-old girl in online chatrooms. Impressed by her initiative, but also concerned about her safety, Edwards instead encouraged Amanda to consider pursuing a longer research project under her mentorship during Summer Fellows. During the spring, Edwards worked with Amanda to hone her project, adding a much-needed theoretical framework: using a communication theory that revealed how online predators use language to gradually lure and entrap children, they would construct a content analysis project using transcripts of online chats involving convicted online predators.

Even with this increased rigor, Edwards was concerned about the content matter that Amanda would be so closely engaging with for two months. She knew that her colleague April Kontostathis, associate professor of computer science, was always interested in practical applications for students to pursue, so she approached her about developing a software program that could be taught to code these conversations. Soon, the project took on a new focus: theory begat praxis, and they were now building a better mousetrap. Over the course of the summer, Amanda worked on both the theoretical framework undergirding the project and on the difficult work of coding these conversations according to the framework (i.e., identifying where a phrase or term fell in the cycle of entrapment constructed by the predators' language). By summer's end, Amanda knew she had much more work in front of her, and began planning for a year-long honors project that built upon her work; this newly formed research team also knew by summer's end that they had a project that could be important for themselves, future students, and the world.

Kontostathis realized that this project was well-suited for funding from the National Science Foundation (NSF); or, as Edwards puts it, "as the project grew from developing a theory of online luring communication to developing a manual coding system and then developing a computer coding system that learned how to recognize illicit cyberlanguage, April recognized that we had a project that the NSF may be interested in funding." And they were right: around the time that Amanda graduated, the NSF awarded her faculty mentors a grant to fund the continuation of the research project in order to develop an open-source software called ChatCoder that will detect online predation as it happens. The grant of course included funding for more student researchers to move the project forward. This past year, two computer science stu-

dents started during Summer Fellows to upgrade ChatCoder to learn, not just code, language and illicit conversations; their work has transformed the program into something far more effective. Three media and communication studies students conducted independent studies on including victims' language into the program to allow the program to better understand how these conversations and relationships develop. Further, first-year students coded transcripts during the Ursinus Bridge program (a program to help students from historically underrepresented groups make the transition to college), while seniors in the media and communication studies senior seminar created thirteen related independent projects that were presented at the Celebration of Student Achievement. And the work goes on: this summer four summer fellows, with the help of three assistants and two faculty mentors, will continue the work that Amanda began two years ago.

As I reflect on it, the current state of the project depends on a number of decisions and contexts that all needed to be just right—and I think all turn out to be tied to the mission and character of a liberal arts college. This project would not have existed without the persistence, passion, and creativity of a committed student who had questions about an important issue: how do online predators lure their victims and how can we stop them? Her capacity and willingness to ask those questions were supported from her first class at the college, the Common Intellectual Experience, which focuses on the "big questions" of our lives: What does it mean to be human? How should we live our lives? What is the universe and what is our place in it? Regardless of the program, every liberal arts college encourages its students to begin if not continue a life as an engaged and inquisitive citizen, and the spirit of critical inquiry that suffuses a liberal arts college curriculum and campus finds its ultimate expression in student research. Amanda's questions may have remained unanswered were it not for a committed faculty member who encouraged those questions to be asked. Turning those questions into a productive and responsible project required a faculty member who knew the capacity and temperament of the student—such knowledge is part and parcel of a liberal arts college culture that emphasizes collegiality and the one-on-one relationship between faculty and student. Turning this project into something more ambitious required a faculty member willing to challenge a student to do more and think harder—and a student willing to do so. To me, the liberal arts emphasis on critical inquiry always has at its heart an ameliorative purpose—can we do/think/solve better?—and research is nothing if not an effort to do better.

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To give Amanda and her project the time and attention required, Edwards also demonstrated an often unstated quality of faculty at liberal arts colleges: sacrifice. Though she had done some work in media coverage of adolescent crimes and the issue of online safety, Edwards's research agenda did not include developing a systematic approach to online predators' luring communication (and for that matter, neither was Kontostathis planning on developing a software program to track it), but she sacrificed some of her time and focus at the beginning of the process because she saw a bright student with a bright future and a bright idea—and faculty at liberal arts colleges seem to be suckers for such a student.

CONCLUDING THOUGHTS

Indeed, in my three experiences as a Summer Fellows mentor, I have yet to work within my specialty of eighteenth-century British literature; instead, I have helped students to explore the didacticism of D. H. Lawrence's later novels; the rhetoric of same-sex marriage in state supreme court cases; and the gender politics of Rebecca West's 1,200-page travel narrative, *Black Lamb and Grey Falcon*. I certainly hadn't planned on exploring any of these areas on my own, and I sacrificed some time and energy (especially with West) because there was a student with such passion and interest that I couldn't help but to help encourage that. That idea of sacrifice, I think, is the mark of any good teacher at any college, but given the emphasis on teaching at liberal arts colleges, it feels like I see more of it here and at similar colleges. I also think that underlying that sacrifice is a commitment to modeling behavior: if faculty aren't willing to leap off a conceptual or disciplinary ledge, then from whom are students going to learn the pleasure, excitement, and rewards of doing so?

Amanda's project may have remained a simple content analysis project had not Edwards engaged her colleague, Kontostathis. The character of a small liberal arts college once more made this project what it is, because without such a college's emphasis on faculty collegiality Edwards might not have even known what Kontostathis was interested in. Further, both modeled the liberal arts college emphasis on breadth of knowledge for Amanda: willing to look beyond their disciplinary turrets, they found that their different sets of knowledge could creatively combine to form something greater than its parts.

There have been obvious benefits of this project. Amanda completed a project that challenged her and will ultimately benefit many others in and outside of the college: as she puts it, "the research I conducted at Ursinus really opened my eyes to the 'real world' and showed that I could make a difference." After graduation, she matriculated into the University of Maryland School of Law. Her faculty mentors received a grant to continue this project, which also challenges them and leads their research in new directions. Current and future students have the opportunity to continue and expand on the work their fellow student began. Beyond these obvious benefits, I have seen, as administrator of the summer fellows program, the subtler and more comprehensive effects student research can have on a college. I watch as nervous students approach the dais to describe their work—and their nerves melt away as they relate their passion. I watch as two students from two completely different majors teach each other about their work with a confidence and patience seldom seen in twenty-year-olds. I watch as faculty ask questions of their own students with caring challenge, and see as they beam as the students return their sallies with confidence and aplomb. I watch as faculty chat with each other about what their students are researching—and what their own work is. Then, I watch as prospective students tentatively walk through the door of the classroom, sit down, and hear peers some three years older than them discuss how Bisphenol A may affect our health, whether ugly criminals get harsher sentences, how we can better diagnose ADHD and OCD, how to define "dignity"—and how we can better catch online predators using communication theory and software. I see in these students a realization that attending a liberal arts college means not just smaller classes or closer faculty-student interaction, but entering into an environment that encourages breadth of knowledge and in-depth study into one's own passion and the pursuit of individual thought and persistent questioning that challenges oneself and leads to the betterment of society. Finally, I watch as a liberal arts college finds its heart as it encourages students to follow their hearts—with a lot of assistance from their minds and the hearts and minds of their faculty mentors. Student research exemplifies a liberal education and can reinvigorate and refocus the mission of a liberal arts college. ▪

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Enhancing Undergraduate Research in the Arts and the Humanities

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Many colleges and universities across the country now have offices dedicated to the expansion and promotion of research activities by undergraduate students. Unfortunately, many undergraduates arrive on campus associating the concept of research with the STEM fields—science, technology, engineering, and math. This narrow (and thus inaccurate) understanding of academic research often means that relatively few undergraduate students get involved in research. Thus, one the major goals of the Office of Undergraduate Research and Creative Endeavors at Florida State University (FSU) is to increase participation by students in the humanities, the social sciences, and the arts. As the name of the office implies, we are interested in promoting academic success and skills not just in the traditional STEM research fields, but also in fields such as art, music, theater, and film, where creative works, rather than research data, may be the scholarly product. This article will discuss the specific strategies that we are using to increase participation by students and faculty outside of the sciences, while enhancing the independent work of future scientists.

CENTRALIZED SUPPORT FOR UNDERGRADUATE RESEARCH AND CREATIVE ENDEAVORS (URACE)

As a Research I institution, Florida State University has a long history of undergraduate involvement in research activity. Faculty mentor undergraduates in every academic field, and undergraduates are engaged in novel research leading to scholarly publications, presentations at national meetings, and creative works that get national attention. Clearly students who participate in an undergraduate research experience are better prepared for graduate and professional school. They have a better understanding of the demands of graduate training in their fields, and benefit from exposure to specific research tools, methods, and techniques. Most important, undergraduate researchers have more highly developed critical thinking skills. For students not planning postgraduate work, the benefits of undergraduate research are also clear, as critical thinking, analytical abilities, and problem-solving skills are all enhanced by undergraduate research.

Given this active research environment, an ad hoc committee on undergraduate research surveyed faculty and administrators to get a better understanding of the needs of faculty and students. The survey confirmed a significant interest in undergraduate research that stemmed from faculty members' understanding of the benefits of research experience to undergraduate training. The committee also recognized the need to provide more support for student researchers, enhance the visibility of faculty who give their time to undergraduates, and expand the scope of the work in which undergraduates participate. Thus, the dean of undergraduate studies and the university provost and executive vice president for academic affairs created the Office of Undergraduate Research and Creative Endeavors (URACE). The URACE office is staffed by a faculty director (a quarter-time URACE appointment) with an active research program and experience teaching undergraduates, as well as a full-time associate director who runs the day-to-day operations of the office. In 2007, this new office joined the long-standing and highly successful Honors Program and Office of National Fellowships in the division of undergraduate studies. Together, these three offices coordinate and promote the Honors, Scholars, and Fellows Program for undergraduates on the FSU campus.

OFFICE GOALS AND PHILOSOPHY

From its inception, the URACE objective has been not only to help students get involved in research, but to help them get the most out of the experience. The undergraduate research process is a continuum that begins with getting students interested in research and later involves helping them identify their interests, find a mentor, and become actively involved in the research process. We provide competitive avenues for funding their work and for support while conducting research, as well as opportunities to present their work on campus and at regional and national venues. Our philosophy is that this continuum applies equally to the sciences and humanities.

Two guiding principals have helped integrate more students from underserved areas of arts and humanities into independent research and creative work. First, the URACE office has actively encouraged faculty in these disciplines to use the "science model" of undergraduate research. In the sciences, undergraduates typically work in teams with graduate students and faculty. At the beginning stages of their work, they help in relatively routine ways, but are exposed to the culture of a working research laboratory. With time, many undergraduates are able to contribute to the laboratory's goals. Undergraduates become coauthors on abstracts, publications, and presentations. This model benefits graduate students and faculty mentors, as well as undergraduate students.

In contrast, undergraduate research projects in the humanities are often independent endeavors with students working on topics related only tangentially to the faculty member's own research. While the one-on-one aspect of this model can be beneficial to the student, the faculty member gains little from the relationship. Thus, at FSU we have encouraged faculty in all disciplines to have undergraduates help them in their research. In the humanities, this may mean having an undergraduate student help a faculty member work on the index of a book he or she is writing, or collect resources for the next project he or she is planning. While many faculty members are quite rightly reluctant to assign students "busy work," I would counter that it is precisely this type of work that students not only need to see, but need to actively participate in to become productive researchers. Students need to be mentored in the *entire* research process. The best way for this to happen is to put students in a position to become a research assistant and be truly useful to the research program. In short, scientists have long put undergraduates to work to the benefit of both the student and the faculty member. This is a model that could serve many in the humanities as well.

The second guiding principal is that students should begin the research process as early in their academic careers as possible. Too often, students learn about the advantages of undergraduate research in their junior or senior years. Many rush to complete an honors thesis in their final two or three semesters. While students clearly benefit from these research experiences, the most valuable experiences take

several years to develop. If students are ultimately going to be able to serve as research assistants and get the most out of the experience, the earlier they start, the better. At FSU we encourage first- and second-year students to explore research opportunities. It takes time to build the kind of relationships that are needed to be part of a research team and be productive. It takes time to develop the skills needed to produce a meaningful product—regardless of whether that product is scientific, artistic, or literary.

STRATEGIES FOR SUCCESS

To facilitate the entire continuum of undergraduate research, the URACE office uses a variety of strategies, including introductory workshops, classes, funding mechanisms, and opportunities for presentation of research and creative works. We conduct a series of fall workshops aimed particularly at students who have not yet identified a research mentor. We target academic areas with separate workshops for sciences, humanities, and the arts. While a variety of formats can be used, we typically have a panel with both faculty and senior members of our Student Council on Undergraduate Research and Creativity talk about the advantages of getting involved in research, tips to finding a research mentor, and how to make the research experience successful. The student panelists have been remarkably candid, sharing both their successes and frustrations with the research process, and giving new students a clear overview of the rigors and demands of undergraduate research.

The office also teaches a second-year research colloquium. This one-credit-hour course is required for all honors students who were admitted to the Honors Program in their second year. Through a series of panel discussions, approximately 400 honors students hear from faculty and students in a variety of fields to learn the benefits of getting an undergraduate research experience, how to get involved, how to be a successful and productive member of a research program, and how academic research is applied. There are also planned activities to help students explore their own interests and identify possible faculty mentors. More advanced students can take advantage of any of several research-oriented seminars, including student-run journal clubs and "frontiers" classes where groups of ten to twelve students meet weekly with a faculty facilitator to discuss cutting-edge research and discovery in a specialized area.

URACE also provides a number of funding opportunities for undergraduate researchers. These funds are largely unrestricted awards distributed in the summer. This permits students to use the money in a variety of ways —including for the purchase of supplies needed to conduct the research or produce the creative work, for travel to support the work, or even as a summer stipend to support the student researcher. To increase participation by students in the arts and humanities, we have included several awards specifically for students proposing work in these areas. For example, we recently named two Atlantic Coast Conference (ACC) fellows in undergraduate research funded by the ACC International Academic Collaborative with money from the ACC football championships. Fellows were each awarded $5,000 to further their ongoing research. At FSU, we designated one award for a student in the sciences, and the other for a student in the arts or humanities. These awards, which were widely covered in the press, have enabled us to showcase the cutting-edge work done by undergraduates. And because one of the recipients used the money to direct and stage a new play, we were able to highlight the important role of research in the arts.

Once students have begun to work and produce research data or creative works, the URACE office seeks to help them find avenues to present their work. In the fall, we hold a symposium for our award winners where students give oral or poster presentations. These symposia are well attended by both faculty and students. In the spring, we broaden the opportunity to all undergraduate researchers, and encourage presentation of "works in progress." We offer workshops on poster making and presentation skills as well as individualized practice sessions and feedback. To ensure that these symposia are inclusive of all fields, we provide students with the ability to present creative works at these sessions. As students advance, we also provide competitive support for students to travel to present their work at regional and national venues.

CONCLUSION

A successful undergraduate research program requires a faculty committed to undergraduate education and a university administration willing to make the investment in the training of its students outside of the classroom. The strategies we are using to increase participation in all fields have been successful. Our early calls for research proposals from undergraduates were answered by applications largely from students in STEM fields. However, in our most recent funding cycle, 60 percent of the applicants were from non-STEM fields. The quality of these proposals has also improved since the implementation of the URACE programs. At FSU, the office of Undergraduate Research and Creative Endeavors has shown that we can foster novel, cutting-edge work in all fields—and the fact that this work is produced by undergraduates gives them an advantage as they transition into postgraduate and professional life. ▪

Low-Cost Strategies for Promoting Undergraduate Research at Research Universities

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A meaningful undergraduate research experience offers students the chance to learn new skills, gain confidence, become more ambitious, and prepare for future careers (e.g., Elgren and Hensel 2006; Russell, Hancock, and McCullough 2007). No longer restricted to small colleges or honors programs, faculty-mentored undergraduate research or creative experience is increasingly featured among the goals and expectations of highly motivated students everywhere. Such experience is recognized as one of ten high-impact educational practices by the Liberal Education and America's Promise (LEAP) initiative of the Association of American Colleges and Universities (Kuh 2008). Moreover, *U.S. News and World Report* now ranks colleges and universities based on reputation for providing opportunities that could lead to scholarly publications and presentations. At the national level, the Council on Undergraduate Research has been a strong advocate for high-quality undergraduate student-faculty collaborations.

At large, public, research-intensive universities such as ours, students now expect to have access to research opportunities. The student body is surrounded by well-funded faculty, postdoctoral fellows, graduate students, and others who have tremendous resources, expertise, and professional networks at their disposal. This sophisticated research enterprise provides a vast array of opportunities for students in all disciplines, and undergraduates are increasingly encouraged by faculty and advisers to take advantage of it. Although student-to-faculty ratios are high and professors are busy with grant-writing, research, teaching, and other professional duties, many faculty gain deep satisfaction from serving as research mentors to enthusiastic students. Working with motivated undergraduates also creates a pipeline to graduate programs and, once an initial training period is completed, may result in much-needed assistance with the faculty member's research program. Funds to support student researchers may be included in grant requests from several national agencies and other sources. Some institutions also provide scholarships for student research projects and award funds to faculty supervisors as incentives for collaborative projects. However, in many cases, the current budget crisis has further strained budgets for enriching the curriculum.

CAMPUSWIDE UNDERGRADUATE RESEARCH OFFICES

To benefit from economies of scale, many universities have established centralized programs that coordinate and support undergraduate research and creative activities in all disciplines (see fig. 1). Central offices complement other efforts on campus that may be more departmental or disciplinary in focus. By coordinating efforts across campus and using Web-based resources, central offices can support a wide variety of initiatives that encourage the integration of research and learning. One of the most useful cost-saving products of a central office is a well-publicized and up-to-date Web site that provides a database of current research opportunities and information about why research experience is useful, how to get started on a research project, how to find funding, and how to present one's results at meetings and in publications.

Many additional activities of a central undergraduate research office can be offered at low cost, funded collaboratively, or funded through external grants or gifts. In addition to one-on-one advising and coaching, a centralized undergraduate research office can offer group sessions—through workshops and seminars—that can reach students more efficiently. These sessions provide

- inspiration for students to seek rewarding research experiences;
- assistance with identifying research opportunities and mentors;
- guidance on applying for funding through internal or external scholarships and awards or summer programs;
- instruction on becoming a professional, the ethical conduct of research, and understanding the research process.

Efficiency can also be gained by offering workshops and online resources to provide faculty with

- guidance on successful mentoring practices;
- assistance with grant applications that include undergraduate research funds or supplements;
- strategies for recruiting and selecting students for specific research opportunities;
- support for including research experiences in courses or in designing capstone research experiences.

In addition, with modest internal or external funding, a central office can offer an annual undergraduate research forum or symposium, provide opportunities for students to publish their work in print or online journals, and introduce students to the review process by integrating them into this work as coplanners, editors, and reviewers. Taken together, all of these efforts raise students' expectations of themselves as scholars, enrich their undergraduate education, and assist them in refining their longer term postgraduate education and career goals. A campuswide undergraduate research office can also work to increase recognition of faculty and academic units that have been successful in developing undergraduate research opportunities. While it is always easier to implement new activities with ample funding, we wish to describe how these efforts can continue to flourish in times of severe budget constraints. Below, we describe some specific examples of low-cost, high-impact strategies for fostering undergraduate research at our universities. Each of these ideas can be implemented for an entire campus or within specific colleges or departments. And although we focus on large universities, many of the approaches we have used may also apply to smaller institutions.

FIGURE 1.
EXAMPLES OF CAMPUSWIDE UNDERGRADUATE RESEARCH WEBSITES AT PUBLIC RESEARCH UNIVERSITIES:

- The Ohio State University **www.undergraduateresearch.osu.edu**
- University of Washington **www.washington.edu/research/urp**
- University of California at Irvine **www.urop.uci.edu**
- Michigan State University **www.urca.msu.edu**
- University of Central Florida **www.our.ucf.edu**
- University of Connecticut **www.ugradresearch.uconn.edu**
- University of Maryland **www.ugresearch.umd.edu**
- University of Michigan **www.lsa.umich.edu/urop** (Arts & Sciences)
- University of Minnesota **www.research.umn.edu/undergraduate**
- University of Missouri **www.undergradresearch.missouri.edu**
- University of Nebraska **www.unl.edu/ous/undergraduate_research/research.shtml**
- University of North Carolina **www.unc.edu/depts/our**
- University of Vermont **https://uvm.edu/ugresearch** (Honors College)

MOBILIZING VOLUNTEERS

Creating a community of student volunteers is an excellent way to get things done for free while providing students with service and leadership experience. Students who have already participated in research can inspire their peers and provide practical advice to help them get involved in research. And students' perspectives and advice are essential for developing effective campus-wide programs that are appealing to undergraduates. At Ohio State, for example, the Undergraduate Research Office (URO) has a Student Advisory Committee, as well as a large group of student researchers who are available for peer advising. Student volunteers are happy to serve on discussion panels, help with events, and give presentations to student organizations and introductory courses. In 2009, URO volunteers reached more than 3,000 Ohio State undergraduates, including 23 percent of the freshman class, by giving short talks about opportunities for getting involved in research. Student volunteers help raise the profile of undergraduate research on campus, with little more than the occasional pizza dinner in return.

At the University of Washington (UW), graduate students and postdoctoral research associates also provide valuable volunteer service that benefits undergraduate research, while gaining important professional experience. For example, most of the more than 750 undergraduates who present their research at UW's annual undergraduate research symposium attend a presentation practice session or a

workshop on writing a research abstract, creating a research poster, or making a PowerPoint presentation. Many of these workshops are delivered by postdoctoral associates or graduate students who are interested in gaining teaching experience for careers at primarily undergraduate institutions. In return for their service, Undergraduate Research Program (URP) staff provides letters of support, participant feedback on their presentations and teaching style, and advice on mentoring undergraduates under their direction. These volunteers provide a highly capable and willing workforce that greatly enhances what the URP staff could offer on its own.

Purposeful undergraduates also generate new ideas and programs. A few years ago, a group of enterprising students approached Ohio State's URO with a proposal to create a peer-reviewed, undergraduate research journal. The URO did not have the staff or resources to help them out, but it turned out that the students didn't really need much assistance. Independently, and with the staff's enthusiastic encouragement, they formed a student organization, developed an editorial board and editorial policies, created a Web site, and solicited manuscripts for an online publication. This year, *JUROS* (the *Journal of Undergraduate Research at Ohio State*) made its debut, complete with scholarly articles that are written and reviewed by students, feature stories, video profiles, and a faculty perspective. The journal can be viewed at www.jurosonline.com. The results were so impressive and professional that the URO decided to allocate funds for an inaugural hard-copy printing of highlights from *JUROS*.

A campuswide undergraduate research symposium can be an effective way to provide a forum for students to learn how to present their work, for undergraduates not yet involved in research to gain access to mentors and generate ideas for projects.

COST-CUTTING AT THE ANNUAL UNDERGRADUATE RESEARCH SYMPOSIUM

A campuswide undergraduate research symposium can be an effective way to provide a forum for students to learn how to present their work, for undergraduates not yet involved in research to gain access to mentors and generate ideas for projects, for the university to showcase the powerful impact that research participation has on undergraduate education, and for students, faculty, and staff to discuss current research with community members and parents in a high-energy setting. At UW, as at many colleges and universities, the symposium serves as a culminating event for students involved in research throughout the academic year. We offer poster sessions, concurrent oral presentation sessions, and a performing arts venue, and typically draw more than 2,000 attendees as well as approximately 750 undergraduate presenters. Even though the event is a critical one for students, it has suffered from budget cuts along with other activities. Recently, we have cut the event budget in half by making just a few changes:

- Replacing a printed booklet with fully searchable, online proceedings for the publication of student abstracts and related materials (www.exp.uw.edu/urp/symp)
- Reducing food costs. We used to provide lunch but now have just cookies and water coolers scattered throughout building
- Recognizing mentors by providing a forum for students to publish mentor appreciation comments, and presenting non-cash awards to outstanding faculty and graduate students
- Utilizing volunteers (students, alumni, staff, graduate students, and postdocs) rather than relying on paid staff for event set up, registration, guest reception, and the myriad tasks involved in running a large community event

CREATING A LOW-COST SUMMER RESEARCH INSTITUTE AND FALL POSTER FORUM

At Ohio State, hundreds of students remain on campus each summer to conduct research, whether paid or unpaid, in organized programs, or independently. About two-thirds of these students are funded by formal programs, each of which functions as an isolated group experience. To bring these disparate groups together and draw in free-floating students, we created a Summer Undergraduate Research Institute, with programs for professional development, brown-bag lunches, social events, Ultimate Frisbee, and softball. A paid undergraduate student leader helps coordinate the program, and the total costs amount to less than $6,000 per summer (255 students enrolled in 2009).

Summer researchers are strongly encouraged to present their work at a new, low-budget Fall Undergraduate Research Forum that complements our much larger, corporate-funded spring forum, which is now in its fifteenth year. The Fall Forum, with about seventy posters

and three hundred attendees, does not include judging or cash prizes. Students submit abstracts and discuss their posters with peers, faculty, and others, including OSU President Gordon Gee. This festive event recognizes their accomplishments and represents a major milestone in their professional development. Simultaneously, to inspire incoming students who attend the Fall Forum, we offer concurrent workshops targeted to freshmen and others who have not yet started doing research.

DEVELOPING INTEGRATED WEB DATABASE BUSINESS APPLICATIONS

The backbone of a successful, centralized undergraduate research program is the ability to manage data, and program information, and communicate with stakeholders effectively and efficiently. The Undergraduate Research Opportunities Program (UROP) at the University of California, Irvine, established in 1995, uses a Web database system to engage more than two thousand undergraduates annually. This homegrown system was developed in 2003 by a student who understood UROP-specific business needs and applications. It is used for many interrelated purposes—student interest forms; distributing information about research opportunities on and off campus; processing student proposals, applications, symposium abstracts, and journal submissions; supplementary documents; workshop RSVPs; nominations for student researcher of the month and faculty mentor of the month; publicizing news and events; and tracking expenses. A great advantage of integrating this information into a comprehensive database is the ability to produce instantaneous reports by department or individual faculty mentor listing students or projects supported by UROP since 1995, with links to students' proposals, abstracts, or papers. These reports have proven to be a very effective way of recognizing faculty efforts and supporting their tenure and promotion cases, not to mention university accreditation reviews.

This Web-based system also allows us to initiate new programs within a short timeline. For example, UROP launched three new programs in summer 2005: the Integrated Micro/Nano Summer Undergraduate Research Program, in collaboration with the School of Engineering and funded by the National Science Foundation as a Research Experience for Undergraduates Site; Inter-Disciplinary Summer Undergraduate Research Experience, in collaboration with the School of Social Ecology and funded by the National Institutes of Health; and the Summer Undergraduate Research Fellowship in Information Technology, cosponsored with the California Institute for Information and Telecommunication Technology. With limited staffing resources, the Web database system has allowed the UROP team to reach far more stakeholders with much greater impact than was previously possible.

CONCLUSIONS: WORTH THE COSTS?

Investing in undergraduate research offers huge benefits that are not easily quantified because they are long term and multifaceted. In addition to providing life-changing educational experiences for students, undergraduate research enhances the university's local reputation and national profile. College applicants and their parents are impressed when they learn about the many opportunities for students to work alongside graduate students and professors to address issues of global significance. Many studies have shown that students who participate in research are more satisfied with their education and more likely to complete their degrees than those who lack this experience (Nagda et al. 1998; Hathaway, Nagda, and Gregerman 2002; Russell Hancock, and McCullough 2007; Kuh 2008). Furthermore, whether they are doing research themselves or learning about it from peers, students benefit from understanding the essential links between research and learning. Quite often, the bonds that form between students and their faculty and graduate student mentors endure for years. Alumni who have taken advantage of research opportunities have good reason to give back to their alma mater later in life. Whether one's institution is well-endowed or operating under great financial strain, supporting student researchers is a very meaningful and cost-effective way to enrich their education. ▪

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Undergraduate Research Learning Communities for First-Year and Lower-Division Students

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The undergraduate research experience at Cleveland State University (CSU) is a progressive new learning community. Through this program, incoming students from almost any major can be immersed in CSU's intellectual community and engaged in research as early as their first semester on campus. Opportunities for undergraduate research at CSU have long existed for select groups but the undergraduate research learning community now provides early opportunities for a wider audience of first-year students to be exposed to research practices that reach beyond the natural sciences into many disciplines. The program serves to advance CSU's overall mission as an urban, commuter university to provide excellent education, and we try to proactively address and meet the needs of the diverse population of students enrolled. Perhaps more important, this initiative has helped more students to understand research as an important dimension of higher learning, and has encouraged their active involvement in the research process.

COLLABORATIVE INQUIRY AND DISCOVERY

CSU faculty, undergraduate program directors, deans, and staff collaborated for months to conceptualize our vision and goals for a meaningful undergraduate research experience and agree upon an acceptable model. Some felt that first-year students were not yet ready for such an experience. These campus professionals finally came to support the model based on the notion that some first-year students have successfully completed Advanced Placement courses in their high schools and have participated in science fair projects at local, regional, and national levels. There was sufficient evidence of requisite academic preparation to engage in and benefit from early exposure to research. Many first-year students possess the intellectual curiosity to engage in meaningful research and have the potential to be trained as budding scientists in their intended majors.

UNDERGRADUATE RESEARCH COMMUNITY OF LEARNERS

We agreed upon a structure that represented a departure from our existing learning community model. A typical CSU learning community experience lasts one semester and features three to four groups of four courses linked thematically and scheduled in a group. Cohorts of twenty-five to thirty first-year students coenroll in the courses and are supported through a systematic process of peer mentoring, coaching, intensive advising, and a variety of other university supports. By contrast, the new undergraduate research learning community is composed of fifteen faculty participants who are actively involved with research, and each works closely with one or two students. Because the program is new, students were identified either on the basis of their expressed interest in the research or their demonstrated performance in other classes. As the program continues and more students report their experiences, we anticipate that students will initiate the contacts and more will request to enroll.

The undergraduate research learning community faculty commitment requires regularly scheduled encounters with students and the intentional involvement of students in meaningful work. Faculty also agree to prepare and deliver one presentation to the community of learners sometime during the semester, at planned weekly sessions. These presentations afford students the opportunity to learn about the exciting work faculty members are doing, and to be exposed to the various research methods used in different disciplines. One tangible benefit for students is the opportunity to enroll in an independent study course, offered in the faculty member's department for variable

credit, based upon the learning agreement and specific outcomes measured at the end of the semester. Learning agreements outline expectations, learning outcomes, and measures and include the following components:

1. commitment to regular faculty/student meetings and encounters around the research project
2. satisfactory completion of assigned research activities and assignments as determined by faculty research instructor
3. participation in a scheduled Peer Research Community for students—enrollment in a one-credit-hour Introduction to University Life course, customized for students conducting undergraduate research
4. specific student outcomes due at end of the semester, such as submission of one final scholarly paper, preparation and submission of one or more conference proposals related to the research activities, or development of a poster or oral presentation about the research

Faculty members' presentations about their research often include student mentees, creating an invaluable experience for any first-year student, especially an aspiring researcher. Faculty enjoy the opportunity to showcase their research. For students, collaborating with faculty and participating in these sessions develops presentation skills and builds a sense of efficacy about the research. We are currently investigating ways to include community leaders from external agencies—such as chemical industries, NASA, and high-profile medical and health care facilities—as presenters and guests in these sessions.

UNDERGRADUATE RESEARCH LEARNING COMMUNITY GOALS

Participating faculty mentors agreed upon three specific goals for the design of the undergraduate learning experience: (1) students will have meaningful involvement in active research activities, (2) students will grow intellectually, and (3) students will gain a foundational understanding of research methods. Kolb's experiential learning theory (Kolb 1984) was useful as we considered elements of the learning community design. This model of experiential learning describes an idealized learning process as one that involves a recursive cycle of experiencing—having a concrete hands-on experience; reflecting—questioning, conversing, and journaling about the experience to draw meaning; observing—watching and drawing conclusions from what is seen and heard; and testing—building theories of one's own. Our undergraduate research learning experience provides the opportunity for students to touch all the bases and have a distinctive and powerful learning experience.

CONCLUSION

We realized great benefit from the inclusion of department chairs, and, in some cases, undergraduate program directors, with faculty and staff in the design and implementation of the undergraduate research experience. Even though many of these department chairs and program directors held administrative assignments, some were also involved in active research. The institution supported their participation in our program, as it provided opportunities to mentor students directly. It should also be noted that the involvement of such faculty and administrators can be quite challenging. For example, it was difficult to facilitate and negotiate the varying roles and priorities of students, faculty, and the department with respect to undergraduate research activities. Ultimately, having these individuals involved and actively engaged in the implementation has helped advance the concept of undergraduate research learning communities; they advised us as we balanced the components of our new initiative with the overall planning needs of the academic programs. These individuals also promoted the undergraduate research concept, identified incentives for students and faculty in their various departments, and identified new research opportunities as well as rewards, scholarships, and prizes. Undergraduate program directors provided another invaluable service to our efforts by facilitating curricular, cocurricular, and scheduling elements of the research learning community in a manner that was consistent with departmental priorities and university policies.

Involvement in hands-on activities and close relationships with faculty appear to contribute to students' sense of efficacy and self-confidence and support their efforts to persist. Undergraduate research also provides students opportunities to explore "the real work" of a scientist or researcher as they consider their own career paths and desires for higher education. These positive benefits of intellectual growth, integrative and critical thinking, career exploration, and confidence building are perfectly aligned with our institutional goal to create engaged learning for our students. Involving talented beginning students and dedicated CSU faculty in research helps invigorate the undergraduate experience for the campus as a whole. One could use the term "glue" to describe the relevance of research in creating engaging student–faculty communities. It helps to connect the forces of teaching and learning in meaningful ways for students and faculty as they become collaborators and colearners in the process (Janusik and Wolvin 2007). At CSU, undergraduate research learning communities set high expectations for incoming students looking for a university experience shaped by academic and social experiences with faculty who are engaged in contemporary research in their fields. ▪

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Science Teacher and Researcher (STAR) Program: Strengthening STEM Education through Authentic Research Experiences for Preservice and Early Career Teachers

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Through an innovative partnership between universities, K–12 districts, federal research agencies, and industry, the Science Teacher and Researcher (STAR) program seeks to develop a new generation of science and math teachers equipped with the skills to inspire more of our nation's students to choose STEM (science, technology, engineering and mathematics) career paths. Founded and implemented at California Polytechnic State University (Cal Poly), San Luis Obispo, on behalf of the California State University (CSU) system, STAR provides research experiences along with career training and mentoring at critical early junctures in a teacher's professional development. STAR is founded on the idea that well-prepared, effective science teachers are professionals who are well-versed in both science and education. By anchoring preservice teachers in a community of scientific research practice, they will come to better understand what it means to be a scientist and a teacher of science or mathematics.

THE STEM EDUCATION AND TEACHER CRISIS AND THE GOALS OF CSU IN PREPARING SCIENCE TEACHERS

To compete in a growing global, high-tech economy, business and industry depend increasingly on workers with special preparation in STEM fields. National and international surveys indicate, however, that too few American students have the requisite knowledge and skills in science and mathematics to participate fully in today's economy.

This crisis is particularly acute for the state of California. National testing data from the most current *Trends in International Mathematics and Science Study* (TIMSS) indicate that performance of California's students is among the poorest in the United States in knowledge and abilities in both science and mathematics. Adding complexity is the state's increasingly diverse population, with nearly two-thirds of K–12 students from traditional minority groups and one-quarter designated as English learners. With high dropout rates, students are not prepared enough to participate in a growing technological society or to enter the STEM workforce.

Complicating this situation is a shortage of qualified science and mathematics teachers. In California, the demand for science and mathematics teachers is far greater than current credentialing rates, particularly in the physical sciences. California will require 33,000 new science and mathematics teachers over the next ten years.

STAR PROGRAM MODEL

The STAR program is part of a larger CSU Math and Science Teacher Initiative (MSTI) focused on addressing these issues by developing a new generation of highly qualified science and mathematics teachers. The STAR component of this program has three main goals for addressing the crisis in science and mathematics teaching: (1) enhanced recruitment of high-quality teachers, (2) improved teacher education and professional development, and (3) improved teacher retention rates.

The STAR program seeks to achieve these goals by:

- providing future science and math teachers with the prestige and experience of a scientific research or engineering design experience in a national laboratory
- fostering the development of inquiry-based science teaching and learning strategies
- supporting aspiring and early career teachers in the critical early years of their development

- creating a sense of belonging to a larger community of scientists, teachers, and educators

Since summer 2007, the STAR program partnership in California has developed a model that integrates intensive summer research experiences with teacher preparation to create teachers who see themselves as both teachers and researchers, or as "teacher–researchers." Ultimately, the goal of STAR is to produce more engaged science and math teachers who can better educate and inspire the next generation of K–12 students to become STEM-literate citizens, and who can propel these students into STEM careers.

Upper-division science, mathematics, and engineering majors, teaching credential students planning to teach secondary school science or mathematics, and early career science and mathematics teachers are eligible to apply for the program. Through a rigorous prequalification process that examines academic qualifications and commitment to teaching, fellows are recommended for summer research placements at partner federal laboratories and research centers.

Once placed in a research laboratory, fellows embark upon an eight- to ten-week research internship that is interspersed with weekly education seminars and workshops. Figure 1 illustrates how the STAR program affects the development of teachers through several phases (dark blue boxes), as well as affects STEM workforce and society outcomes (gray boxes). Light blue boxes illustrate the three main program goals described in more detail below.

Goal 1. STAR enhances the *recruitment of high-quality science, math, and engineering majors into teaching* by increasing their awareness of teaching careers, enhancing the prestige of teaching as a career, and making more apparent the requirements for entry into teaching credential programs.

- Science and math education faculty members at partner universities are important STAR program supporters, recruiters, and promoters. In addition, a specific *faculty liaison*, who is a science or math education faculty member from a local university, is assigned to each laboratory site for the summer. Liaisons play an important role in helping STAR fellows direct their summer research experience toward successful completion of a teacher preparation program.

Goal 2. STAR improves science teacher preparation and development by promoting a deeper and more personal understanding of the nature of scientific discovery and/or engineering design through the summer research experience.

- *STAR fellows* participate side by side with research scientists and their associates on projects of highly significant scientific importance. The *research–mentors* play a critical role in this aspect of the program. STAR fellows also gain an appreciation for inquiry-based instructional practices as they make connections between the "doing" and "teaching" of science and math. This program is facilitated by the science education laboratory staff at the research laboratory site in collaboration with the faculty liaison and a middle or high school *master teacher*, who is also a teacher–researcher role model. The master teacher is a critical link in helping students transfer their emerging personal and practical knowledge about scientific discovery or engineering design to their ability to inspire students to achieve at higher levels and enter the STEM career workforce. Finally, the cohort of STAR fellows during each summer and beyond helps to reinforce the communal nature of scientific discovery, learning, and teaching.

Goal 3. STAR is also designed to *improve science teacher retention rates* in a number of ways.

- One reason science teachers cite for leaving the profession is their lack of connection to the scientific community. The broader community of teacher–researchers, research–mentors, faculty members, and science education laboratory staff that has developed in this program (and will continue to expand) also plays an important role in retention. Also, by connecting science and mathematics teachers with others who have had similar experiences, they can support and learn from each other in a lifelong learning community.

STAR fellows are encouraged to participate in the program for two or three summers during these early critical years of education and development so that their research experiences, inquiry-based instructional training, and ties to the scientific community are fully developed and deeply engrained for lifelong learning along their teacher–researcher career path. Presently, approximately 20 percent of STAR participants return for a second summer of research; we anticipate that as appreciation for the benefits of STAR program experiences grow, a higher percentage of pre- and entering-service teachers will elect to participate in research for two or more summers.

STAR PROGRAM IMPLEMENTATION

The STAR program began with a pilot program during 2007 with the placement of sixteen STAR Fellows at Lawrence Livermore National Laboratory through funding provided by the National Science Foundation (NSF). During the next two years, the program expanded in California to include eight partner research sites with thirty research placements in 2008 and thirty-nine placements in 2009. The program was open to individuals who were currently or had been affiliated with a CSU undergraduate, graduate, or credential program. During 2008 and 2009, the program was funded primarily by the Stephen Bechtel Fund, with matching funds from the Fluor Corporation Foundation, the NSF Noyce Scholars Program, Cal Poly, and the California State University System.

Through funding provided by the NSF Noyce Scholars Program, the 2010 STAR Program has expanded to involve fifty-nine STAR Fellows at eleven sites in California and twelve STAR Fellows placed in four additional states (Colorado, Maryland, Tennessee, and Washington) as part of a national pilot expansion. In addition to CSU affiliates, the summer 2010 program is open to all current and former NSF Noyce Scholars at universities within proximity of the five states currently involved in the program. Statewide recruitment and coordination efforts have been facilitated by the following anchor university partners: University of Colorado, Boulder; Towson University; Middle Tennessee State University; and Western Washington University.

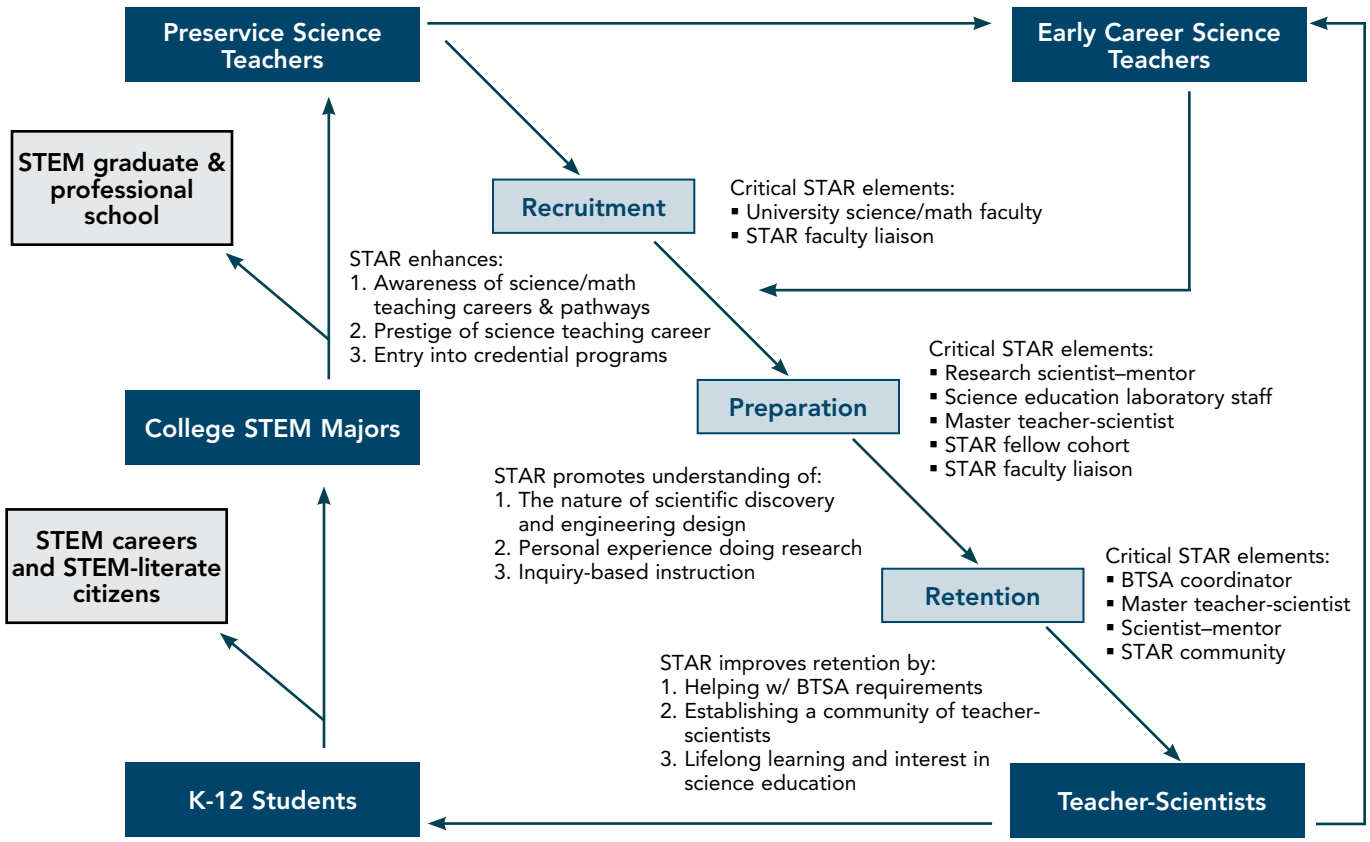
Of the 156 STAR placements that have been arranged between 2007–2010, the program has involved students from all but two of the twenty-three CSU campuses, and has involved fifty Noyce Scholars. The majority of these participants have been undergraduate preservice teachers (50 percent) and credential students (34 percent). The remaining fellows were early career teachers (11 percent) or master's students (5 percent).

STAR PROGRAM DETAILS

The majority of the STAR summer internship is focused on conducting authentic research with research-mentors at partner research facilities. The national laboratories and research centers are ideal STAR program partners because of their commitment to STEM education in general and to teacher professional development in particular, their highly developed science education and outreach infrastructures, and their cutting-edge research expertise. At the end of the program, STAR fellows present research posters describing their work at poster sessions held at each research site.

A second essential component of the program is weekly two- to four-hour seminars addressing translation of the STAR experience into the classroom. These sessions are run by the master teacher, university faculty liaison, and lab site education representative described in the Program Model above. These workshops target four primary educational objectives—being an active member of the scientific community as a teacher,

FIGURE 1. SCIENCE TEACHER AND RESEARCHER (STAR) PROGRAM MODEL



STEM Workforce & Society Outcomes are shown in gray. Dark blue boxes show the development of Teacher–Researchers in various phases. The light blue boxes highlight the central STAR Program Goals.

creating and managing a research learning environment in the classroom, presenting and sharing research investigations and results, and progressing through a career as a teacher–researcher.

In addition, the STAR Program involves both an opening and closing conference. Early on, the opening conference brings together all STAR fellows from across lab sites to orient students to important objectives of the program, including helping students to foster new identities as teacher–researchers. A powerful component of this conference involves presentations by former STAR fellows. At the closing conference, plans for future networking are discussed, including attendance at the upcoming science and math teacher association meetings. STAR fellows also present their summer research to each other in a poster session and provide focus-group feedback into future program improvement.

Finally, an online resource tool has been developed to help facilitate cross-lab communication and professional online networking between STAR fellows. Using the STAR Professional Online Resource Tool (STARPORT), STAR fellows and administrators are able to send e-mails and post messages, chat synchronously, and store and transfer documents, including weekly workshop materials and research posters. The STARPORT is also used as a networking platform throughout the school year following this summer program.

EFFECTIVENESS OF TEACHER–RESEARCHER MODEL FOR INSERVICE TEACHERS

Previous research has shown that immersing inservice science teachers in research experiences like STAR have the following positive effects on developing teachers:

- improved scientific skills and content knowledge (Brown and Melear 2007; Holoch, Grove, and Bretz 2007)
- improved teacher retention (Weisbaum and Huang 2001)
- increased teacher identity as a scientist and understanding of the nature of science (Varelas, House, and Wenzel 2005; Westerlund et al. 2002; Rahm et al. 2003;)
- increased inquiry-based instructional practices engaging students in science (Holoch, Grove, and Bretz 2007; Melear et al. 2000)
- establishment of a professional development mindset related to science and to teaching (Weisbaum and Huang 2001; Rahm et al. 2003)

Inservice teacher–research programs also have an effect on teacher retention. Evaluations of the Industry Initiatives for Science and Math Education (IISME) program have demonstrated that teacher participants ("fellows") were twice as likely to remain in classroom teaching as other California teachers (Weisbaum and Huang 2001).

Studies have also shown that teachers' participation in laboratory research experiences improves student achievement. (Industry Initiatives for Science and Mathematics Education 2007). Effective science teaching utilizes engaging inquiry-based methods that mirror those practiced by scientists in the discovery process. By anchoring teachers in an environment of real-world scientific inquiry, they come to better understand what it means to be a scientist and a teacher of science (Tobias and Baffert 2009). These teachers are better equipped to deliver a science curriculum that engages students in the real-world applications of science and enables them to see themselves as potential future scientists (Clavin and Gilmer 2008). Evaluation of Columbia University's Summer Research Program (CUSRP) inservice teacher–researcher program showed that a sixteen-week research and professional development experience over two summers changed teacher practice toward more data-driven and research-rich learning environments, and resulted in a significant improvement in student academic performance on required high-stakes New York State Regents examinations (Silverstein et al. 2009).

EFFECTIVENESS OF STAR MODEL FOR PRESERVICE TEACHERS

Preservice teachers represent a distinctly different population than inservice teachers. By carefully evaluating the outcomes of STAR program experiences on preservice teachers and on their students' academic achievement, and comparing these outcomes with those of a program for inservice teachers of demonstrated effectiveness, the STAR Program provides the opportunity to develop a comprehensive understanding of the value of preservice "teacher–researcher" teacher training.

Evaluation results indicated that STAR has been successful in attracting high-quality science majors to the teaching profession. STAR fellows represent a diversity of scientific disciplines, career development phases, CSU campuses, and ethnic backgrounds. Focusing on the most recent evaluation report from summer 2009, the STAR fellows unanimously reported that the STAR experience was valuable, with 89 percent reporting that they strongly agreed. When asked at the end of the summer about the effects of specific elements of the STAR Program, fellows reported the following:

- Eighty-nine percent indicated that the STAR experience increased confidence in their teaching abilities. Eighty-nine percent indicated that STAR increased their interest in teaching.
- Eighty-nine percent indicated that STAR contributed to feeling more prestige about teaching as a profession.
- Ninety-five percent indicated that STAR increased their desire to combine teaching and research.
- One hundred percent indicated that the STAR experience made them feel like they were part of a broader community of teacher–researchers.

Over half of the participants stated that the relationships and interactions they made with other teachers, researchers, mentors, and peers was the most defining aspect of the STAR program. Several participants spoke quite highly about STAR fellows and affiliates. For example, one participant said the most significant part of the STAR experience was, "…being surrounded by scientists, and meeting exceptional and inspiring people." Another participant reported that one of the best parts of the experience was "being able to meet such an amazing group of people all rooting for me to grow as a teacher–researcher." The importance of community building and establishing relationships through the STAR program came out strongly in the post-program evaluation. Ninety-seven percent of the fellows ranked their relationships with research mentors and with each other as positive. Similarly high percentages reported positive relationships with their master teacher (94 percent) and faculty liaison (92 percent).

Self-efficacy in teaching was measured using the Science Teaching Efficacy Belief Instrument (STEBI), which assesses two types of self-efficacy: teaching efficacy, and outcome expectancy (Bleicher 2004; Riggs and Knochs 1990). The literature substantiates that higher teacher self-efficacy is positively correlated to increases in both teacher and student outcomes (Moore and Esselman 1992; Tschannen-Moran, Woolfolk Hoy, and Hoy 1998). Results comparing pre-summer and post-summer STEBI reports reveal that average efficacy belief (teaching self-efficacy) increased 5 percent and outcome expectancy (outcome teaching efficacy) increased an average of 10 percent. Both increases were statistically significant [$p < .01$].

Many significant changes also occurred in the STAR fellows' beliefs about the nature of science (NOS), another important outcome assessment. The Views on Science and Education Questionnaire (VOSE) was the measure of the fellows' beliefs about the NOS (Chen 2006). A sampling of VOSE questions that had statistically significant differences between pre- and post-program scores reveals the following changes in fellows' beliefs about the nature of science:

- increased belief that theories can change and do evolve to be more accurate with accumulated data
- increased endorsement that scientists' personal beliefs and expectations can influence observations
- increased belief that a scientist's intuition contributes to science
- increased belief that scientists must invent new methods beyond the traditional definition of the scientific method. Also, increased belief that no fixed scientific method exists
- apparent shift in priorities from teaching definitions to greater student involvement and discovery

The fellows reported that the STAR experience increased the confidence, knowledge, interest and motivation to be science/math teachers. They expressed high praise for the experience. As one fellow put it, "This was the best experience of my life."

These preliminary results indicate that the program is meeting several of its objectives with regards to recruitment and preparation of quality science and math teachers. As the STAR program continues to grow, we can now begin tracking STAR alumni through their careers to see how the program affects teacher retention and student achievement. We have plans to conduct a longitudinal study of STAR alumni, including analysis of the performance of students of STAR fellows, to track participants through their careers and see how the program affects retention, teaching success and satisfaction. We anticipate that STAR alums may also become teacher-leaders in their schools and districts, so will evaluate this possible impact as the program continues to grow. Whatever the outcome, the data obtained will deepen our understanding of the "teacher–researcher" model and provide a sound, data-driven and experimentally validated platform for expansion of this potentially paradigm-changing approach to STEM teacher professional education and development. ▪

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Undergraduate Research as a High-Impact Student Experience

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The positive effects of an undergraduate research experience on student learning, attitude, and career choice have passed from anecdote to systematic data. Many educators, particularly in the sciences, have come to see the potential for authentic undergraduate research to be a high-impact educational practice for achieving excellence in liberal education. In the past decade research on these student experiences has revealed the extensive array of professional and personal benefits. Initial efforts to understand these benefits started with evaluation of the relatively clear experience in which a student spent a summer working exclusively on research as an apprentice to a faculty scholar, typically in the sciences. Many students in summer science research programs —usually about ten weeks in duration, free of regular coursework —evaluate their experience by completing the Summer Undergraduate Research Experience (SURE) survey, an online assessment instrument. An advantage of the SURE is that a standard set of potential learning gains are offered for evaluation by each student respondent. These gains include the research skills and personal development items described here.

The general taxonomy of benefits include student-reported gains on a variety of disciplinary skills, research design, information or data collection and analysis, information literacy, and communication. Student respondents also evaluate their professional advancement through opportunities such as scholarly publication, becoming part of a learning community, and relationships with mentors and peers. Professional development items include clarification of a career path, understanding the research process in the field, and understanding how scientists think. In addition, students evaluate gains in personal development, including the growth of self-confidence, independence of work and thought, and a sense of accomplishment (Lopatto 2006). Although studied independently of any of the Association of American Colleges and Universities' initiatives, these benefits of undergraduate research align well with the essential learning outcomes that emerge from initiatives such as Liberal Education and America's Promise (see Kuh 2008).

Student results from the SURE survey indicate that most research experiences enhance intellectual skills such as inquiry and analysis, reading and understanding primary literature, communication, and teamwork. Some skills are positively correlated with program components. Students in programs that provide instruction in research ethics report higher gains in this area than other students; students in programs that require written and oral communication report higher gains in these areas. These gains are potentially portable within and beyond the sciences. Even more ubiquitous are the variety of personal gains reported by undergraduates. Undergraduate researchers learn tolerance for obstacles faced in the research process, how knowledge is constructed, independence, increased self-confidence,

Undergraduate researchers learn tolerance for obstacles faced in the research process, how knowledge is constructed, independence, increased self-confidence, and a readiness for more demanding research. These benefits are an advantage in any career path.

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Less clear is the effect of the research experience on the student's choice of career. In science, it has long been believed that a research experience compels the student's interest in a science career. The evidence for this belief is equivocal. Most undergraduate research experiences are undertaken by third- and fourth-year students who have already declared a science major. Many of these students have been interested in science since high school. They find the undergraduate experience interesting and useful, but its effect on their career plans is subtle. Sometimes students will use the research experience to fine-tune their career plans. For example, at the conclusion of a summer research program, about 15 percent of students who initially thought of themselves as premedical students migrate toward planning for science PhD programs. For students already interested in science, undergraduate research has the benefit of adding to the student's credentials for being admitted to graduate school, so the experience has instrumental value in continuing the student's career trajectory. To expand recruitment beyond the upper-level students, a recent trend in undergraduate research programs is to recruit younger students — including first-year college or even high school students —on the premise that an early research experience will capture the interest of a student who has not yet decided on a career. Evidence for the success of this strategy has not yet accumulated, and there are grounds for skepticism. Young students who have not committed to a career track may feel a strong desire to keep their options open and sample among a variety of valuable experiences, such as travel or internship experiences.

The SURE survey provides a picture of short-term student evaluations of the research experience. As with any research program, the success in describing the benefits of undergraduate research was accompanied by new questions. Questions about the generalizability of the initial findings, based on students enrolled in liberal arts colleges, were answered when the survey results were replicated in a larger array of colleges, including master's institutions and research universities. Now additional questions about the role of mentoring, the long-term effects of the research experience, and the adaptation of research experiences to courses within the regular curriculum drive new inquiries into the undergraduate research experience.

THE RESEARCH COMMUNITY

Many educators, as well as employers, feel that contemporary undergraduate researchers have a better experience if they work with other undergraduates as teammates or peer mentors. The SURE survey asks the student if he or she works with a team of researchers. The variations in team structure are difficult to characterize. Some research teams work closely on one project; others divide their labor among separate but related projects. Some undergraduates work only with peers, while other work in diverse groups of undergraduates, graduate students, and other researchers. Given the complexity of the phrase "work with others," perhaps the most interpretable response option is "I work alone." About 25 percent of student survey respondents report that they work alone. They may be missing something. Working with other undergraduates on research is evaluated as either moderately or significantly enhancing the research experience by almost 80 percent of students who work in teams. Most student teams are composed of undergraduates who work as equal partners; only one group in ten reports that an undergraduate has assumed the role of peer mentor. The peer mentor is an undergraduate student, typically older and more experienced than the other students in the research group, who is formally or informally given the responsibility of teaching, supporting, and helping the other members in the group. Recent survey results indicate that although peer mentors rarely receive formal training, most rate their experience as positive or very positive, and nearly all would choose to mentor again if they could. Peer mentors report that they enjoy the teaching aspect of the role and the responsibility assigned to them. They seldom report that they were on their own too often or were given responsibility beyond their experience. Peer mentors report many benefits for themselves as a result of the mentoring experience. They gain confidence as researchers, increase their motivation to work on the research, deepen their understanding of the research project, and improve their communication skills. When asked to evaluate their experience on the list of standard learning gains in the SURE survey, peer mentors as a group evaluate their gains as greater than the gains reported by a comparison

cohort of students who had no peer mentoring in their research experience.

How do students react to the presence of a peer mentor? The SURE survey provides an opportunity for these students to evaluate this experience. Most students who worked with a peer mentor evaluated the experience as positive. Over 80 percent of these students agree or strongly agree with the assertions that the peer mentor "helped me appreciate the significance of the research;" "understood my concerns about doing research;" and "had a significant positive impact on my research experience." Most of these respondents disagreed that the use of peer mentors enabled the faculty or graduate mentors to ignore them, so the presence of a peer mentor does not mean that the research supervisor is absent from the group. Students who were not peer mentors but had access to a peer mentor in their group also reported higher learning gains than students who had no peer mentoring in their experience. The survey data supports the conclusion that the inclusion of peer mentors in research groups enhances the experience of both the mentors and the mentored.

Every undergraduate researcher has a graduate, postdoc, or faculty supervisor functioning as a mentor, and some have more than one. Recent survey data indicate that about 66 percent of undergraduate researchers work primarily with faculty mentors, about 12 percent work primarily with graduate student mentors, 9 percent work with postdocs, and the rest work with other professionals such as industry researchers at a commercial or government site. Students at primarily undergraduate institutions are most likely to have faculty mentors. A great deal of responsibility is placed on the shoulders of the research mentor. Mentors are described as teachers, coaches, career advisers, and gatekeepers to the community of scholars. But does mentoring really matter? The SURE survey permits student respondents to evaluate their mentor. This evaluation may be correlated with other responses. In each year of SURE data, the report of learning gains correlates directly with the evaluation of the student's mentor. The majority of the evaluations are positive, and over the last three years we have accumulated over 5,000 cases that permit a statistical analysis. When we examine the students' reported learning gains, we find a clear almost step-wise relation between the students' opinion of the mentor and the pattern of student learning gains. Students who rated their supervisor as an "outstanding mentor" reported significantly higher gains than those who rated their supervisors "above average," who in turn reported higher gains than students who rated their supervisors as "average," and so on. As impressive as this pattern is, the quantitative approach does not capture the range of benefits of good mentoring. The social relationships among research group members have a strong impact on the undergraduate researcher's plans for continuing her education in the research field. As one student wrote on her survey, "These interpersonal relationships are just as important to me as the research itself." The observation occurred in the context of explaining that she was leaving her planned science career path because of poor mentoring (Lopatto 2009).

There is one more benefit of a good research experience that may be simply stated: a research experience helps one to be a better student.

RESEARCH AND THE CURRICULUM

As the epitome of the undergraduate research experience, the summer research program offers a refined look at the benefits of the experience, but other forms of the experience exist. Many research opportunities occur during the academic year as independent study, honors work, or paid positions. The SURE survey asks students to evaluate the relative benefits of doing research during the summer or during the academic year, when research time competes with courses and other activities. Students recognize the tension between research time and class time during the academic year. Almost two-thirds of survey respondents report that it is difficult to balance research and coursework. More than half characterize research as more interesting than coursework, and only about 18 percent report learning more from courses than from their research experience. Despite the tension caused by competing demands on their time, students report learning gains from academic-year research experiences in much the same way they report learning gains from summer experiences.

There is one more benefit of a good research experience that may be simply stated: a research experience helps one to be a better student. The presence of undergraduate researchers in a science course after they have had research experience may enhance their course experience. The effect of experienced undergraduate researchers on subsequent science course behavior is one of many questions to be explored through assessment. As a follow up to the SURE research, students who had completed the survey shortly after completing a summer experience were contacted again nine months later and asked to complete a follow-up survey. The results indicated that the students' longer-

term recollection of the experience slightly magnified their short-term evaluation of the learning experience. For students who enjoyed the experience, a reevaluation of learning gains yielded slightly higher mean scores than did the original SURE responses; for students who did not enjoy the experience, a reevaluation of learning gains yielded slightly lower mean scores than the original SURE responses. An encouraging result of the summer experience is that a majority of the students, reflecting on courses they had taken in the intervening months, reported that they felt that they were better able to think independently and formulate their own ideas, that they were more intrinsically motivated to learn, and that they had become more active learners. One student commented, "I became more driven to do well in my science classes, since I saw more meaning to them."

Students benefit from academic-year research experiences and carry the benefit into the classroom. Another variation on the research experience is to embed the experience in an existing course. How do students benefit from research or "research-like" experiences embedded in the course curriculum? There is wide variety in the approaches to infusing research experiences into courses, ranging from precise focus on one aspect of the research experience (such as reading primary literature or analyzing data) to complete immersion in research as the central activity (such as the "phage hunters" courses supported by the Howard Hughes Medical Institute). With a variation on the SURE called the CURE (Classroom Undergraduate Research Experiences), we have been able to survey a variety of undergraduate science courses that exhibit more or less research-like quality. Although high research-like courses differ from traditional courses to the degree that they employ activities such as group work, reading primary literature, and data collection and analysis, the signature distinction is that in high research-like courses, undergraduate students conduct research in which the outcome is not known (even to the course instructor) and have at least some input into the research topic and design of the methodological approach. Students in high research-like courses report learning gains similar in kind and degree to gains reported by students in dedicated summer research programs. Students in high research-like courses often report higher gains than summer researchers in those areas that might be covered more completely in a class setting, such as skill in science writing, learning ethical conduct, and understanding primary literature. Most of the reported learning gains by this group are higher than gains reported by students in traditional lecture and lab courses. Traditional courses are not without advantages: students in those courses rate their learning gains higher than students in high research-like courses on a few familiar items, including listening to lectures, reading a textbook, and taking tests.

FUTURE DIRECTIONS

As current research questions are explored and answers emerge, still more questions occur. Interdisciplinary coursework and research experiences, either between the scientific disciplines or between science, social science, and humanities, are becoming more frequent. The SURE survey data from ostensibly interdisciplinary research areas—neuroscience or bioinformatics, for example—indicates that undergraduate researchers working in interdisciplinary areas report benefits similar to undergraduate researchers working in the traditional disciplines. The prototypical interdisciplinary research experience is elusive in that students may not realize they are "having" an interdisciplinary experience. One student engaged in a neuroscience project, a nominally interdisciplinary area, was asked if her work was interdisciplinary and replied, "No, it's neuroscience." In an effort to capture the essential features and the benefits of interdisciplinary experiences, a collaboration involving a group of liberal arts colleges and funded by the Howard Hughes Medical Institute is studying interdisciplinary course work in the sciences. A branch of this effort is the Research on the Integrated Science Curriculum (RISC) survey, an outgrowth of the SURE and CURE survey work. In a preliminary study, course instructors complete a version of the RISC that provides a list of items related to course goals and pedagogies. Later in the term, students evaluate their learning experience on the same items. Preliminary results indicate a correspondence between the instructor's emphasis on interdisciplinary problems and students' reports of interdisciplinary learning. A cluster of course characteristics, including learning to ask "big questions," reading literature from multiple disciplines, working on a problem that requires integrating two or more disciplines, and learning that disciplines may approach problems in different and sometimes conflicting ways, are emphasized by instructors and reported as learning gains by students. It is too early to tell if this approach will help us understand interdisciplinary research and course experiences, but the effort illustrates that the high-impact practice of undergraduate research still provokes interesting questions for research on student learning. ▪

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The Challenge of Undergraduate Research

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Undergraduate research is a discussion topic at academic administrators' conferences these days for a number of excellent reasons. Often lost in these discussions, however, are the challenges professors face as they try to integrate the mentoring of undergraduate students who engage in scholarship, research, and creative projects with their traditional duties of teaching, service, and their own research agendas.

Engaging undergraduates in serious academic activities that a generation ago would have been the province of graduate students is surely an effective way to enhance their learning. Even students who are unlikely to pursue an advanced degree benefit from the skills they develop in intellectual discipline, information gathering and evaluation, research methodology, presentation development, and other areas cultivated by extended independent inquiry into a scholarly topic, or by producing a substantial body of creative work.

However, faculty members feel strongly obligated to their own research, scholarship, or creative activity as well, and this work, and their consequent disciplinary expertise, are key resources they bring to mentoring undergraduate projects. Colleges and universities have generally not yet managed to find fair, appropriate ways to value mentoring of undergraduate research in the tenure and promotion process. Even more challenging, many faculty see a clash between the demands of personal scholarship and an institutional urge to promote undergraduate research. Even at small, teaching-oriented undergraduate institutions, evolving faculty roles have pushed professors to be more productive scholars, which can conflict with an increased role supervising undergraduates who are developing serious, large-scale projects of their own.

Ironically, small colleges are ideally positioned to develop distinguished undergraduate research programs, as they have been built on the principle of close student–faculty relationships that are foundational to helping undergraduates succeed as scholars. At the same time, though, small-college faculty are often faced with high teaching loads, broad curricular responsibilities, significant service demands, and the panoply of activities that bear a vague but real relationship with professional success in the small-college setting.

Excellent mentorship of undergraduate research is immensely time-consuming. Undergraduates are by definition not disciplinary experts, and their laboratory, library, fieldwork, or studio techniques are rarely mature. Developing those skills is part of the point, of course, but doing so requires a serious commitment of faculty time and energy. The rewards brought by this commitment can be huge—I know many colleagues who have seen their students find prestigious and competitive internships, gain entry into outstanding graduate and professional programs, or simply blossom as scholars and people as a result of their research work. These faculty simultaneously worry, though, that their work with these students will be relegated to the "teaching" category of their evaluations, and will not meet, or will even detract from, their evaluation as scholars.

The currency of the profession is research productivity, and helping undergraduates with their research, while calling upon many of the same skills and inclinations, is for many faculty an opting out of the academic economy. It requires them to gamble that their institutions will recognize the worthiness of such work when it comes to tenure, promotion, and merit evaluation, and (undoubtedly and unfortunately) willingly to reduce their value on the market for other positions. While no individual institution can do much about the external market, institutions that truly value faculty support for undergraduate research will have to articulate that value, and recognize and reward faculty participation. An institution's resources flow through channels defined by its values, and if colleges and universities are serious about undergraduate research, they must be equally serious about supporting it financially and in other, less tangible ways. ▪

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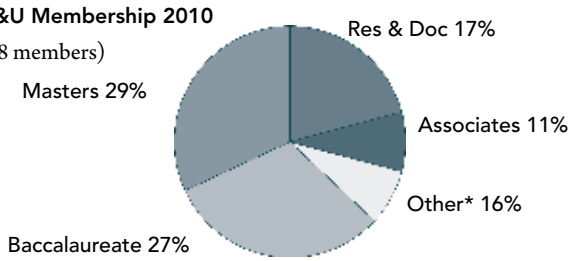

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