CUR Quarterly

COUNCIL ON UNDERGRADUATE RESEARCH

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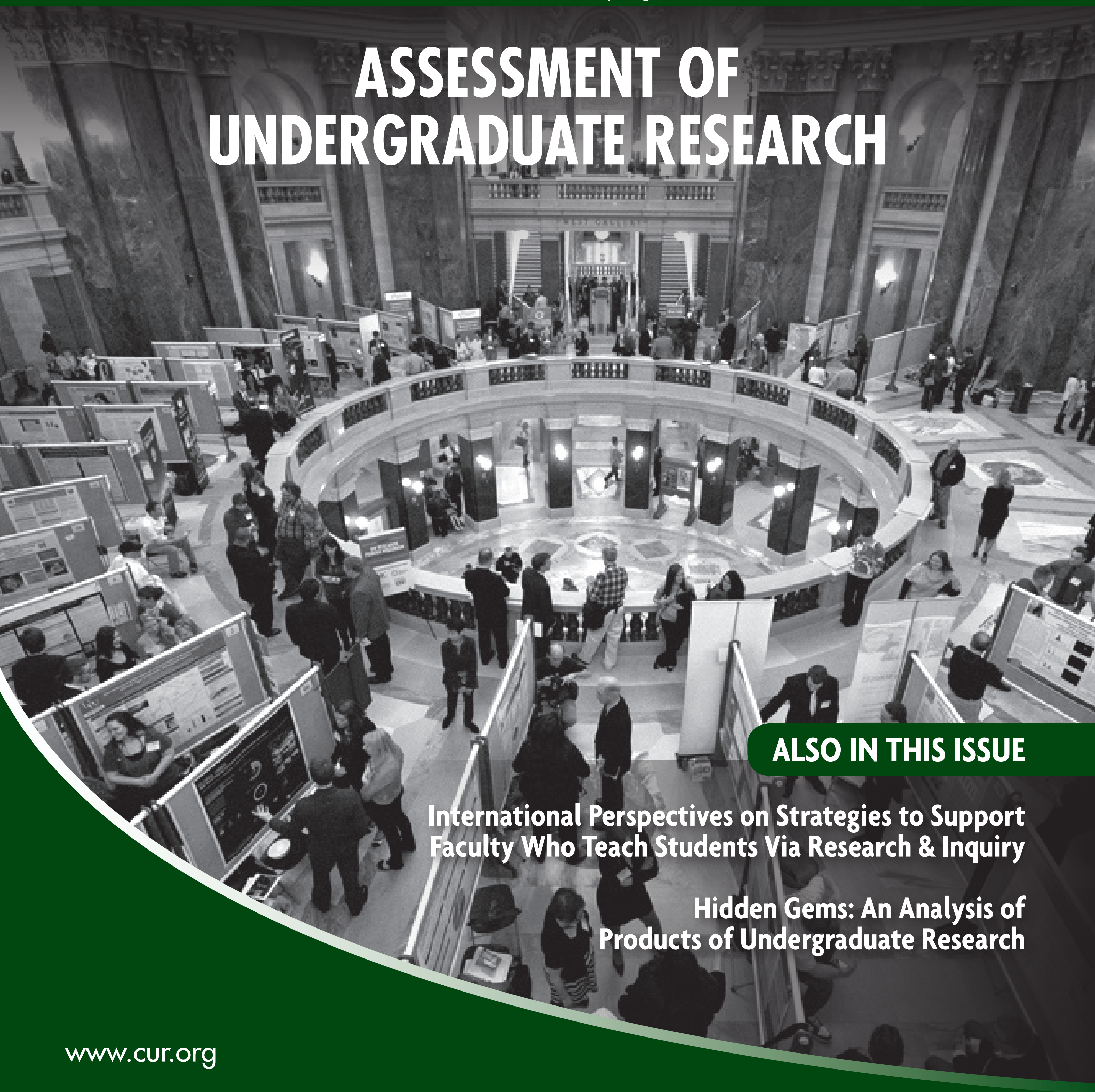

ASSESSMENT OF UNDERGRADUATE RESEARCH

ALSO IN THIS ISSUE

International Perspectives on Strategies to Support Faculty Who Teach Students Via Research & Inquiry

Hidden Gems: An Analysis of Products of Undergraduate Research

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The *Council on Undergraduate Research Quarterly* and *CURQ on the Web* serve as the official public "voice" of CUR to both its members and to a broader community. Their purpose is to provide useful and inspiring information about student-faculty collaborative research and scholarship from all disciplines at all types of institutions. The goal and function is to advance the mission of CUR. To this end, the operation and editorial policies are flexible so that its content and deadlines meet the immediate needs of the communities that it serves. The *CURQ on the Web* can be found at www.cur.org/publications/curquarterly/.

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Cover Photo:
Posters in the Rotunda is held annually at the Wisconsin State House. Outstanding undergraduate student researchers from across the University of Wisconsin System gather together with their faculty advisors to share their research findings on important topics with legislators, state leaders, UW alumni, and other supporters.

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From CUR's President

At the beginning of every new semester, I find myself sitting around a conference room table with my undergraduate research students anticipating the work that lies ahead of us. However, before we even think of setting foot in the laboratory and starting our experiments, we must design a specific plan for what we want to do and how we intend to do it. Although that sounds quite straightforward, charting a course for how to move one's research to the next stage without taking the time to look back and fully assess what you have already done is foolish and a waste of time, effort, and money. The assessment process I engage in with my research students is an integral part of the scientific process that creates new knowledge by building on the existing framework of facts that are evidenced-based and iterative. Modeling for my students how to analyze and interpret data on a routine basis helps them acquire a habit of scholarly reflection that aptly informs future work, work that produces results that move a project forward sequentially, with tangible outcomes that ultimately can be disseminated and peer-reviewed.

The practice of engaging in undergraduate research, scholarship, and creative activities is an enterprise in its own right and requires a process of periodic assessment to validate its claims as a high-impact learning pedagogy that proposes to benefit student participants, their faculty mentors, and the institutions that provide the financial support and resources. The Council on Undergraduate Research would be remiss if it did not take a leading role as the "Voice of Undergraduate Research" in the assessment of undergraduate research, one of CUR's five Strategic Pillars. This is not only an important priority of our organization, but it is also fundamental to our mission and an integral service we must provide to our members. We must take the initiative to gather the data, critically analyze it, provide a contextual interpretation, and then disseminate it to encourage and foster buy-in for the argument regarding the educational value of undergraduate research.

This themed issue of the *CUR Quarterly* brings our *reason d'être* into focus and helps explain how CUR is supporting the assessment effort. Hopefully, the articles presented in this issue highlight the importance of assessment as a worthy, but often challenging, endeavor. For example, Herb Childress shares his perspective on how we need to do a better job of equipping ourselves with the appropriate assessment tool for our specific question. As any tradesperson knows, choosing the correct tool for a job is half the battle. The insights provided in this issue's articles about the need for meaningful and accurate methods of assessment encourage us to be mindful of the need for evaluating all that we do to help provide accountability and justification for UR.

CUR takes this responsibility seriously and tries to walk the talk of assessment in all that we do, such as getting input from participants of CUR institutes designed to provide timely and effective faculty development or programs like Posters on the Hill to help individuals advocate for supportive federal policies that provide undergraduates with more opportunities for active learning through experiential endeavors. We are currently in the process of evaluating the *CUR Quarterly* itself, asking the tough questions about its value to its readers and how effectively it serves as a practitioner's guide on how to be a good mentor to our student research collaborators.

A relatively recent and involved means of assessment was CUR's publication of the *Characteristics of Excellence in Undergraduate Research (COEUR),* a document that provides institutions with a roadmap of how to assess their own campus-wide UR programs. This compendium highlights the attributes of a quality UR program and suggests ways to make improvements that will be meaningful and provide positive student outcomes. Regardless of the endeavors that you or your institution are engaged in, routine assessment can provide more productive outcomes that will allow for continued intellectual and personal growth for students, scholarly achievements for faculty, and a means for institutional accountability and implementation of mission.

Amelia J. Ahern-Rindell
CUR President
Associate Professor of Biology
University of Portland

From CUR's Executive Officer

"After all, assessment and evaluation are all about accountability; of government to the people, of CUR's officers and staff to its members, and of faculty and administrators to students and the larger society."

True words, and written by CUR's second Executive Officer, K. Elaine Hoagland, in 1997 to commemorate her first *CUR Quarterly* column, the move of CUR's office to Washington, D.C., and a *CUR Quarterly* themed issue on assessment and evaluation. A critical reading of the articles written in 1997, compared to those in this themed issue on assessment of undergraduate research close to 20 years later, reveal similarities and differences, as would be expected. A prime similarity is that the basic question posed by Patricia Reggio, the issue editor of the 1997 edition, remains the same: *"How do we measure the value, as well as the outcomes of the undergraduate research experience?"*

It is clear, however, that assessment of undergraduate research has broadened and deepened to include more detailed attention to longitudinal outcomes (see the article by Johnson Schmitz and Havholm in this issue); the value added by faculty mentoring (the article by Sams and her colleagues); and dealing with the reality (and perception) of tensions between why faculty and why students undertake scholarship (Laursen). Do we closely match the questions we want to ask to the sometimes blunt tools that we use during our assessment processes? According to Herb Childress, no, and we all have more work to do! All of these diverse and thoughtful perspectives on assessment are rich soil from which will surely flower next-generation undergraduate research culture and practice.

As the culture and practice of assessing undergraduate research evolves, so too does CUR. Now, more than ever, CUR is called upon to provide more systematic evidence of the impact of undergraduate research and its importance to student, faculty, and institutional success. In early 2015, CUR anticipates the release of a special issue of Jossey-Bass's *New Directions for Higher Education* series focusing on the results of a National Science Foundation grant to CUR (DUE 09-20275). The grant allowed the organization to work with six higher-education systems over the last five years to expand and develop their undergraduate research capacity. Starting in 2015, CUR will also be part of a newly funded National Science Foundation project, Widening Implementation & Demonstration of Evidence-Based Reforms (WIDER), in collaboration with the State University of New York (SUNY) at Buffalo. Under the leadership of Jill Singer, director of Buffalo's Center for Undergraduate Research, this NSF WIDER project will disseminate and study the impact of research-experience assessments that measure changes in faculty and students' perceptions of skills development throughout the course of intensive research programs.

"CUR is now undergoing its own assessment and evaluation of its mission, programs, and governance." Elaine Hoagland described an outside review conducted by the Research Corporation for Science Advancement in 1997 that was used to shape CUR's early development. Then, as now, CUR continues to turn a high-magnification lens on itself, through yearly evaluations of its professional-development events for faculty and students. In addition, as it had been eight years since a comprehensive membership-needs assessment had been done, a survey of CUR's members was conducted in fall 2014. This sampling of CUR's membership revealed that most respondents are at higher-education institutions (no surprise) and are about evenly divided between public and private institutions.

One of the most striking aspects of the survey was the significant percentage of respondents (~30 percent) representing individual members that had joined CUR in the last three years—not too surprising when you consider CUR's recent rapid growth. Several of the survey questions asked what CUR members specifically value about their membership. Many respondents affirmed that their commitment to the organization's mission, the opportunity to remain current in their knowledge of undergraduate research developments, and the networking and learning opportunities afforded by CUR were all reasons to retain membership. When asked to identify specific CUR offerings in which they engaged, the top choice, identified by 80 percent of respondents, was … wait for it … the *CUR Quarterly*. Again, that was no surprise to those of us who look forward to reading each issue, but it was excellent validation of the journal and its evident positive impact, nonetheless!

Elizabeth Ambos
Executive Officer

From the *CURQ* Issue Editor

Assessment of Undergraduate Research

Assessment is a bridge that connects the many elements of the Council on Undergraduate Research. The standing-room-only crowds of faculty and administrators at the assessment panels and workshops during the CUR national conferences reflect the appetite for assessment tools, procedures, and best practices. Our CUR institutes work with teams of faculty and administrators to design and administer more effective assessment protocols. For the *CUR Quarterly*, our divisional and issue editors seek manuscripts that articulate effective models of assessing undergraduate research on college campuses. Our theme for the Spring 2015 *CUR Quarterly* extends that bridge by exploring the challenges, major findings, and future directions of the assessment of undergraduate research.

In the introductory essay to our print issue, Herb Childress reminds us to directly assess the outcomes that we care about. While we may be enamored with our undergraduate research activities, they are not the outcomes, and it is critical to name directly the kinds of things that institutions are trying to achieve through undergraduate research. Assessment can be a bridge to articulating those outcomes that matter for our students, faculty, departments, and institutions, with qualitative research as our guide. In their article Heather Johnson Schmitz and Karen Havholm note the clear gaps between the skills employers seek (such as leadership, decision-making and intercultural skills) and the learning outcomes that are tracked and assessed by higher education. The authors demonstrate that the assessment of undergraduate research can bridge that gap. A survey of alumni who participated in undergraduate research at the University of Wisconsin-Eau Claire revealed high gains across all categories of learning outcomes, including higher-order thinking, preparation for graduate school or careers, and discipline-specific skills.

Sandra Laursen from the University of Colorado-Boulder reminds us of the challenges and limitations of self-reporting by undergraduate students in assessment surveys, and she suggests new assessment approaches tied to specific types of outcomes, such as creativity, persistence, and invention. Through experimental design, assessment of undergraduate research can build a bridge to more effective program evaluation. Doreen Sams and colleagues propose a self-efficacy and scientific-literacy scale to measure the personal and professional growth of students across diverse disciplines. A pilot project at Georgia College and State University expands upon previous studies that have largely focused on measuring student gains in STEM disciplines. The authors demonstrate construct validity through factor analysis, and the scales employed provide a bridge to measure undergraduate self-efficacy and scientific literacy in non-STEM disciplines.

I also encourage you to explore the two insightful articles in the *CUR Quarterly on the Web*. Kelly Laurila and colleagues at the University of Arizona describe the assessment of a research-based training program focused on Native American undergraduates, which is situated within the Partnership for Native American Cancer Prevention. In contrast to the traditional pipeline approach, the authors describe a network ("weaving the web") with multiple entry and reentry points to accommodate the unique needs of Native American students. The assessment reveals that a small number of training programs have a direct impact on the ability of students to navigate a pathway to success.

Our second article builds a bridge from CUR's publication *COEUR (Characteristics of Excellence in Undergraduate Research)* to the assessment of undergraduate research experiences at

CUR Calendar

APRIL 2015	
13-18	Undergraduate Research Week
16-18	National Conference on Undergraduate Research, Eastern Washington University, Cheney, WA
JUNE 2015	
23-25	Undergraduate Research Programs Conference, University of Oklahoma, Norman, OK
JULY 2015	
16-20	Proposal Writing Institute, Minneapolis Marriott Southwest, MN
OCTOBER 2015	
15-17	Initiating and Sustaining Undergraduate Research Programs Institute
NOVEMBER 2015	
6-8	Creative Inquiry in the Arts and Humanities Institute

Be sure to check www.cur.org for the most up-to-date news and the Event Calendar.

the Air Force Institute of Technology. Mary Lanzerotti and colleagues report on the assessment of a summer undergraduate research program that captures several of the best practices outlined in *COEUR*. The authors articulate how student feedback from the assessments produced changes to the orientations, student cohorts, seminars, and presentations.

Our three print vignettes in the Spring 2015 *CUR Quarterly* highlight a variety of innovative assessment techniques. They describe student-learning agreements, a robust faculty evaluation process with peer review, and YouTube video research presentations as part of program assessment. Additionally, the vignette in the *CUR Quarterly on the Web* outlines assessment-driven efforts to improve undergraduate-research writing and communication through workshops, consultations, training of graduate students as reviewers, and rubrics for judging posters and oral presentations.

While the membership of the Council on Undergraduate Research and the readers of this journal are disciples of the power of undergraduate research, we still desire more effective tools for assessment and strong evidence of the documented impact on student learning. We hope the articles and vignettes in this issue help with not only the theoretical issues but also with the applied elements of assessing undergraduate research. We endeavor to improve our assessment protocols for our accrediting bodies but, most importantly, for our students and their pathways to academic success.

James T. LaPlant
Valdosta State University
CURQ Issue Editor

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Herb Childress,
Teleidoscope Group LLC

CUR Focus

The Outcomes Are the Outcomes: Making Sure We Assess What We Actually Care About

For many years, I taught a first-year seminar for incoming undergraduate and master's students in architecture. The course was intended to be both an intellectual and an emotional journey through the possibilities of architecture as a social and cultural act, as a way to change lives.

Architecture students select the field based on their prior interests in making and drawing, through their visual literacy. The word "LEGO"® comes up a lot in their narratives of discovery. I wanted to help them understand that their love of invention, though crucial, was not sufficient for success in the design professions. So I developed a session of the course devoted to the idea that designers are strange people.

We are, after all. Designers care about buildings; we're interested in structures and site plans and neighborhood layouts. But most people aren't, and it's crucial that we remember that. Most people want profitable businesses, smart students, satisfying work lives, happy families; they buy buildings because they imagine that those buildings might help them achieve their *real* goals. The building isn't the object of their concern; it's a proxy, a means toward a greater end.

Every profession, not just architecture, has the tendency to focus on its specific content area and the outcomes it can directly influence. A doctor probably focuses more on a patient's blood pressure than she does on his enjoyment of life, because she understands the physiology of blood pressure and the pharmacological possibilities of its treatment. And yet that patient probably has no idea what his blood pressure is at any particular moment; he knows that he feels good or tired or light-headed. For him, blood pressure is not the end goal—feeling good is.

Undergraduate Research as a Process, Not an Outcome

All too often in my work as a facilitator at CUR institutes and as an organizational consultant, I hear teams say that their assessment criteria will be the creation of a campus UR office, or that a certain number of faculty have gone through some form of training, or that their funding for UR increases. All of those are indeed measurable and important outcomes, but they're missing the mark, because they measure inputs, not outcomes. As with architects or physicians or other types of professionals, that's understandable. We plan and staff the office, we provide the training, we seek and budget the funding. We want someone to stand back periodically and admire the mighty edifice we've constructed.

But the existence and elegance and strength of our UR activities, admirable as they may be, are not the outcomes. Any UR effort or program serves larger ends—for students, for faculty, for departments, for institutions, for disciplines. And we need to be brave enough to put ourselves on the line and say, "This is what we intend to be true because we're doing undergraduate research." Like the doctor's patient or the architect's client, the people who create and conduct UR opportunities should state their fundamental goals in simple, straightforward terms. Many of the stakeholders have invested themselves in UR because of some profound emotional goals about student growth or departmental culture or institutional mission. But if those fundamental goals never reach the surface for discussion, we may find ourselves working at cross purposes or becoming more invested in the means than the ends. So it's crucial to name directly the kinds of things schools are trying to achieve through their work in undergraduate research.

For example, I work with students because I want them to have a sense of agency. I want them to be capable, and to believe that they are capable; I want them to have a growing sense of self-direction and "right livelihood." And I do the work because it helps me to be more productive, and because I take pleasure in the relationships that grow as my students and I work together on common projects. All of these outcomes can be operationalized in more detailed ways that allow me to study and assess them, but at root, these fundamental desires are what drive my involvement in undergraduate research.

There are many such outcomes we might want to assess in any UR practice or program, outcomes that are too rarely named. For example:

- For students, we might want improved career options, which we could possibly measure by their continuation to graduate school or employment in allied industries. We might hope for increased gains in knowledge and disciplinary commitment, which we could possibly measure through comparing the GPA's of students who have and have not participated in research or through the differences in future course-taking patterns between those two groups. We might hope that students start to see themselves as empowered agents, which we might measure through their increased participation and leadership in other campus (and off-campus) organizations.

- For faculty, we might want increased scholarly productivity, which we might measure through the number and citation frequency of their publications, through the dollars of their grant support, through the connections and increasing roles they take on in professional societies. We might want to foster a more effective entry for new faculty into professorial life, which we might measure through course evaluations and steady progress toward their review and tenure applications, as well as through increased and intentional participation in institutional work.
- For departments, we might hope for greater strength, which we could measure through increased numbers of majors, increased proportions of their students presenting at meetings, the addition of a faculty line (and the quality of candidates for it), the argument that leads to the department's obtaining a greater share of funding. We could also talk about the social goals of the department, with faculty members coming together around the common project of undergraduate research in ways that enrich both their thinking and their sense of belonging.
- The institution as a whole might hope to become more prestigious and desirable, which we could examine through increased press coverage, greater numbers of institutional partnerships, increased attendance at recruitment events, and a "buzz" among high-school counselors. We may hope that our institution drops off the list of top 20 party schools and enters the next edition of *Colleges that Change Lives* (Pope and Oswald 2012).

We don't want undergraduate research for its own sake. We want all of these other things that indicate intellectual growth and satisfaction, and we use UR as a demonstrably powerful method to achieve those larger outcomes.

The Importance of Qualitative Assessment

Naming these deeper goals requires care and bravery. It's easy to say that we're aiming at having a certain number of students participate in UR, but much less comfortable to say that we want our UR students to be inspired and creative. If we understand that undergraduate research is not the outcome, we can start to recognize that the real outcomes are mostly about quality of life, about institutional culture, about students having a stronger and more empowered sense of self. And that ties directly to the historic mission of undergraduate education, which was not merely to provide job-readiness and the accumulation of measurable skills, but to be a place of reflection that results in changed attitudes toward the possibilities of life.

These deeper goals inevitably lead toward a mixed-methods research approach to assessment. To paraphrase Robert and Barbara Sommer, if you want to find out what people do, watch them; if you want to find out what they think, ask them (Sommer and Sommer 2001, 6). It is crucial, in order to assess the deeper effects of undergraduate research, that we also engage in significant qualitative research to uncover patterns across the experiences of our participants. How will we know whether our students think differently about their capabilities? How will we know whether our faculty think differently about the responsibilities and pleasures of mentorship?

An excellent example of qualitative UR assessment comes from the work of the Ethnography and Evaluation Research unit at the University of Colorado at Boulder. Along with asking what students were learning about science in their summer REU (Research Experiences for Undergraduates) project, the research team explored what it meant to "become a scientist": to take on the attitudes, mindsets, and social networks of a community (Hunter, Laursen, and Seymour 2001). Traits of perseverance, curiosity, collaboration, and the tolerance of uncertainty are all crucial elements of what it means to be an intellectual in any field, and deserve to be explored in their own rights.

This kind of qualitative research is itself an outstanding opportunity for student-faculty collaboration. The understanding of changed attitudes among students, faculty, potential students, and other groups is a research project that could be taken up by students and faculty mentors in sociology, anthropology, or education. The work relates directly to the professional capabilities of their fields, and adds to the richness of the quantitative assessments typically carried out by a college's administration or office of institutional research. And just as importantly, it allows students to turn their increasingly trained critical minds toward the nature of higher education, which will serve them well as citizens and as the parents and mentors they may become.

Not *Our* Work, But *Their* Work

As faculty and administrators charged with promoting the research experiences of our students, it's not surprising when our thoughts of assessment turn to the things that we have immediate control over: fund-raising, proposal writing, professional development, event management. And those things are all worthy of assessment, the search for information that can guide changes in our practice. But the primary focus of our assessment is not the work that we do, but the work that we enable; not the programs we run, but the lives we change. We have to be careful to name the fundamental outcomes to which we hope to contribute, and to devise ways of understanding whether those deeper goals are being reached.

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Herb Childress

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Herb Childress is Director of Metaphor at Teleidoscope Group LLC, an organizational consulting firm with special interest in issues of higher education. He received his BA in architecture from the University of California at Berkeley in 1989, and his PhD in architecture (environment-behavior studies) from the University of Wisconsin–Milwaukee in 1996. Before entering private practice, he was dean of research and assessment at the Boston Architectural College, where he led accreditation efforts, designed and conducted student and faculty performance assessment, and coordinated curriculum redesign. His research interests focus on helping students see themselves as engaged in the health and vitality of the places where they live.

CUR Quarterly
COUNCIL ON UNDERGRADUATE RESEARCH

Sandra L. Laursen,
University of Colorado Boulder

CUR Focus

Assessing Undergraduate Research in the Sciences: The Next Generation

Inherent in the conceptualization of the apprentice model of undergraduate research (UR) is a fundamental tension between the educational goals of UR and its foundation in faculty scholarship (Laursen, Seymour and Hunter 2012). This tension in goals leads to challenges for faculty in guiding undergraduate researchers in their daily work, as well as in positioning faculty's own UR work within the institutionally bifurcated domains of teaching and research.

In interviews, faculty UR advisors explain how the task of crafting and supervising developmentally appropriate projects is "very much a teaching thing," as one faculty interviewee put it, and faculty recognize and make use of the many rich learning opportunities for students that are embedded in real research problems. The teaching aspect of UR is also a source of great pleasure, pride, and learning for faculty as they see their student researchers' progress and become independent. But faculty also describe challenges: They must consider carefully how to build and support their own overall scholarly trajectory given the constraints of students' slower pace, variable progress, and the need to cobble together the contributions of multiple "short-term helpers in a long-term enterprise." While faculty members navigate these tensions in their everyday work as UR advisors, institutional descriptions often over-simplify UR as either education-focused or as scholarly work.

This tension between the educational and scholarly purposes of UR also generates challenges when it comes to measuring the outcomes of UR. Traditionally, at least in the sciences where UR is most established, institutions have counted their successes in terms of student researchers' scholarly contributions—such as numbers of student-coauthored publications and presentations—and research-oriented career choices, especially the number of students who go on to pursue graduate degrees in a similar field. Such measures help to identify the value of students' contributions to new knowledge; they call out the importance of maintaining the scholarly engagement of faculty (especially at primarily undergraduate institutions) and of developing the skilled research workforce in scientific disciplines. Yet these measures may overstate the role of scholarly publication, which is valued by faculty and institutions but which research to date has not linked to the quality or extent of students' educational outcomes. Indeed, deep learning from authentic undergraduate research experiences requires that students have opportunities to try out their own ideas, make mistakes, and try again. At the same time, giving students such independence may also slow faculty's acquisition of publishable results (Laursen, Hunter, Seymour, Thiry and Melton 2010). And, by counting only those students who go on to graduate school, we undervalue other contributions to the nation's workforce and electorate, such as developing research-literate technicians, science teachers, physicians, parents, and citizens.

Gaya Shivega working in the lab at Concordia College.
(Photo credit: Paige Borst)

In this article, I analyze these and other reasons that assessing the outcomes of the apprentice model in undergraduate research is an inherently difficult proposition. These challenges mean that development of new approaches to assessing undergraduate research is itself a topic for research. I note strengths and limitations of the assessment approaches tried to date and suggest other questions and approaches for individual investigators and the community at large to consider, with the goal of prompting thinking and inspiring experimentation that will lead to the next generation of UR assessment tools.

My focus here is on the traditional, intensive model of undergraduate research in which students pursue a multi-week, open-ended scientific project outside class and under the guidance of a faculty member and other, more experienced, researchers in the research group. Many students engage in apprentice-model UR as an immersive summer project, but they may also participate during the academic year. However, I note useful lessons that may be learned from assessing outcomes of research-based courses. In this article, I focus on scientific disciplines in which the apprentice model is common and in which most previous research and evaluation of student outcomes has been carried out. Finally, I use the term "assessment" to refer to any measurement of UR student outcomes, which may use a variety of methods such as surveys, tests, interviews, or review of students' research products, and which may be carried out for purposes of research, evaluation, or monitoring.

Measuring Outcomes: A Worthy Challenge

Assessing outcomes of undergraduate research is of keen interest to faculty, administrators, funders, and policymakers. Indeed, faculty who work with undergraduate researchers have long known and valued the learning they observe among their students, and more recently research has begun to document these outcomes (see reviews in Laursen et al. 2010; Sadler, Burgin, McKinney and Ponjuan 2010; Crowe and Brakke 2008). Large-scale studies identify UR as one of several "high-impact" practices that foster deep learning and persistence in college, especially for students from underrepresented minority groups (Eagan et al. 2013; Hurtado, Cabrera, Lin, Arellano and Espinosa 2009; Kuh 2008; see also studies reviewed in Laursen et al. 2010). In this era of accountability, funders of UR seek good information about the value of their investment; departments and institutions are interested in pinpointing the educational contributions of these important out-of-class experiences to their overall program; and faculty have a stake in seeing that their UR work is indeed recognized for the educational value it delivers.

At the same time, assessing UR outcomes in uniform ways is challenging. Both students and their research advisors experience UR differently, depending on their discipline and its intellectual and pragmatic ways of working. Even within the same research group, each student's outcomes will differ depending on the nature and stage of her individual project and its relation to ongoing work in the laboratory, as well as her own characteristics and background. Moreover, many of the most valued outcomes of research activity are not only highly contextual but also inherently difficult to define and measure, such as understanding the nature of science or of scientific inquiry (Lederman 1992; Lederman et al. 2014). There are also measurement and sampling challenges: In any department, program, or institution, the number of participants is often small, and both institutional and self-selection influence which students have the chance to participate, making comparisons of UR participants with non-participants problematic. Alas, probing the outcomes of undergraduate research is not as simple as sticking a probe in students' ears or scanning them with a Starfleet tricorder.

Strengths and Weaknesses of Current Studies

The first generation of UR assessments has been derived from education research that has documented students' personal and professional learning as a result of UR, including their acquisition of new skills and conceptual understandings of their field and of disciplinary inquiry, growth in confidence and responsibility, and development of a scientific identity (Laursen et al. 2010, and studies cited within). This body of work helps to balance prior emphasis on students' scholarly contributions by recognizing the strong educational role of UR. Interview studies, in particular, reveal the types and depth of student learning from UR and find commonalities in outcomes across multiple disciplines and research settings. Often based on long-established and well-designed examples of apprentice-model UR, such studies help by identifying student outcomes that result from best-case scenarios; these outcomes then guide what can be searched for when examining programs with other designs or durations. Interview data also capture the language students themselves use to express their nascent understanding of complex ideas about the scientific process and the nature of the knowledge it generates, or use to describe their developing identities. Use of a semi-structured interview protocol enables interviewers to identify and probe emergent issues—whether benefits not anticipated or difficulties not perceived by program designers. Thus interviews and focus groups remain a useful tool for program evaluation, but the time commitment and cost of data analysis are barriers to their routine use.

Survey instruments based on these interview-derived findings seek to capture these gains in a holistic manner from students' perspective, asking students to self-report their gains across multiple domains. Compared to interviews and focus groups, instruments such as the Undergraduate Research Student Self-Assessment (URSSA, Hunter, Weston, Laursen and Thiry 2009) and the Survey of Undergraduate Research Experiences (SURE, Lopatto 2004) are inexpensive and easy to use, and thus complement other sources of information. Such instruments have advantages in that the set of items covers many learning domains already identified through qualitative research; responses can be compared over time or across programs and linked to particular experiences and activities that students also report. Self-report is an obvious way to probe student gains that are personal, internal, and not easily tested, such as changes in students' career plans or the growth in confidence that is so important for student researchers. A recent validity study of URSSA based on more than 3,600 student responses supports the reliability and validity of the four main categories of student gains captured by that survey, but that study also points to possible improvements that can be made to improve the sensitivity and discrimination of this instrument (Weston and Laursen 2014).

To measure other gains, such as research competencies and skills, self-assessment may be less satisfactory; the literature does not show a predictable relationship of self-report to criterion-referenced measures such as tests of knowledge or experts' rating of student skills (Boud and Falchikov 1989). Poor survey design, such as when students do not understand the questions or do not have the relevant knowledge to answer them, can compromise survey items. Careful development using approaches such as think-aloud interviews is needed to craft relevant items and to determine whether the intended audience can answer them (Hunter et al. 2009). And self-reports of competencies work best when people have received feedback on their progress and abilities; indeed, some level of skill in a domain is required in order to evaluate one's own competence in that domain (Kruger and Dunning 1999). The availability of such feedback may be variable (and certainly unsystematic) for research students, especially in domains new to them.

Different risks to the reliability of self-report arise when consequences such as grades, money, or advancement depend upon students' responses to survey questions (Albanese et al. 2006). For UR, candid responses are more likely when students can respond anonymously and have no stake in how the results are used. Social-desirability bias can arise when students feel pressure from their research advisor or program director to answer a certain way. We commonly observe pitfalls of these types, especially those that compromise student anonymity, when surveys are used in evaluating UR programs. For example, small numbers of participants mean that individuals may be easily identified from demographics; consequences such as stipend payments may be tied to completion of the survey; programs want to link survey responses to long-term outcomes so program administrators do not wish to give surveys anonymously, yet non-anonymous survey answers may be biased because students continue to depend on their advisors for recommendations and support. Thus those who lead UR programs express a need for other assessment tools to augment students' self-reports.

In addition to the measurement problems inherent in survey approaches, issues of research design often surface in existing studies of student outcomes from undergraduate research. Eagan and coauthors (2013) note that such studies too often generalize from small, non-representative samples, draw on retrospective reflections (e.g., of program alumni) rather than real-time probes, and do not properly account for selection bias both in who chooses to apply and who is admitted to UR programs. In their own study examining the relationship between UR and students' intention to enroll in STEM graduate programs, Eagan et al. (2013) mitigate some of these problems through the use of data on students' degree aspirations from an anonymous, nationwide survey administered in students' first year and again in their senior year of college.

While aspiring to an advanced degree is not the same as earning one, the authors argue that aspiring to that degree is a necessary first step, citing research showing that intention to pursue a graduate degree is the strongest predictor of eventual enrollment in a graduate or professional program. With more than 4,000 students in their sample, these authors were able to apply sophisticated statistical methods, using propensity scoring and hierarchical modeling with student- and institution-level covariates to statistically control for student self-selection into UR programs. They conclude that UR participation had a significant positive effect on undergraduate STEM majors' intent to pursue STEM-related postgraduate study, increasing this likelihood by between 14 and 17 percent compared with non-participants.

Steps Forward: Tighter Focus in Research Studies of UR

The study by Eagan and coauthors cited above is a useful example because it points the way toward one promising strand of future work on assessment of UR. This carefully designed study focuses on a single outcome, in this case intent to pursue graduate study. By probing at two distinct times students' self-reported intentions to pursue graduate study, the authors could identify changes in students' thinking in a less biased manner than would be possible from retrospective self-report, and by carefully controlling for influences other than UR, they could attribute changes in students' plans for STEM graduate study to UR experience. Other studies in this vein might similarly target specific outcomes or narrow domains, drawing on prior work to develop and validate surveys or tests for domains already known to be related to UR experiences, such as:

- formation of a scientific identify (e.g., Estrada, Woodcock, Hernandez and Schultz 2011),
- project ownership (e.g., Hanauer and Dolan 2014),
- understandings of the nature of scientific inquiry (e.g., Lederman et al. 2014),
- student beliefs about science (e.g., Adams et al. 2006), and
- experimental design (e.g., Dasgupta, Anderson and Pelaez 2014).

Other important constructs might include creativity, persistence, and invention. Because students develop in these domains as a result of many types of experiences, not just UR, good data about students' prior experiences and background are also needed if the goal is to establish a causal relationship between a particular outcome and the UR experience.

Initial work to develop or adapt and test such targeted assessments might be carried out in venues other than apprentice-model research environments, especially in inquiry-driven or research-based courses (Auchincloss et al. 2014; Gasper, Minchella, Weaver, Csonka and Gardner 2012; Dasgupta, Anderson and Pelaez 2014). Research-based courses offer certain advantages for exploring the domain and for testing measurement approaches, such as larger sample sizes and faster iteration times, and, at least within a given course, a more standardized and less context-based intervention. Because some of these tools have been developed to study science learners who are less experienced than the typical UR student (Adams et al. 2006; Lederman et al. 2014), additional up-front work will be required to determine whether and how the instruments and methods are useful in detecting outcomes of apprentice-model UR, and whether they apply across varied scientific approaches and disciplines (see Schwartz and Lederman 2008). In some domains, further research to identify and generalize (if possible) elements of advanced learning in the domain may be needed.

For example, Dasgupta, Anderson, and Pelaez (2014) review existing literature on experimental design to categorize student difficulties in the ability to design experiments, drawing on studies of middle-school, high-school, and college students. They apply this categorization together with some existing assessments to diagnose student difficulties with experimental design and to measure changes in this ability as the result of a college course. This study offers a model of careful thinking about a specific domain—in this case, experimental design—and validation of a measurement approach, while also raising the question: Are there other difficulties or understandings of experimental design that would be identified in a sample of more experienced researchers? As the authors point out, this type of assessment could also help to identify the processes or experiences through which students learn to design experiments and could lead to development of good interventions to teach that skill. Thus, while I argue that this type of targeted study offers one promising strand to follow in preparing the next generation of UR assessments, it is likely to require work by experienced educational researchers, and would not be easily carried out within single UR programs by the science faculty who run them.

Steps Forward: Approaches to Program Evaluation

A research agenda that turns attention to specific outcomes will ultimately produce results useful to practitioners. But in the meantime, practitioners will continue to need assessment tools for evaluating local programs. These tools must yield data of a depth and quality that help practitioners to monitor, improve, and justify their programs but need not presume a standardized approach across units or institutions. Assessment for program evaluation should focus on questions about what is good and what can be improved about the local UR program, not on comparing or trying to generalize student outcomes. Program directors are likely to prefer holistic or broad approaches that do not focus on one outcome to the neglect of others. Familiarity with the research literature may be helpful in identifying which outcomes are most likely and what program elements give rise to them; it also helps in making "golden spike" arguments that connect local evaluation of practice to evidence from research (Urban and Trochim, 2009). Measurement issues, such as the small samples, student selection, and self-report biases discussed above, may limit the claims that can be made relative to other programs, but such problems do not invalidate the worth of knowing, rather than assuming, what happens in one's own program and why.

To prompt creativity in this type of local program evaluation, I suggest some other sources of information that are amenable to local use and that examine multiple or broad domains. Some of these are straightforward, and some are better suited for those ready to explore more deeply. Sources of information may include:

1. Reflections from students, such as exit interviews, a facilitated group discussion, or a personal reflective essay. These activities offer intriguing opportunities for spurring student metacognition about their research experiences, at the same time that they document student perspectives and help students to recognize gains as they develop graduate school or job applications. Singer and Zimmerman (2012) note such metacognitive benefits from the repeated use of a student self-evaluation rubric in concert with faculty ratings of students on the same rubric.

2. Faculty-developed rubrics applied to students' research work or research products, such as abstracts (perhaps both a technical abstract and a general-audience summary), posters, or talks. In speaking with faculty UR advisors at liberal arts colleges (Laursen et al. 2010), our research team found that faculty could offer sophisticated judgments of students' research skills and capacities, for example when they wrote letters of recommendation, but that faculty colleagues did not generally have ways to standardize these so that they could compare research skills among students who worked with different advisors. Thus the process of coming to consensus on this rubric could itself be a valuable exercise for some departments. Dahm, Newell, and Newell (2003) describe how developing a rubric for a semester-long team engineering "clinic" course provided greater clarity to students and faculty alike about course goals and student achievement of these goals.

3. Broad tests of integrated content knowledge. Content knowledge is not often the focus of UR assessment, but students commonly report growth in their depth of understanding of disciplinary concepts and in their ability to connect concepts across disciplines or subdisciplines. Could that growth be detected by appropriate instruments? One interesting disciplinary example is a test offered by the American Chemical Society Exams Institute, the Diagnostic of Undergraduate Chemistry Knowledge (DUCK) (http://chemexams.chem.iastate.edu/exam-details?id=41783).

4. Oral exams by outside experts (Wright et al., 1998). In this study, oral exams designed and given by outside faculty examiners were used to judge the competence of students who had taken one of two versions of a course, one more collaborative and project-oriented

and the other lecture-based. The examiners developed their own questions and did not know which course each student had taken, but reported the greatest difference in student skills when they chose to focus their assessment on students' problem-solving abilities. The study shows, the authors argue, that "it is possible to measure in an unbiased and quantitative way the extent to which the goal of increasing student competence can be achieved." Could this approach be applied to settings such as UR to assess general competency in research thinking or problem-solving?

5. A normed test of transferable critical thinking. For example, the Critical Thinking Assessment Test (CAT) examines a set of critical-thinking skills valued by faculty across disciplines (Stein and Haynes 2011; https://www.tntech.edu/cat/). This carefully developed test is said to be sensitive both to course-level changes in student skills and to changes across the college career. Could this test offer useful data to a department in considering how its majors develop these skills over time—not only through research but also through other experiences in the major?
6. Systematic tracking of participants. Records of student involvement in presenting and publishing research and documentation of students' graduate and career outcomes are likely to continue to hold value locally. Departments can improve their practice by being systematic in tracking and proudly reporting outcomes for all their majors—not just those who go on to graduate school.

As an example, imagine a chemistry department that seeks evidence to offer an accrediting body that its summer undergraduate research activity is an important and meritorious part of its educational activities. The faculty members decide to administer the URSSA anonymously to measure student gains and the learning experiences that give rise to them. They also ask students to write an individual one-page reflection that prepares them for an end-of-summer group debriefing session facilitated by a colleague from the campus teaching center. These combined approaches provide the faculty with a picture that is both broad and deep; they offer additional benefit by inviting students' reflection and metacognition about their research experience. The department members gather to review the outcomes data and identify what is good for students' growth as chemists, as communicators and team members, as future professionals, and as science-literate world citizens. Later on, the data help the department to refine its criteria for how student research work is weighed in considering departmental honors.

Our imaginary chemists also decide to keep track more systematically of their graduates' career paths, not just rely on graduates to update their faculty mentors of their own record. In examining data on students' experiences in their UR program, the faculty members learn what can be improved and identify small ways in which their summer activities can be refined to build community among summer research students, increase students' communication skills, and adjust the requirements to smooth the path for students who wish to submit their UR work for departmental honors. Their goal is not to demonstrate that their UR program is better than the one in the math department or than the one down the road at a neighboring institution, but rather to make explicit the value that UR adds to their own major. Yet the simplicity and success of their approach leads to a feature about the chemistry department on an institutional web site about engaged teaching and learning. Ideas like these for assessing and improving a local program are no means novel, but this scenario shows how they might augment current practices on many campuses.

These approaches are likely to work best when integrated into an overall approach to assessment that looks broadly at student outcomes in the major. Yet because it offers both educational and scholarly contributions to the organizational mission, undergraduate research may be a good place to begin such conversations about assessment. Institutions and funding agencies should recognize that there is value in experimenting with different approaches to outcomes assessment and developing assessment "habits of mind," even when sample size and other constraints prevent the resulting data from meeting publication-level standards of research design. As they assess and communicate about their UR programs with students, colleagues, and administrators, program directors and scientists who work with undergraduate researchers can value both scholarly achievements and educational outcomes, and thus honor the special types of teaching and learning processes by which these are achieved.

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CUR Focus

Undergraduate Research and Alumni: Perspectives on Learning Gains and Post-graduation Benefits

Despite many areas of overlap in the values expressed by higher education and business/industry, clear gaps exist between the skills employers seek and the learning outcomes that are tracked and assessed by higher education. Undergraduate research, as a high-impact practice providing myriad benefits, provides a credible option to bridge this gap. To illuminate the potential of undergraduate research to further the values of both higher education and business and industry, research administrators at the University of Wisconsin-Eau Claire surveyed alumni who had participated in undergraduate research to understand their perceptions regarding learning outcome gains and benefits as they continued their education or sought employment.

The survey, Undergraduate Research Learning Outcomes and Gains (URLOG), was developed after a thorough literature review to identify and evaluate existing processes, tools, and surveys. Alumni reported significant gains across all the categories of learning outcomes surveyed, including higher-order thinking, preparation for graduate school or careers, and discipline-specific skills. Further, a majority of respondents indicated that undergraduate research was a significant positive factor in their actual admission to graduate school, employment, or both.

Table 1. Existing National Assessments that Address Learning Outcomes, Skills, and Concerns, Grouped by Target Population

Assessment Name	Author	Audience for Results	Measure Type	Sample learning outcomes, skills. concerns
UNDERGRADUATES				
Collegiate Learning Assessment	Council for Aid to Education	Higher education	Performance-based tasks	Critical thinking, written communication
The University Learning Outcomes Assessment (UniLOA)	Center for Measuring College Behaviors and Academics	Higher education	Perceptions & behaviors	Critical thinking, self-awareness, citizenship
Collegiate Assessment of Academic Proficiency (CAAP)	American College Testing (ACT)	Higher education	Performance-based tasks	Reading, writing, mathematics, science, critical-thinking skills
Proficiency Profile (formerly Measure of Academic Proficiency and Progress)	Educational Testing Service (ETS)	Higher education	Performance-based tasks	Critical thinking, reading, writing, mathematics
Valid Assessment of Learning in Undergraduate Education (VALUE)	Association of American Colleges and Universities (AAC&U)	Higher education	Rubrics (16 total)	Intellectual and practical skills, integrative and applied learning
College Senior Survey	Higher Education Research Institute	Higher education	Perceptions	Ability to see the world from someone else's perspective, critical-thinking skills
EMPLOYERS AND BUSINESS/INDUSTRY				
What America Needs to Know about Higher Education Redesign	Gallup and Lumina Foundation	Mixed	Perceptions	Preferred employee skills, level of graduate preparation for workforce, skill gaps
It Takes More Than a Major	Hart Research Associates, AAC&U	Mixed	Perceptions	Preferred employee skills, level of graduate preparation for workforce
Job Outlook	National Association of Colleges and Employers (NACE)	Mixed	Perceptions & intentions	Preferred employee skills, hiring plans
Skills and Employment Trends	Accenture	Mixed	Perceptions & intentions	Skill gaps, hiring and training plans
Talent Shortage Survey	ManpowerGroup	Mixed	Perceptions & intentions	Talent shortages, strategies to fill gaps
UNDERGRADUATES WHO PARTICIPATE IN RESEARCH				
Classroom Undergraduate Research Experience (CURE) – Post-course	Lopatto	Higher education	Perceptions	Become responsible for part of the project, write a research proposal (also includes the list of learning benefits from the SURE survey)
Research on Learning & Education	Lopatto	Higher education	Perceptions	Understand the research process, clarify career path
Survey of Undergraduate Research Experiences (SURE)	Lopatto	Higher Education	Perceptions	Understand how scientists think, self-confidence
Undergraduate Research Student Self-Assessment (URSSA)	Hunter, Weston, Thiry, and Laursen	Higher education	Perceptions	Write scientific reports or papers, confidence in ability to contribute to science
Research Skill Development Framework	Willison and O'Regan	Higher education	Rubric	Evaluate information sources, use discipline-specific language
ALUMNI				
Alumni Outcomes Survey	American College Testing	Higher education	Perceptions	Objective thinking, problem defining and solving
Alumni Survey	Higher Education Data Sharing Consortium (HEDS)	Higher education (private institutions only)	Perceptions	Critical thinking, information literacy

UW-Eau Claire students share research at the annual Celebration of Excellence in Research and Creative Activity (CERCA). In 2014, 607 students and 222 faculty mentors shared 343 collaborative projects.

What Does Academia Want Undergraduates to Learn?

In 2006, Secretary of Education Margaret Spellings and her Commission on the Future of Higher Education released an initial report, which offered the following caution regarding the quality of learning outcomes: "the continued ability of American postsecondary institutions to produce informed and skilled citizens who are able to lead and compete in the 21st-century global marketplace may soon be questioned" (Spellings 2006, 13).

Table 2. Higher Education and Business/Industry: Shared and Unique Values Regarding Learning Outcomes and Skills

Shared Values: Higher Education and Business/Industry
Communication skills
Critical thinking
Information literacy
People management/teamwork
Personal growth
Higher Education Values
Citizenship
Creativity
Life skills
Business and Industry Values
Application of knowledge to real-world settings
Decision making
Ethics
Intercultural skills
Leadership
Problem solving
Technology

As part of its recommendations, the commission noted that colleges and universities must define appropriate learning outcomes and develop methods of measuring progress. In the last several years, many educational organizations have endeavored to heed the commission's advice. This work to define and measure learning outcomes coincides with increasing pressure for accountability on multiple fronts—inside higher education and from government and employers (Markle et al. 2013). Recent examples of responses include publication by the Association of American Colleges and Universities (AAC&U) of *Liberal Education and America's Promise* (LEAP 2005) and the National Research Council's *Assessing 21st Century Skills* (2011). According to recent analysis (Markle et al. 2013), a review of desired learning outcomes championed by seven organizations (including AAC&U and international groups) found considerable agreement on outcomes associated with creativity, critical thinking, teamwork, communication, information literacy, citizenship, and life skills.

In tandem with the outgrowth of defined learning outcomes, several surveys have been developed to measure students' gains in learning (see Table 1 on page 15). These tools largely focus on the current undergraduate population. Not surprisingly, given the work of national groups to define important learning outcomes, there is considerable overlap in the desirable outcomes included in each survey. For example, concepts related to critical thinking, citizenship, communication skills, and personal growth are present across all the higher-education groups' identified learning outcomes (see Table 2).

What Do Employers Want Graduates to Know and Do?

In a recent study commissioned by the AAC&U, employers identified necessary skills and abilities for the workplace (Hart Research Associates 2013). Employers highly ranked ethics, intercultural skills, and professional development and considered those characteristics as priorities when hiring. The majority of employers surveyed (75 percent) wanted higher-education institutions to put more emphasis on critical thinking, problem solving, written and oral communication, and application of knowledge to real-world settings.

Similar responses have been found in a variety of other national and business/industry-based surveys of employers. In the *Job Outlook 2014 Survey* (National Association of Colleges and Employers), employers rated the following skills as most important: ability to make decisions and solve problems, communicate verbally, and find and process information. The Accenture *Skills and Employment Trends Survey* (2013) also identified problem solving and communication as important abilities, but also included leadership, knowledge of technology, and people management.

While there is considerable overlap in the skills valued by higher education and employers, a "disconnect" remains. The *Talent Shortage Survey* (ManpowerGroup 2013) found that 48 percent of employers had difficulty filling jobs due to a lack of technical skills among applicants and 33 percent due to limited workplace or "soft" skills. Employers have suggested ways to ameliorate the deficiencies. According to the Hart Research Associates study (2013), employers overwhelmingly agreed that the following activities, embedded during the undergraduate experience, would help prepare students for the workforce: develop discipline-based research questions

(83 percent); complete a project that demonstrates knowledge and skills (79 percent); conduct collaborative research (74 percent); and engage in hands-on experiences (69 percent). Likewise, in a recent survey by Gallup and the Lumina Foundation (2014), employers' most popular suggestion was "internships or practical hands-on experiences" when asked "what talent, knowledge, or skills should higher education institutions develop in students to best prepare graduates."

Further, employers have identified a lengthy list of skills that have not yet been commonly adopted as discrete learning outcomes in higher education (Table 2). The divide is evidenced in recent surveys that found only 11 percent of business leaders "strongly agree" that college graduates have the necessary skills and abilities (Gallup and Lumina Foundation 2014). In contrast, 87 percent of chief academic officers "agree" or "strongly agree" that their institution is increasing efforts to ensure that degree programs help graduates get jobs (Gallup and Inside Higher Ed 2014).

The Missing Links: Alumni Perspectives and Undergraduate Research

Alumni Perspectives. Recent college graduates are in an ideal position to bridge perspectives between higher education and business and industry. They have fresh experience on both sides—in college and in the workforce—and can consider their learning gains from both viewpoints. While those in academia also have personal experience as employees, their work to define learning outcomes and measure them in undergraduates is not focused through this lens. Similarly, employers may well have matriculated from higher education, but efforts to gather their perspectives have asked for their views as business leaders only. Indeed, individuals in academia and business each have a position to defend when representing their respective professional realms. Given the divide between the opinions of higher education and business, seeking input from an alumni point of view may provide a more balanced perspective.

Undergraduate Research. As noted in the Council on Undergraduate Research's *Characteristics of Excellence in Undergraduate Research* (COEUR 2012), undergraduate research is perhaps "one of the most powerful learning strategies," leading to "innovation and economic development," and ensuring student success in careers or continuing education (Hensel 2012, iv). Further, undergraduate research is a high-impact practice that provides multiple benefits to students. Kuh (2008) outlined essential learning outcomes and goals of liberal education that are connected to 10 "best practices" in higher education. One of those practices was undergraduate research.

Kuh found a significant positive relationship between student-faculty research and deep learning, as well as gains in general, personal, and practical learning. Specifically, undergraduate research helps students achieve desired learning outcomes that include "practicing integrative and applied learning" and "strengthening intellectual and practical skills" (Kuh 2008, 6). Such outcomes align with both higher education's goals and employers' needs.

As summarized in Table 1, there are a number of measures of learning outcomes—based on both performance and perceptions of gains—for undergraduates and students who participate in undergraduate research. Several surveys exist to gauge employer needs and values related to learning and skills. However, the list has few measures of alumni perspectives. Only two of them gauge the perceived learning gains of alumni, neither of which is targeted at individuals who participated in undergraduate research.

The Eau Claire Study of Alumni

Designated in 1988 as the University of Wisconsin System's "Center of Excellence for Faculty and Undergraduate Student Research Collaboration," the University of Wisconsin-Eau Claire's Office of Research and Sponsored Programs supports a dynamic program. Indeed, 37 percent of our graduating seniors have had an in-depth research experience during their undergraduate careers. For example, our annual event highlighting student research in 2014 included 607 students and 222 faculty mentors. These individuals shared 343 collaborative projects via performances, oral presentations, artwork, exhibits, and research posters. Based on this, we felt confident about the high level of student and faculty participation in undergraduate research. Further, we have regularly tracked and reviewed data on participation in such activity by department, discipline, and among underrepresented students to ensure that undergraduate research was a broadly available opportunity. However, we had only anecdotal evidence of students' learning gains and the post-graduation benefits arising from the research experience. Students would spontaneously share stories about how much they learned or how the experience helped them—but we simply did not have a process or tool to collect formal data.

During academic year 2011-12, we had conducted a thorough literature review to identify and evaluate possible processes, tools, or surveys that we could adopt or adapt to collect data on the benefits of undergraduate research. Based on examples in the literature (Alexander, et al. 2000; Bauer and Bennett 2003; Campbell and Skoog 2004; Harsh, Adam, and Tai 2011), we sharpened our focus on the learning outcomes and gains that students may achieve as a result of undergraduate research.

CUR's publication on facets of excellence in undergraduate research (COEUR 2012) provided a further impetus to formally assess learning outcomes related to undergraduate research. This publication provided benchmarks against which to evaluate institutional commitment to undergraduate research and quality of programming. Although UW-Eau Claire employed many of the best practices outlined (Rowlett, Blockus, and Larson 2012), a systematic and sustained assessment of student learning was a challenge, as it has been for many institutions (see, e.g., Chapdelaine 2012, 25).

Based on our analysis of the overlaps and divides in values between higher education and business and industry (Table 2) and Bauer and Bennett's (2003) landmark study of alumni perceptions, we decided that alumni would be an ideal target population to survey. Data from alumni would provide a benchmark against which to measure learning gains perceived by current undergraduates in a future survey. An additional goal was to understand the benefits of undergraduate research perceived by alumni as they continued their education or sought employment.

Survey Instrument

Borrowing from the method used by Craney et al. (2011), the *Teaching Goals Inventory* (*TGI*) developed by Angelo and Cross (1993) provided a comprehensive list of core learning outcomes. Since this inventory was designed to help educators identify instructional goals and apply classroom assessment techniques, we had to adapt this method to examine the cocurricular undergraduate research experience.

We vetted the *TGI* to ensure that it was comprehensive and would cover both higher education and business and industry values (Table 2). Specifically, we compared the *TGI* learning outcomes to those more recently identified by academia and business and industry and found significant overlap; all measures included concepts related to critical thinking, communication skills, problem solving, and life or personal skills. In addition, we compared the *TGI* against two well-respected survey instruments that measure undergraduate-research benefits among current students. These were the Research on Learning and Education (ROLE; Lopatto 2000) and the Undergraduate Research Student Self-Assessment (URSSA; Hunter et al. 2009) instruments. As a final step, we compared the *TGI* to the American College Testing (ACT) alumni survey, which included several questions related to learning gains, because our institution had ACT survey data from 2007, and we could potentially use the overlapping content to make comparisons between all alumni and alumni who participated in undergraduate research.

Our comparison and analysis revealed that the broad, nondisciplinary learning outcomes included on the ROLE, URSSA, and ACT surveys were represented on the *TGI*. We were comfortable with the differences identified because they related to specific disciplinary concerns that were outside our area of interest. For example, the ROLE survey item "tolerance for obstacles faced in research process" and the URSSA survey's "confidence in my ability to do well in future science courses" queried a level of specificity regarding students' perceptions that was outside our scope.

After this comparison, we were confident that the *TGI* would meet our needs. In creating our survey, we maintained the six categories of the full *TGI* (see Table 3), but eliminated 15 learning outcomes that were redundant for our purposes. For example, several questions touched on ethics, so we included a single question about ethics within the "Discipline-Specific Knowledge" category. Our purposes in reducing the number of learning outcomes were to limit the overall time required for respondents to complete the survey and to keep our data collection and analysis focused and manageable.

Table 3. Alumni Survey Categories and Sample Learning Outcomes

Category	Sample Learning Outcomes
Liberal Arts and Academic Values	• Appreciation of other cultures • Knowledge of rights and responsibilities of citizenship
Basic Academic Success	• Listening skills • Writing skills
Graduate School/ Career Preparation	• Ability to work with others • Leadership skills
Personal Development	• Self-esteem/Self-confidence • Sense of responsibility
Discipline-Specific Knowledge	• Capacity to evaluate methods and materials • Skill in using techniques, methods, materials, tools and/or technology
Higher-Order Thinking	• Ability to apply principles already learned to new problems and situations • Ability to think creatively • Problem solving and analytic skills

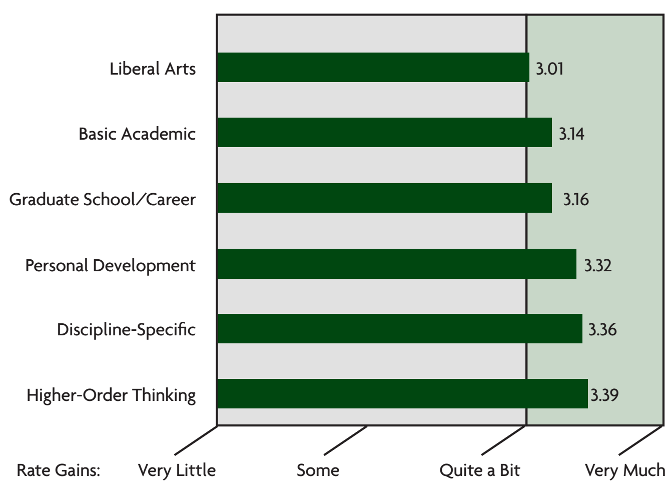
When we administered our survey in spring 2013, alumni were asked to rank their perceived learning gains using a 4-point rating scale, with 4 reflecting "very much" and 1 "very little." Alumni also were asked to comment on whether their undergraduate-research experience was helpful in securing employment, admission to graduate school, or both. Alumni had the option of providing open-ended responses to the questions about employment and admission to graduate school, as well concerning their overall perceptions about the undergraduate-research experience. An online survey tool (Qualtrics) provided an ideal platform in which to create the survey, which was distributed via email.

Respondents' Demographics, Perceived Learning Gains, and Post-Graduation Benefits

Working with our campus institutional research office, we identified individuals who had graduated within the past five years (2006-07 to 2010-11) and who had participated in undergraduate research funded by UW-Eau Claire's Office of Research and Sponsored Programs. Respondents (n=135/781, 17 percent) were asked to select the disciplinary category that best described their undergraduate research experience. The three most frequently cited ones were natural sciences (30 percent of respondents), social sciences, (26 percent), and humanities and fine arts combined (18 percent). Those areas were followed by health sciences (15 percent), education (8 percent), and business (3 percent).

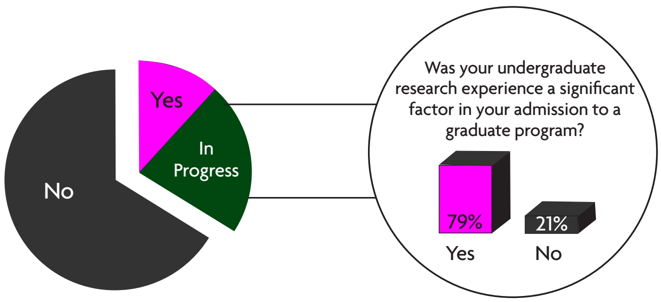
The reported race of respondents was 88 percent white and 12 percent non-white, compared to 92 percent white and 8 percent non-white in the general student population. Forty-six percent of respondents had been first-generation college students, compared to approximately 41 percent of the general student body. Of the respondents, 72 percent identified themselves as women and 28 percent as men, which reflects a greater representation of women than in the general university population, which is 59 percent female (UWEC Factbook 2013-14). On average, alumni reported learning gains of 3.0 or above (on a 4-point rating scale), representing "quite a bit" or "very much" gain (see Figure 1).

Figure 1. Summary of Alumni-Reported Learning-Outcome Gains



In the area of advanced education, 34 percent of respondents reported they either had a master's or doctoral/professional degree or were currently pursuing such a degree. This is more than double the levels reported in UW-Eau Claire's most recent ACT alumni survey (11 percent) and the five-year average of our annual career-services alumni survey (14 percent). Alumni who had completed a graduate degree or were progressing toward one were asked whether their undergraduate-research experience was a significant factor in admission to a graduate program, and 79 percent responded "yes" (see Figure 2).

Figure 2. Alumni-Reported Graduate School Status: Have You Received a Master's or Doctoral/Professional Degree?



In the open-ended comment area provided for respondents to elaborate on their responses regarding graduate school, the majority of the 44 comments stated three main themes: Undergraduate research gave an advantage or was an outright necessity for admission; it was a topic of discussion during interviews or in application letters; it allowed students to jump-start their master's education—they already had thesis topics or were well-prepared to join faculty research projects (Table 4 on page 20).

It has been widely reported that undergraduate research tends to spark or reinforce students' interest in graduate school (e.g., Craney et al. 2011; Lopatto 2004; Russell, Hancock, and McCullough 2007). There is also a widespread belief that undergraduate research provides a solid foundation for graduate-school admission and success. More recently, May, Cook and Panu (2012) suggested a strategy to formally measure the importance of various aspects of the undergraduate experience as predictors of graduate-school admission. Their logistic regression model compares the efficacy of a variety of undergraduate experiences, including undergraduate research. However, there has been little effort to ask alumni about what actions they ultimately took and why. Perhaps future research could combine survey methods based on intention and prediction with qualitative, experience-based data from alumni to expand the evidence on the benefit of undergraduate research for the pursuit of graduate education.

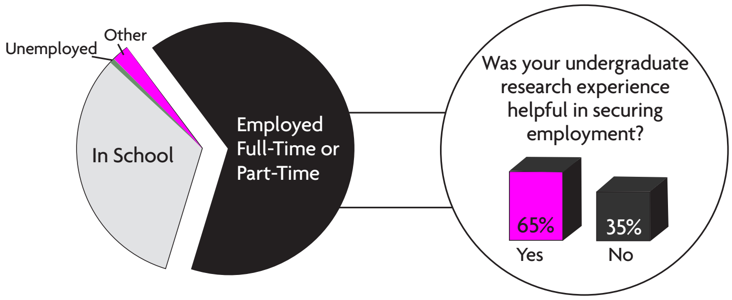
Alumni who indicated they were currently employed were asked whether their undergraduate-research experience was helpful in securing employment, and 65 percent answered "yes" (see Figure 3). Alumni also had the option of explain-

Table 4. Selected Alumni Comments

Please comment on your overall perceptions of your undergraduate research experience at UW-Eau Claire:	Was your undergraduate research experience helpful in securing employment? Please explain:	Was your undergraduate research experience a significant factor in your admission to a graduate program? Please explain:
As someone who went on to graduate school where research is incredibly important, I believe that UWEC should emphasize research as an undergraduate even more.	*My experience gave me a leg up on other candidates applying for my job.*	*Without my research experience, I doubt I would have been accepted into a graduate program.*
My research experiences at UWEC were the best part of my education. Every step of my undergraduate research experiences helped prepare me for graduate school, which I am currently attending.	*It added credibility to my resume and also taught me a lot of valuable lessons that I have applied in my work habits.*	*I always thought grad school was appealing but had no interest other than curiosity. Now I feel driven to attend.*
Undergraduate research is essential in the field of science. Without experiences like these, students lack real-world application of their education. I gained cultural and scientific knowledge on my trip to ... Ecuador. Additionally, I participated in lab work after the trip, giving me experience in that as well. These are the type of experiences that students remember and learn from. I am in medical school now and even last week I was able to apply what I had learned.	*It gave me experience performing a specific technique, helped me get hired at my current job, and has helped me learn/be trained faster at my job because of my experience.*	*The knowledge I gained during research, ability to think critically, and the recommendation letter I received from my research advisor were important pieces in my admission.*
It is a unique experience that you would have hard time finding at larger universities.	*I believe it was impressive to employers, both in demonstrating my involvement and in displaying my capabilities.*	*I had extensive experience that allowed me to start my thesis work right away.*
It was an opportunity that not only helped set me apart from others in my class, but also helped me get a job in my field after I graduated.	*It was a discussion point in my interview that helped set me apart from other candidates.*	*My research experience "gave me an edge" when applying to my graduate program.*
My overall experience was very rewarding and not only was a great learning experience, it was a great experience to be able to network and get to know the faculty on more of a personal level.	*My undergrad research allowed me to show a finished, published product that endorses my skills, determination, and dedication to projects.*	*It offered leadership experience and a chance to talk about something that not everyone got to experience.*
It was a great way to apply skills I had been learning to real-world situations.	*Employers often cite it when discussing my resume with me.*	*I was able to meet my master's advisor while presenting my undergraduate research at an international conference.*

ing their answer, and alumni comments (79 total) noted connections between undergraduate research and employment. A common theme included the perception that the research experience provided a competitive advantage and allowed them to share concrete examples to demonstrate their skills during job interviews (See Table 4 for specific examples of alumni comments).

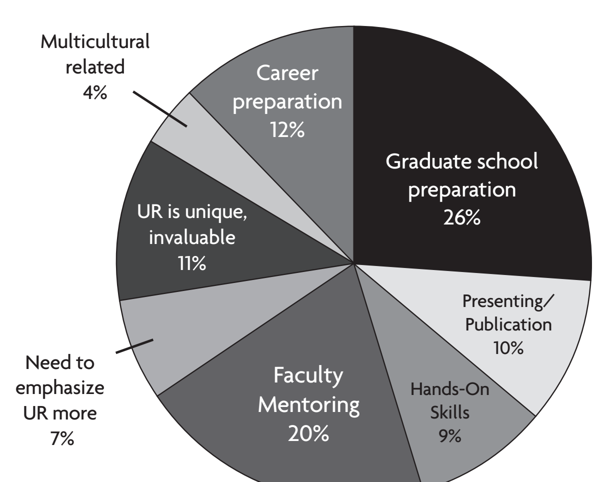
Figure 3. Alumni-Reported Current Employment Status



Research has revealed a consensus among employers that new graduates are lacking important workplace skills and that higher education should place more emphasis on developing these skills (Gallup and the Lumina Foundation 2014; Hart Research Associates 2013; ManpowerGroup 2013). Employers also agree that having undergraduates complete a project that demonstrates knowledge and skills, conduct collaborative research, and engage in hands-on experiences would help fill the skills gap (Gallup and the Lumina Foundation 2014; Hart Research Associates 2013). On our Undergraduate Research Learning Outcomes and Gains (URLOG) survey, alumni who had research experiences reported significant gains in learning outcomes associated with employers' desired skills. Higher-order thinking and discipline-specific skills (with reported gains of 3.39 and 3.36, respectively, on a 4-point scale) were the two highest ranked skill categories. Through their anecdotal responses, alumni agreed that undergraduate research helped them secure employment.

Alumni also had the option of providing comments on their overall perceptions about the undergraduate research experience, and 73 (54 percent) responded. After coding the comments as either generally positive or generally negative, the vast majority (90 percent) were predominantly positive in nature. Further coding was completed to identify common

Figure 4. Common Themes and Their Frequencies in Alumni Comments Regarding Overall Perceptions of Undergraduate Research Experience



themes and their frequencies in all the alumni comments; these are presented in Figure 4.

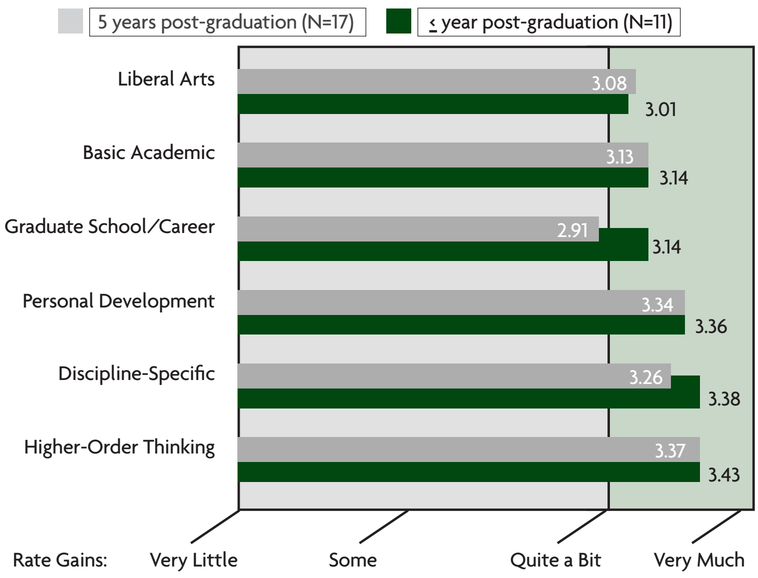
While other surveys of individuals who participate in undergraduate research measure perceptions of learning gains and benefits during or immediately after a research experience (Table 1), UW-Eau Claire's URLOG surveyed alumni up to five years after the undergraduate-research experience. Of alumni who indicated their year of graduation, 27 percent had graduated three to five years ago. However, differences in perceived learning gains between alumni who had graduated five years ago and those who graduated ≤ 1 year ago were modest (see Figure 5).

Survey Uses and the Future

To date, we have shared our alumni-survey findings with several university offices, including the Office of Integrated Marketing and Communications, the Office of Admissions, and the university foundation. Personnel have incorporated data in several marketing documents about the value of undergraduate research that alumni perceive in securing employment and admission to graduate school. In addition, the Office of Research and Sponsored Programs has used quotes from the alumni survey in marketing materials targeted at current and prospective students.

In the near future, we plan to discuss how findings from the alumni survey can support the university's new marketing and branding strategy, specifically, ways to highlight undergraduate research as a distinctive feature and reason to choose UW-Eau Claire. Also, Ray Cross, president of the University of Wisconsin System, has started a system-wide Talent Development Initiative. The overall purpose is to encourage "new and innovative ways to produce high-talent graduates to close skills gaps in the state" (Kremer 2014). By continuing to share the alumni-survey findings and building new data related to perceived benefits of undergraduate research, we can contribute to this system-wide initiative.

Figure 5. Summary of Alumni-Reported Learning-Outcome Gains: ≤1 Year Post-Graduation vs. 5 Years Post-Graduation



Early in the process, we realized the importance of working closely with our university foundation and alumni office to gather alumni contact information and coordinate our communications with alumni. The foundation and alumni offices had email addresses for our list of alumni who had participated in undergraduate research. However, given that some of the alumni were up to five years post-graduation, the contact information was not always current. Hence the alumni office was able to provide email addresses for 1,443 of these individuals, but only 781 of these were unique and ultimately deliverable (54 percent).

While working with institutional research, they shared plans to conduct an alumni survey the same time as ours, and we wanted to avoid "survey fatigue" or redundancy. We shared drafts of our survey with institutional-research-office personnel to gain feedback and to identify areas of possible overlap. Ultimately, our survey population was a subset of alumni—only alumni who participated in undergraduate research and graduated in the past five years—rather than targeting all alumni. Therefore, we did not encounter any challenges or negative feedback related to survey fatigue.

Our next step will be to send the same survey to alumni who participated in undergraduate research and graduated in the five years (2001-02 to 2005-06) prior to the alumni already surveyed. Comparing the results of the first survey with data gathered on alumni who are even further removed from their undergraduate-research experience will reveal whether the perceived gains and benefits hold over the long-term.

In spring 2014, we used the core of the alumni survey (38 learning outcomes organized into six categories) to develop a survey of current undergraduates who had participated in undergraduate research, based on their recent involvement in our annual student-research event. We plan to compare perceived learning gains between the undergraduate and alumni groups. Going forward, our goal is to administer this undergraduate survey every spring.

We also plan to work with academic departments to develop targeted modules to add to the base undergraduate survey and assist in developing mechanisms for departments to measure student outcomes more directly. Other campuses in the University of Wisconsin System have expressed an interest in our surveys, and they will be shared through the newly established Wisconsin System Council on Undergraduate Research (WiSCUR).

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CUR Focus

Measuring Self-Efficacy and Scientific Literacy Across Disciplines as Value-Added Outcomes of Undergraduate Research Mentoring: Scale Development

Increasingly, non-science disciplines have embraced undergraduate research as a signature pedagogy of engagement and retention. Yet studies on the benefits of undergraduate research focus largely on the gains in self-efficacy and science literacy that students report from science-related mentored experiences. To extend assessment research on the value added by mentored student experiences across disciplines, we analyzed various scales that offered reliability, validity, and high internal consistency and adapted two scales to measure students' feelings regarding gains in self-efficacy and scientific literacy from mentored research. The adapted scientific-literacy scale was designed to demonstrate that selected items from such scales could be administered in any discipline to measure gains in a student's ability to use data to think through a problem. The six-item scientific-literacy scale and the 17-item Likert-type self-efficacy scale were administered to students and alumni as part of a triangulation study. Results suggest that the adapted scales measured perceived gains in both constructs for any discipline and were useful for measuring both one-to-one or "one-to-many" mentoring relationships.

At Georgia College and State University, the work described above was undertaken as part of a pilot project to develop and field-test a triangulation methodology to assess gains in self-efficacy and scientific literacy by undergraduate students engaged in mentored research. Our primary goal was to design a reliable and valid instrument to measure the effects of research mentoring on self-efficacy and scientific literacy—two critical characteristics of student personal and professional growth—across diverse disciplines, thereby contributing to the growing body of work on the benefits of undergraduate research (Bauer and Bennett 2003; Crowe and Brakke 2008; Kuh 2008; Lopatto 2010; Seymour et al. 2004).

Our interest in this pilot emerged from a retreat in 2012 by our teaching circle of cross-disciplinary faculty and staff representing chemistry, education, grants and sponsored projects, law, marketing, and psychology. For almost two years, the circle had been meeting monthly to learn, share, apply, and disseminate best-practice approaches for mentoring undergraduate research (Sams 2011) as part of a vibrant university-wide conversation on community engagement, diversity, undergraduate research, and the liberal arts (Georgia College 2014; Richards, Lewis, Manoylov, Brown, and Busch 2014).

Therapy, a new major concentration, has a full service clinic to engage students working with research patients. (Photo credit: University Communications, Georgia College)

Mounting evidence from our literature review suggested that an effective faculty-student mentoring relationship builds a vital bridge between traditional classroom experiences and those required to prepare students for graduate school, business, and industry (Craney, Mckay, Mazzeo,

Peng Hao, chemistry major, working in the Green Synthetic Organic Chemistry lab to help develop new synthetic methodology in green chemistry. (Photo credit: University Communications, Georgia College)

Morris, Prigodich, and de Groot 2011; Russell, Hancock, and McCullough 2007; Temple, Sibley, and Orr 2010). In addition, employers reported concerns that colleges and universities were not adequately preparing students as effective communicators, critical thinkers, or citizens who can find and evaluate options and make logical, informed decisions (Fisher 2013). At the same time, two studies by Peter D. Hart Research Associates (2007, 2013) described employers as having the greatest confidence in college practices that developed those core cognitive competencies in students.

We found that a substantial portion of the literature on mentored undergraduate research (Kardash 2000; Seymour et al. 2004; Hunter et al. 2006; Lopatto 2007; Thirty and Larson 2009) focused on gains in self-efficacy and scientific literacy by students engaged in research in the sciences. Self-efficacy has been defined as "an individual's belief in his or her ability to successfully perform a task and affect change in similar future situations through mastery" (Bandura 1994, 71). Scientific literacy is defined as the ease with which an individual investigates and thinks through information in order to draw sound conclusions or pose new questions related to a problem within an interdisciplinary context (Lopatto 2010). Reports in the scientific literature reveal that gains in self-efficacy among mentored research students ranged from enhancement of the skills associated with performing experiments to increased independence and intrinsic motivation to learn. Similarly, undergraduates and faculty mentors reported enhancement in students' scientific literacy, including positive gains in thinking and working like a scientist, becoming a scientist, and understanding how scientists work on real problems.

Even as the Council on Undergraduate Research has expanded membership among faculty in non-science disciplines (Osborn et al. 2014), studies measuring the effects on scientific literacy of mentored student research in non-STEM fields has remained scarce despite international concerns about the low levels of scientific literacy among students (Olson and Riordan 2012).

Yet of concern in scale design and development is content validity in adequately measuring the domain of interest, in this case two specific outcomes of research mentoring. Items must be combined to create a scale. To accomplish this, scales are purified through factor analysis or construct validity to meet design, administration, and interpretation standards for demonstrating reliable and valid impact measures (Nunnally 1978).

To demonstrate reliability, scales must demonstrate internal consistency or homogeneity of items measured (Hinkin 1995). At values .70 or higher, scales are considered reliable, with values $\geq$.80 preferred (Hair, Anderson, Tatham, and Black 1998). To further estimate the reliability of a sample, "Cronbach alpha" is measured (Hair, Anderson, Tatham, and Black 1998), with Cronbach alpha being the analysis that assesses the correlation of survey items to determine if the same set of scale items would produce the same responses if recast and administered to different sets of respondents.

Our research team settled on two important criteria for the study. First, scales were designed to measure outcomes of mentored undergraduate research, regardless of the discipline or the length of the undergraduate research experience. Second, in order to reduce response fatigue and increase the response rate from undergraduates and recent alumni, we created the fewest possible number of scale items required to capture key elements of self-efficacy and scientific literacy. To that end, the two scales were created as part of a mixed-methods study to examine one-to-one mentoring or one-to-many mentoring.

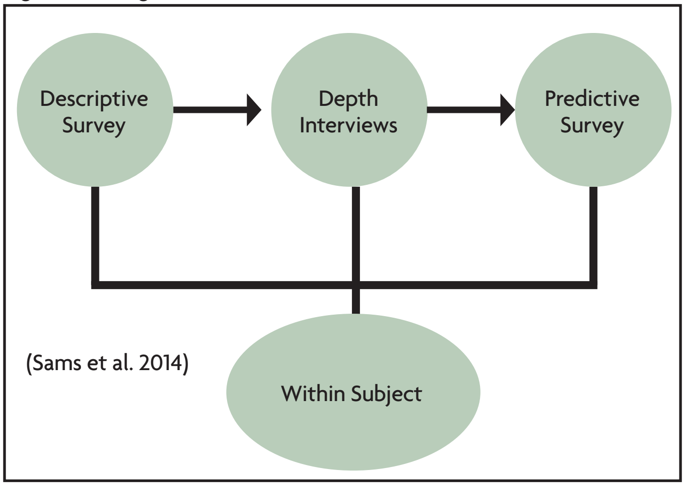
Research Design

We designed a triangulation protocol comprised of a three-component series using Seidman's (2006) methodology

(Figure 1). The first component, an online descriptive survey, was created to collect demographic data—such as major and academic standing—in order to identify quantifiable subsets within the population of mentored students and ensure a representative sample for the subsequent interviews. When respondents confirmed their interest in participating in the study via the descriptive survey, we employed the second component, a qualitative in-depth interview script. An interview script was used to collect details of participants' experiences (Anderson-Levitt 2006).

During the interview, we gathered data on respondents' decisions to engage in a mentoring relationship, the level of influence of mentoring on decisions to matriculate to graduate school or to work in the disciplinary field, and participants' confidence levels for engaging in opportunities to showcase their research. The third component of the protocol was a quantitative predictive exit survey, administered after the in-depth interviews. The exit survey was designed to measure scientific literacy and self-efficacy. The scale development of this survey is the single component of the triangulation study presented here. In order to reduce response bias, the exit survey was administered after the in-depth interviews. To triangulate, we compared individual participants' responses across each component of the three-part protocol (i.e., within subject–comparing a respondent's responses between components and not against other respondent's responses. The quantitative and qualitative outcomes of these surveys provided insight into the respondents' perceptions of the mentored research experience.

Figure 1. Triangulation Mode



Scale Development

The exit survey consisted of scale items to assess respondents' gains in scientific literacy and self-efficacy. Table 1 displays selected scientific-literacy items adapted from Lopatto (2007). The survey consisted of a six-item, Likert-type five-point scale in which 1 represented a student's belief he or she "was already proficient in this," with 5 indicating the student felt his or her literacy had increased significantly. Other options were "increased," "not sure," and "not relevant to my mentorship."

Table 1. Selected Scientific-Literacy Scale Items

Please indicate the level of increase in knowledge of the following as outcomes from your faculty/student mentoring experience(s)…
… how data can be used to solve complex problems
… scientific data-analysis methods
… various means of interpreting different types of data
… scientific data-collection methods
… value of valid and reliable data
… various means of interpreting different types of data

To measure gains in self-efficacy, we employed a 17-item, Likert-type scale with1 equaling "not at all" and 6 equaling "extensively," with an option for "not sure." To prompt the respondents, the scale items were preceded by the following wording: "For the following statements, please indicate the level to which you believe each factor increased as a direct result of your mentorship experience." Items included in the scale ranged from problem-solving and leadership to self-reliance and self-motivation. The scale was adapted from Sams and Sams (2011), which had demonstrated that affirmation and encouragement by valued others increases self-efficacy by the receiver, regardless of previous experiences. Other work (Bandura 1993; Holley and Taylor 2009; Parjares and Bengston 1995) had shown that as self-efficacy increases, obstacles transform from threats into challenges. The new self-efficacy scale differed from the Sams and Sams (2011) one because several of its items were not relevant to mentoring.

Sampling

A "snowball" sampling methodology was used to gain a representative sample. Georgia College faculty engaged in research mentorships were asked to share contact information for their current and former mentees. The response provided our circle with a potential sample of 89 contacts. A total of 83 respondents agreed to participate in the three-part study; four, however, abandoned the first descriptive survey without completing it. The remaining participants (79) completed the first survey, providing a representative sample of the mentoring relationships occurring on campus at the time of the study: business (6 mentees), communications (1), education (8), humanities (7), social sciences (28), STEM fields (19), unreported majors (10). Each respondent was asked via email to participate in an hour-long telephone interview. Despite multiple telephone calls, only 29 responded and agreed to be interviewed, and 25 completed the interview process and the predictive exit survey.

These final respondents represented business (3), communications (1), humanities (6), social sciences (7), and STEM (8). This sample consisted of college seniors and alumni who had engaged either in course-related/required mentorships or in self-selected experiences. Of these, 24 completed one mentored research experience and the remaining participant completed two. Although we desired a larger sample, our study contained enough data to examine reliability and validity of our adapted self-efficacy and scientific-literacy scales.

Findings

The data were analyzed to ensure that psychometrically sound scales were developed and purified. Reliability was examined for both scales using SPSS21® scale reliability analysis. Exploratory factor analyses (EFAs) were conducted to reduce a large number of variables and to provide evidence of construct validity by measuring variance. This was accomplished through an EFA with a Varimax Rotation analysis using SPSS21® statistical software of the adapted self-efficacy scale. To gauge the degree of each scale's reliability, Cronbach alpha analyses were used to measure internal consistency or correlation of scale items within each construct in the survey.

Curious Galapagos sea lion inspects a visiting GCSU student during study abroad at Punta Espinosa, Fernandina Island, Galapagos. (Photo credit: University Communications, Georgia College)

Table 2. Self-Efficacy Rotated Component Matrix

Outcome Components	Component	
	Strength of Perceived Self-Efficacy	Transferability of Self-Efficacy
Problem solving	.865	.099
Critical thinking	.855	.062
Leadership	.828	.170
Independence	.691	-.068
Self-reliance	.682	.332
Reading for meaning	.678	-.440
Sense making	.650	.217
Innovativeness	.623	.333
Strategic thinking	.615	.278
Ability to organize thoughts	.613	.520
Creativity	.596	.057
Self-motivation	.507	.451
Desire for lifelong learning	.394	.370
Advocacy	.155	.767
Feeling of self-worth	.140	.727
Persistence	.531	.551
Writing	.100	-.419

Extraction Method: *Principal Component Analysis*
Rotation Method: *Varimax with Kaiser Normalization*

Adapted Self-Efficacy Scale. This scale included items such as those seen in Table 2 above. From an EFA, the cumulative Eigenvalue loading 53.122 percent, revealed a multidimensional scale with two factors loading from a fully acceptable loading of .615 (strength of perceived self-efficacy) to .865 (transferability of self-efficacy). Results indicate that together, the two dimensions account for 53.122 percent of the variance (Table 2). Scale items "ability to organize thoughts" and "self-motivation" were removed due to cross-loadings (that is, shared variance). The "desire for lifelong learning" and "writing skills" factors were removed due to low loadings (<.5). A minimum of ten observations per variable was required to avoid computational difficulties. This finding alone was not sufficient. Thus, the Kaiser-Meyer-Olkin measure of sampling was conducted. Results showed that the factors extracted account for a fair amount (.605) of the variance (with a suggested minimum value of .6). Therefore, 13 out of 17 scale items met the requirements of factor analysis to remain in the scale measuring this construct. This purified 13-item self-efficacy scale was subjected to SPSS21® scale reliability analysis for which a highly reliable alpha of .890 was obtained (Hair, Anderson, Tatham, and Black 1998). Together, the 13 items created a scale demonstrating that higher scores represented higher levels of self-efficacy reported by participants.

Adapted Scientific-Literacy Scale. The adapted scientific-literacy scale included items such as solving complex problems, generating evidence, data collection and analysis, and means of interpreting different types of data. From an EFA, a cumulative Eigenvalue loading emerged of 64.392 percent, with factor loadings from a fully acceptable loading of .664 to .910 on one factor. This means that one dimension accounts for 64.392 percent of the variance. The higher coefficient scores for scientific literacy indicated relatively high average correlation. Similar to the self-efficacy analysis, a minimum of ten observations per variable was required; therefore, the Kaiser-Meyer-Olkin Measure of Sampling was conducted. Results showed that the factor extracted accounted for a fair amount (.721) of the variance. Therefore, all scale items met the requirements of factor analysis to remain in the scale measuring this construct. The purified six-item scientific literacy scale was subjected to SPSS21® scale reliability analysis (Table 3) for which a highly reliable alpha of .884 was obtained (Hair, Anderson, Tatham, and Black 1998).

Table 3. Scientific Literacy Rotated Component Matrix

	Component
	1
Valid and Reliable Data	.910
Interpreting Different Types of Data	.844
Data Collection	.831
Scientific Methods	.794
Data Generates Evidence	.749
Solve Complex Problems	.664

Extraction Method: Principal Component Analysis
One component extracted

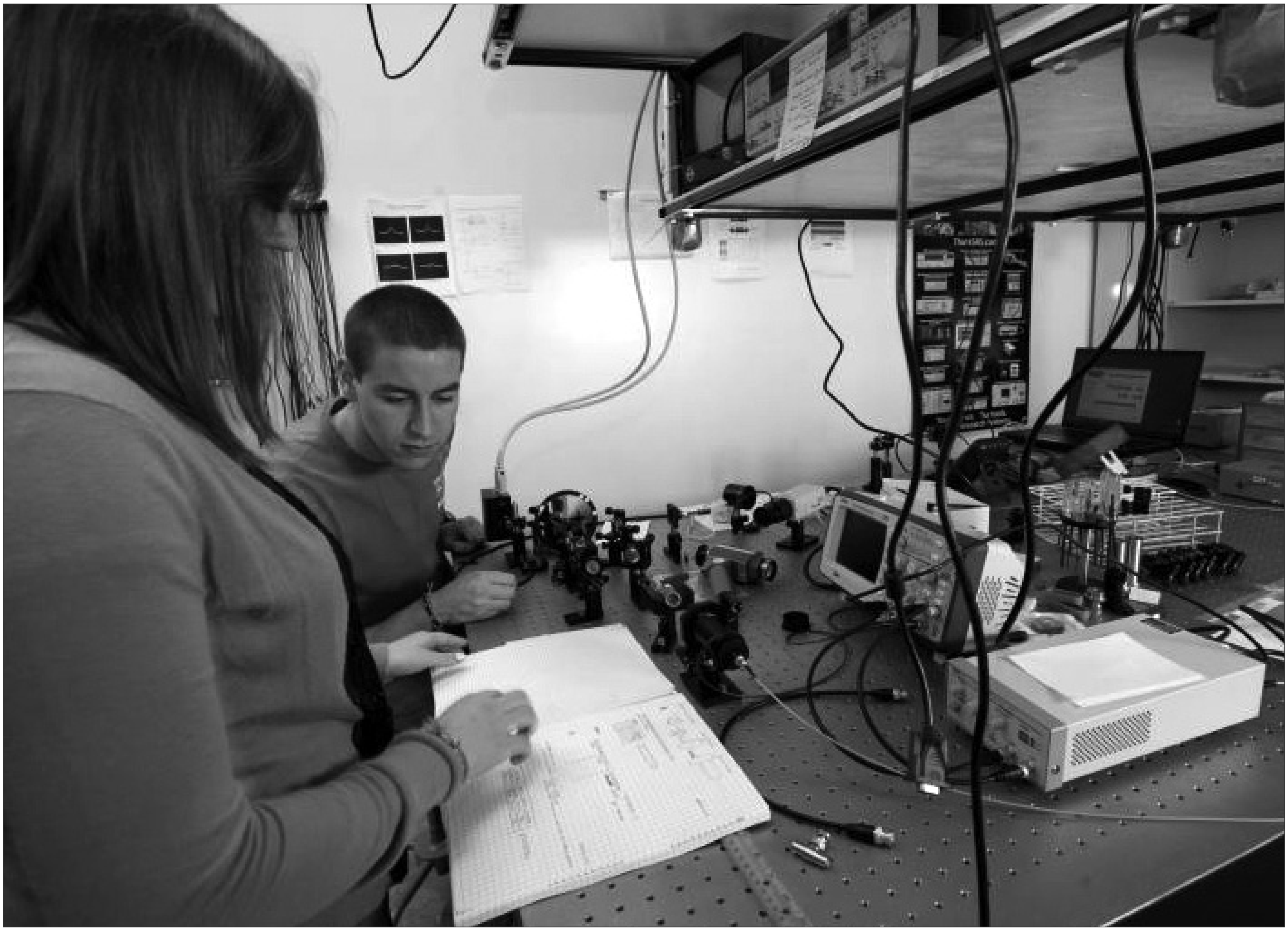
Discriminant and Convergent Scale Validity. Assessing discriminant validity is important as it provides assurance that the scale indicators used to measure one construct, for example self-efficacy, are distinctively different from indicators measuring another construct. This was accomplished by conducting a factor analysis examining its correlation coefficient analysis. Table 4 shows that there is no significant relationship between scientific literacy and the dimensions of self-efficacy (that is, strength of perceived self-efficacy or

Table 4. Discriminant and Convergent Validity Correlation Matrix

		Scientific Literacy	Strength of Perceived Self-Efficacy	Transfer-ability of Self-efficacy
Scientific Literacy	Pearson Correlation	1		
	Sig. (2-tailed)			
	N	25		
Strength of Perceived Self-Efficacy	Pearson Correlation	-.031	1	
	Sig. (2-tailed)	.880		
	N	25	25	
Transfer-ability of Self-efficacy	Pearson Correlation	.148	.469*	1
	Sig. (2-tailed)	.472	.016	
	N	25	25	25

*Correlation is significant at the 0.05 level (2-tail)

Early Childhood Education student teaching local students chair caning as a living history lesson under a "Traveling Trunks" research grant to improve social studies instruction. (Photo credit: University Communications, Georgia College)



Alicia Knebel and Brad Williams working in the Atomic Molecular Optical Physics lab on senior capstone projects. Ms. Knebel is currently in Optometry School and Mr. Williams teaches high school Physics. (Photo credit: University Communications, Georgia College)

transferability of self-efficacy) clearly indicating these scales are measuring two different constructs. Our findings pointed to two theoretically distinct constructs and revealed discriminant validity. Further, it can be noted in Table 4 below that the dimensions of self-efficacy are moderately correlated (.469) and are significant (.016). These two dimensions are theoretically related and demonstrate a moderate correlation; thus, the findings reveal convergent validity.

In sum, our findings demonstrate that the strength of association of the individual items is high, indicating that the scales can be used with a high level of confidence.

Conclusions and Limitations

This pilot study extends the literature on assessment of undergraduate-research mentoring in two interesting ways. First, the adapted scientific-literacy scale has roots in scale items that have been used historically to assess gains by students mentored in science-related undergraduate research. Outcomes of the scale analyses suggest that scientific literacy can be measured with confidence across different disciplines. Second, the study offers quantitative scales that measure respondents' perceptions of gains in self-efficacy and scientific literacy for one-to-one mentoring relationships or one-to-many mentoring relationships. Further, by administering these scales with the in-depth interviews, overall findings demonstrate the depth and breadth in gains in both constructs by respondents.

These scales are limited to self-reported perceptions. However, the use of self-report scales is theoretically sound; perceptions of gains in knowledge are psychological in nature and involve attitudes and emotions known only to the person surveyed (Spector and Jex 1998). The pilot study also is limited by the sample size (n = 29) and should be tested on a larger sample. Nevertheless, respondents served as expert judges of the reliable translation of the scale items based on their understanding of the terminology. A larger sampling would improve the measure of standard error.

We anticipate that both scales will offer a model for colleges and universities to confidently adopt as a measure of added value across disciplinary realms. We are continuing the study by exploring the outcomes of the three components of the triangulation protocol. By expanding the pool of respondents and alumni, we intend to uncover a more meaningful picture of the dynamics of the mentored student experience.

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CUR Quarterly
COUNCIL ON UNDERGRADUATE RESEARCH

Alan Jenkins, *Emeritus, Oxford Brookes University*
Mick Healey, *Emeritus, University of Gloucestershire*

From the International Desk

International Perspectives on Strategies to Support Faculty Who Teach Students Via Research and Inquiry

How can institutions and departments support faculty teaching designed to bring undergraduate students into the worlds of disciplinary research and develop their understanding of the complexity of knowledge? While recognizing the strengths of undergraduate programs for selected students that are a feature at many U.S. institutions, our approach is to embed research and inquiry in all curricula for all students. We argue that this can be achieved "through structured interventions at course team, departmental, institutional and national levels" (Healey and Jenkins 2009, 3). Such interventions need to include specific support enabling faculty to teach in ways that develop students as researchers. Departments, and, in particular, institutions, can play central roles in this agenda for they have the resources and the "political" power to intervene structurally to help faculty teach "emphasizing the construction of knowledge by students" (Hattie and Marsh 1996, 534).

Our focus here is to provide an international perspective by presenting a wide range of initiatives, from a range of national systems, that we think can be easily adapted by U.S. institutions committed to embedding undergraduate research in the mainstream curriculum. This article draws in part on arguments and material in our previous publications (Healey and Jenkins 2009; Healey, Jenkins and Lea 2014; Jenkins and Healey 2012). Table 1 sets out selected strategies that can be adapted by institutions and departments.

Table 1. Strategies for Institutions and Departments to Support Faculty Who Teach Through Student Research and Inquiry

1. Develop courses that engage students in research and inquiry from the beginning of their first year.
2. Ensure that progression in research and inquiry is built into programs.
3. Celebrate and share what is already in place.
4. Create opportunities for faculty and students to experiment.
5. Review and enhance what is in place.
6. Ensure that initial training in teaching and subsequent continuing professional development emphasize student research and inquiry.
7. Reshape academic timetables.
8. Create alternative learning spaces.

1. Develop courses that engage students in research and inquiry from the beginning of their first year.

Developing an expectation that students will be engaged in research and inquiry from the time they enter the institution is an effective way to encourage faculty to build this approach into their courses. For example, the president and provost at University College London recently stated that "our top strategic priority for the next 20 years is to close the divide between teaching and research. We want to integrate research into every stage of an undergraduate degree, moving from research-led to research-based teaching" (Arthur 2014).

For many years Canada's McMaster University has had a series of faculty-based optional courses incorporating inquiry for first-year students. Case study A outlines one in the Faculty of Social Sciences began in the late 1990s.

Case Study A: Inquiry-based course introducing first-year students to social sciences at McMaster University, Canada

The course is typically taught to classes of no more than 25 students, and the instructor subdivides the class into groups of four or five students. The essence of the course is that students learn how to learn through investigating a researchable question that they have developed. All of the classes have the same curriculum, reading material, process of assessment, and goals, which are outlined in a detailed compendium. The classes meet for 12 three-hour concurrent sessions. Class time consists of a combination of exercises and tasks aimed at building students' critical abilities, and time is allowed for students to share ideas about their individual inquiries related to the one "researchable question" that the group is pursuing. Students investigate aspects of a broad social-science theme, such as "self-identity," and address a common question, such as, "Why do images of ethnicity, race, gender, sexuality, age, class, or abilities help to create aspects of personal and community identity?" Students have to propose their own question, related to the common theme, such as, "Why do some children apparently become violent after watching violent cartoons while others seem to be unaffected?" They have to justify why the question is important in relation to existing literature. They then investigate the question through a process that involves developing and testing hypotheses using secondary sources. There is strong research evidence of the positive impact of this inquiry course on the students' subsequent performances at McMaster.
Sources: Justice et al. (2007, 2009)

2. Ensure that progression in research and inquiry is built into programs.

Many faculty members incorporate elements of research and inquiry into their courses, but it is rarer for curricular teams to have thought through strategically what progression in research and inquiry looks like throughout their programs. Case study B, from Australia, provides an illustration of how this might be done. Making greater use of prerequisites for courses may help to build in such progression in programs in the United States.

Case Study B: Coordinated interventions in zoology at University of Tasmania, Australia

The zoology school has developed a set of linked strategies or interventions, including:

Year One

- A workshop on the use of animals in research: Students are put in the position of a researcher, considering experimental design and ethics in the use of animals to complete an application form for a research project using animals.
- Throughout the year, students are encouraged to interact with a web portal with links to "Hot Topics" in zoology related to lecture material.

Year Two

- Over several weeks students are assessed on a task in which real, experimental data is given to the students, and they are guided through analysis of it and preparation of a manuscript for publication based upon it.

Year Three

- Courses include group research projects, critical reviews of current literature, writing of research-grant applications, lectures from scientists outside the institution, and training in scientific communication.
- Zoology research unit: Individual students are matched with an academic supervisor to complete a semester-long research project.
- Selected students work with staff to prepare a research paper for the institution's *Nexus Journal of Undergraduate Science, Engineering and Technology.*

Years Two and Three

- All students are invited to participate in the Student Research Volunteers program. Volunteers are matched with mentors, usually postgraduate or honors students in the zoology department, for short-term, in-house research tasks that may offer either laboratory or field experiences.

Years One, Two and Three

- "Reach into Research" seminars are held several times each semester. Speakers from industry, collaborating institutions, and PhD students present their research, and then everyone except the undergraduates in the audience and a facilitator leave the room so that *undergraduate* students' comments are the focus of the ensuing discussion.

Source: Edwards et al. (2007); http://www.utas.edu.au/zoology/

A few universities have developed institution-wide approaches, which effectively provide opportunities for all students to engage in undergraduate research and inquiry. Case study C, for example, at Roskilde University in Denmark, shows such an approach, since half of the curriculum for all students is based around project work.

Case Study C: An institutional focus on project-based learning at Roskilde University, Denmark

The Roskilde Model refers to three different aspects of project-based learning. The first one is problem-oriented interdisciplinary and participant-directed project work. At Roskilde University, half of all study activities in the assessed curriculum are organized in line with this particular pedagogical approach. The second aspect of the model is the organization of university education on the basis of four interdisciplinary bachelor's-degree programs. These programs are part of the humanities, social sciences, natural sciences, and humanistic-technological sciences, and prepare bachelor's students for admission to two-year master's programs in a broad range of disciplines. The third aspect of the model is the interdisciplinary academic and educational profile of the university (Siig and Heilesen 2015).

The projects involve students working in groups guided by staff. "Problem-orientated project work … [is] participant directed indicating that it is the group members that collectively … take the responsibility for the project. … The result is a body of knowledge owned for the most part by the students that produced it and not borrowed from the teachers who taught it" (Legge 1997, 5). In the first two years, students undertake group interdisciplinary projects; later projects tend to be within one discipline and sometimes may be undertaken individually.

Sources: Legge (1997); Siig and Heilesen (2015); http://www.ruc.dk/en/education/full-degree-graduate/interdisciplinarity-and-project-work/; http://www.ruc.dk/en/education/full-degree-graduate/interdisciplinarity-and-project-work/50-courses-50-project-work/

3. Celebrate and share what is already in place.

Start by recognizing, valuing, and celebrating the reality that many faculty will already have developed good practices for implementing inquiry-based teaching. However, such practices may not have been shared, even with other members of the faculty member's department, and almost certainly have not been shared across the institution. That was the experience of faculty and administrators working on the national enhancement project developed by the Quality Assurance Agency (QAA) Scotland (Land 2013). This project gathered interesting practices used to bring teaching and research together in disciplinary communities and institutions, and also disseminated good practices through publications and workshops that further embedded the strategies. Institutions in many national systems now have web sites dedicated to research-based learning and often include examples of practices within the institution, for example, McGill University (2013); Queen Mary University London (nd); and University of Sydney (2014).

Such web dissemination is important, but more "active" methods may have greater impact and provide more case studies to present on institutional web sites. Case study D's example of a "swap shop" at the University of Gloucestershire is one that can easily be adopted by departmental or curricular teams, perhaps at an off-site faculty seminar or conference.

Case Study D: Faculty celebrate student engagement in inquiry and research through a 'swap shop' at the University of Gloucestershire, UK

> Supported by the British government's funding of Centres of Teaching Excellence, the University of Gloucestershire from 2005 through 2010, celebrated ways in which faculty involved students in research by running a "swap shop" in each university faculty and in some departments. Faculty were invited to attend a workshop armed with an interesting practice they would like to "swap" for an interesting practice used by another faculty member. After an introduction putting the nature of the practices to be exchanged into context, three or four colleagues sat at tables and each faculty member had five minutes to outline his or her practice and five minutes to answer questions about it. Participants then went to another table and repeated the process with different colleagues. This was followed by a plenary session discussing key ideas participants had learned and how the interesting practices could be publicized further.
> Sources: Mick Healey (mhealey@glos.ac.uk); Healey and Roberts (2004)

4. Create opportunities for faculty and students to experiment.

One way to move practice forward is to create special events and structures that enable, and in some cases require, staff and students to experiment with teaching approaches that emphasize students constructing knowledge. Case study E from Oxford Polytechnic (now Oxford Brookes University) shows how this could be a limited experimental activity.

Case Study E: 'Non-traditional teaching week' at Oxford Polytechnic, UK

> From 1986 to 1989 Oxford Polytechnic designated a week during term two (of a three-term year) as "non-traditional" teaching week. Faculty were assured that they could teach the same content as they normally would, but were told that they should not lecture or give the traditional teacher-led seminar or laboratory session. They were urged to use methods in which the emphasis was on *student activity and involvement*. The week was organized with the close involvement of leaders of the student union, who led certain key events— including a competition between faculty and student volunteers to give the most boring lecture. The week inspired IT Term in 1996—a term-long period of innovation and public events aimed at stimulating the use of information technology in courses. Other institutions adapting this case study could move the emphasis on student activity and involvement toward practices that require the activities to focus explicitly on undergraduate research. Sources: Jenkins (1999); Pepper and Jenkins (1988)

Such experimental periods could become permanent features of the institutional structure. The Massachusetts Institute of Technology (MIT) has a period each year between the two formal semesters called the "independent activities period" (IAP), lasting about three weeks. During this period, students are encouraged to set their own educational agendas, pursue independent projects, meet with faculty, or pursue many other inquiry-based options not possible during the semester. Faculty are free to introduce innovative educational experiments as IAP activities (MIT 2013).

5. Review and enhance what is in place.

Most institutions and national systems have policies that require programs of study to be periodically reviewed and enhanced. Making support of student inquiry and research a feature of such reviews can ensure that curricular committees see that as a priority. Departments themselves can initiate such reviews. Institutions can also run structured events in advance of such reviews to encourage faculty leaders to enhance their practices, for example by publicizing particular features of programs within the institution seen as representing best practices and highlighting interesting practices from other institutions. Durham University has linked its course review explicitly to the development of research-led education.

Case Study F: Research-led educational program requirements at Durham University, UK

In March 2011 the senate (the governing body of Durham University) voted to require that research-led education, broadly defined, be embedded within the curriculum of all programs of study during a three-year implementation period. Specific requirements included the directive that, "Research-led education will be ... a coherent, progressive and explicit strand at all stages of a programme. The University will expect that this begins at year one of undergraduate programmes. ... All degree programmes will include a major research project, dissertation or equivalent. ... This major ... will provide a 'capstone' to their Durham education that allows students to demonstrate their ability as independent learners and researchers."
Sources: https://www.dur.ac.uk/learningandteaching.handbook/4/4/5/
https://www.dur.ac.uk/learningandteaching.handbook/3/principles/

6. Ensure that initial training in teaching and subsequent faculty professional development emphasize student research and inquiry.

Ernest Boyer's *Scholarship Reconsidered* (1990) stimulated reform among educators in the U.S. and abroad through conceptualizing "the scholarship of teaching." In effect this was part of an international movement to professionalize university teaching. In the U.S. this has in part focused on ensuring that graduate students who teach are helped to learn how to teach and to take a scholarly approach to their teaching (Walker et al. 2008). In countries such as the UK, Australia, and New Zealand in contrast, the initial focus has been on offering courses to newly appointed faculty members on the practice and the research evidence regarding university teaching. In the UK, such courses may be required. Many such courses include explicit discussion of ways to engage students in research and inquiry. While such courses are largely run by institutions, in the UK they are accredited through a national professional standards framework (UKPSF) run by the Higher Education Academy (HEA). One of the requirements of the framework is that faculty "engage in continuing professional development in subjects/disciplines and their pedagogy, incorporating research, scholarship and the evaluation of professional practice" (HEA 2012, 3). To support such courses, publications now exist aimed specifically at helping new faculty members develop ways to engage their students in research and inquiry (Jenkins and Healey 2012). As Case Study G illustrates many such courses include explicit discussion of ways of engaging students in research and inquiry.

Case Study G: The "Teaching Research" course at the University of Plymouth, UK

The University of Plymouth was one of the first in the UK to consider the links between teaching and research in its postgraduate certificate program for new faculty. A 20-credit masters-level course called Teaching Research was developed that provided the opportunity for both new and established academics to examine the links between research in their own discipline and their teaching. However, as an optional course, it was felt that this did not go far enough to ensure that all participants could explain the principles and critically appreciate the practices of teaching research. Therefore, under a recent change, the key elements of Teaching Research form part of the core course and a new optional course called Research Management is available for those who wish to pursue the issue (or related topics) in greater depth. Institutions adapting this approach can move the focus from the varied pedagogies associated with linking teaching and discipline-based research toward an explicit focus on supporting students learning in research mode.
Sources: Correspondence with Debby Cotton (D.Cotton@plymouth.ac.uk)

Sometimes the support given to faculty is specific to a particular mode of teaching. For example, at Maastricht University in the Netherlands, problem-based learning is the dominant mode of instruction, and the university trains and guides new tutors in problem-based learning by regularly offering specific courses such as "teaching in the international classroom" and "the use of e-learning" (Maastricht University, nd). Interestingly, there has been a move in the last few years to engage students in selected courses more directly in undergraduate research, although this has proven more resource-intensive (Bastiaens and Nijhuis 2012).

We think all the interventions outlined above can be selectively incorporated in many departments and institutions as permanent structures or policies. By contrast, the following two strategies are clearly designed for those occasional periods when an institution goes through significant large-scale change. Institutional and departmental leaders may consider implementing the following strategies at such times.

7. Reshape academic timetables.

Institutions world-wide are reviewing the timetables of their curricular structures to respond to various online-learning initiatives; they are moving away from the once-dominant one-hour teaching slot. Moving to a teaching block of from two to four hours may be seen as a strategic priority, if it has not already been undertaken. Such changes can also significantly support student inquiry, which generally requires more focused time than the one-hour block allows. Institutional policies often enable fieldwork disciplines such as the biosciences, geography, and geology to schedule extended periods—generally three to seven days—during which students can investigate issues in depth outside the classroom. It might be argued that this flexibility should be an institution-wide feature and that the curricula for all programs and students should allow such concentrated timeframes, if appropriate for the pedagogies of particular disciplines. Early in the career of Ernest Boyer, when he was dean at Upland College, he introduced a program that gave students a period in the mid-year term during which they would not attend class but rather take on individual projects, supported by faculty (Goldberg 1995). Case study H, describing block teaching at Canada's Quest University clearly represents a major restructuring of the traditional university timetable.

Case Study H: Block teaching and the final two-year research project at Quest University, Canada

> Quest University in British Columbia, which held its inaugural class in 2007, is Canada's only private, secular non-profit university, with an enrollment of 425 students in 2012. The curricular emphasis is on student inquiry and research. Faculty-to-student ratios are high, and much teaching is seminar-based, with a maximum class size of 20. There are no lectures or lecture halls. Quest uses a block system in which students take one month-long course at a time. In their second year, students spend an entire block, with 15 peers and a tutor, formulating a central question. Students spend their last two years focused on that question. Each student typically answers the question in the form of a thesis, but alternative research products are supported, for example, an original play or a graphic novel. Faculty are not expected or required to undertake standard discipline-based research.
> Sources: Millar (2012); Helfand (2013);
> http://www.questu.ca/about_quest/a_quest_degree.php;
> http://www.questu.ca/academics/the_block_plan.php;
> http://www.questu.ca/academics/experiential_learning.php

Quest University was able to introduce this radical structure from its beginning. This would be more difficult for larger existing institutions to implement, but administrators might find it easier to initiate block teaching in summer programs or in January inter-terms, which several U.S. universities have adopted.

The Grand Challenges program at Exeter University incorporates some aspects of the Quest curriculum, but its small scale makes it more adaptable for other institutions. Case study I shows that there are similarities between the Exeter program, the "independent activities period" at MIT, and the interterm programs offered elsewhere in the U.S.

Case Study I: Grand Challenges—a researcher-led program for first-year undergraduates at the University of Exeter, UK

> This program provides first-year students with a researcher-led, 11-day educational experience at the end of the academic year. Students produce solutions and ideas for tackling some of the key dilemmas of the 21st century, such as climate change, aging populations, ethical banking practices, child health, and international security. The program includes a cultural, social, and sporting festival on campus during the weekend of the 11-day program. Hence students work in cross-disciplinary groups to address significant cultural, social, economic, and/or environmental issues. Divided into small groups facilitated by a postgraduate student, the first-year students research key questions and collaborate to produce such items as policy papers, YouTube videos, debates, awareness campaigns, and dramatic presentations that are communicated to wider audiences.
> Source: Correspondence with Sue Burkill (Sue.Burkill@exeter.ac.uk); Burkill (2015); http://www.exeter.ac.uk/grandchallenges/

8. Create alternative learning spaces.

Although many research studies have shown that lectures have limited impact on students' understanding of the production and complexity of knowledge (Bligh 2000), many course teams and institutions nevertheless want to have such lecture halls as part of the institutional structures. Prompted by the move to various forms of online learning, however, many institutions around the world are significantly reshaping or creating new learning spaces to better support student inquiry (Narum 2004).

These efforts often involve close cooperation between curricular leaders and the heads of library and information-technology resources. One example is the redesigned "learning commons" at Hong Kong University, which was created to support large-scale reform of institutional curricula (Exploring Learning Spaces and Libraries in Asia 2012).

Case study J, at Australia's Swinburne University of Technology, an institution with a strong applied focus and links with external partners, represents general principles of classroom redesign that are relevant for many other institutions.

Case Study J: The "Project Hub" at Swinburne University of Technology, Australia

Swinburne University's Hawthorn Project Hub was designed as a learning space offering 24-hour, seven-day-a-week access to approximately 2,000 students who are undertaking capstone projects in the final year of their undergraduate degrees. This developed out of the institution's decree in 2009 that all final-year students would undertake a major capstone project, with an emphasis on interdisciplinary group work, industry/professional relevance, and links with external organizations. The hub contains meeting rooms, state-of-the-art technology, and social, open working spaces. It was built as a result of undergraduates' stating that the most important thing Swinburne could do to improve the capstone learning experience would be to provide facilities dedicated to undergraduate projects and group work. Sources: Lee (2009); http://www.future.swinburne.edu.au/student-life/why-swinburne/capstone-projects/; http://www.swinburne.edu.au/spl/learningspacesproject/trials/index.html

Conclusion

Bringing students into the disciplinary worlds of research requires a series of structured interventions from the level of the individual academic to that of national systems. In that context, institutions and departments can play central roles by supporting and changing how faculty teach in order to support student inquiry. Drawing on a range of international case studies we have demonstrated seven examples of possible strategic interventions; which of those a campus might give priority to will clearly depend on particular institutional contexts. Some campuses might focus on other interventions—such as requiring faculty to grade students in ways that encourage student inquiry or ensuring that all students undertake an inquiry-based capstone course in their final undergraduate year (Healey 2014).

Institutions and departments could also adapt the creative approach to enhancing practice and policy pioneered by the Scottish Quality Assurance Agency (QAA 2014) in which specific enhancement themes were identified for the sector to work on for one or two years. In the context of developing student inquiry and research, an institution might develop a rolling program of structured and linked interventions in the curriculum, including how faculty teach. A theme, such as using information technology to support inquiry or changing the assessment of first-year students to focus on some aspect of disciplinary research, could be a theme for, say, one to two years. This could then be followed and linked with other themes that help faculty teach in ways that encourage and enhance student inquiry and research. Such structured interventions must be appropriately targeted and linked to a coherent institutional vision.

We believe that the strategies we have set out here are particularly appropriate for those institutions seeking to "mainstream" undergraduate research for all students, but they are also relevant for faculty and administrators at institutions that offer undergraduate research programs to smaller numbers of students. All the approaches are part of the wider agenda of engaging students as partners in their own learning (Healey, Flint and Harrington 2014)—offering a broad array of initiatives that institutions can act upon.

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Barbara Howes and Anne M. Wilson, *Butler University*

Hidden Gems: An Analysis of Products of Undergraduate Research

This article describes a case study of the outputs of undergraduate research. We evaluated production of undergraduate theses and publications by undergraduate co-authors of peer-reviewed publications at Butler University from 1968 to the present in the science, technology, engineering, and mathematics (STEM) disciplines. We then undertook a more detailed evaluation of theses and publications at Butler between the years of 2003 to 2012 as we feel these are more representative of our students' current achievements in the STEM disciplines. In order to evaluate the data gathered from this intensive examination, the data on senior theses and peer-reviewed publications at Butler were compared to data from four other institutions during the same time period.

Outcomes of undergraduate research in the form of final academic products are rarely discussed even though undergraduate research is a cornerstone of undergraduate science programs throughout the country. Undergraduate research has demonstrated benefits for students who engage in this activity (Seymour, Hunter, Laursen, and Deantoni 2004; Hunter, Laursen, Seymour 2006; Beckman and Hensel 2009). The National Survey of Student Engagement has identified undergraduate research as a "high impact practice" (NSSE 2012). Yet there are few analyses of the "final products" of meaningful undergraduate research.

Such final products could be a presentation at a local, regional, or national meeting, an undergraduate thesis, or a publication in a peer-reviewed journal. The latter two products, theses and publications, are reasonably easy to track and evaluate, yet there are few reports of such data. The lack of such tracking means that benchmarks for production of theses or peer-reviewed, co-authored articles stemming from undergraduate research have not been established in the literature.

Thus, we offer our case study analyzing thesis production and undergraduate co-authored, peer-reviewed publications at one university as a starting point for benchmarking.

Butler University is a master's comprehensive university that has recently grown to more than 4,000 undergraduates. We award BA and BS degrees in science, technology, engineering and mathematics (STEM) disciplines through the College of Liberal Arts and Sciences (LAS). We are fortunate to have a large *thesis collection* and long record of scientific publication. In the following, we collect and evaluate these data to provide an example of expected outcomes of undergraduate research in the sciences at our institution. We also analyzed the synergies between production of undergraduate theses and peer-reviewed publications.

In previous research, undergraduate theses have been utilized for a series of citation analyses (Kriebel and Lapham 2008; Leiding 2005) and to examine the challenges of thesis-topic selection and data collection (I'Anson and Smith 2004). Recently, the archiving of theses has transitioned from paper formats to electronic formats to allow for ease of search and content management (Levy, Pyles, Szarejko, and Wyatt 2012). Guidelines for the production and analysis of an undergraduate thesis have been published (Reynolds, Smit, Moskovitz, and Sayle 2009). However, there has not been an analysis of a thesis collection. What is a strong thesis-production rate for an undergraduate institution? What is an appropriate benchmark? What percentage of undergraduates can be expected to participate in an elective thesis process?

Publication of undergraduate research and the kind of publications that students engage in have been the subject of examination in science education (Gilbert 2004; Jungck, Harris, Mercuri, and Tusin 2004; Siegel 2004; Osborne and Holland 2009). In addition, how authors are listed and if student authors should be listed (especially undergraduate students) also has been the subject of vigorous discussion (Weltzin, Belote, Williams, Keller, and Engel 2006; Burks and Chumschal 2009). Other discussions have focused on the engagement of undergraduates in scholarly communication, whether in presentations or publications (Davis-Kahl 2012). There have been efforts to facilitate undergraduate research activities through curricular instruction (Rasche 2004; Williams, Tata, Koether, Bevilacqua, Huck, and Hart 2002; Mickley, Kenmuir, and Remmers- Roeber 2003), even making it a critical component (Schowen 1998) or centerpiece of instruction (Hanks and Wright 2002). To our knowledge, however, there has not been discourse on benchmarks for undergraduate co-authors in research-active undergraduate programs.

Successful publication in the peer-reviewed literature is a significant component of the reward structure for faculty. It is our view that at primarily undergraduate institutions, peer-reviewed publication with undergraduate co-authors is frequently viewed equally highly or perhaps valued even more highly than publications authored solely by faculty members. What is an appropriate benchmark for undergraduate co-authorship? What is an appropriate ratio of student participants in undergraduate research to their publication rate? While we do not claim to provide definitive answers to these questions, this case study provides a starting point for conversation.

Thesis Requirements at Butler University

Since the founding of the honors program in 1924 at Butler, an undergraduate thesis has been required for completion of the program. Departmental honors upon graduation, a recognition that is separate from completion of the honors program, also have been awarded since 1968 and continue to the present day. An eligible student may choose to complete the requirements for either the honors program, for departmental honors, or for both. A senior thesis is also required for the highest departmental honors. Butler has a one student/one thesis policy, so students wishing to produce an undergraduate thesis that will also serve for departmental honors must ensure that the thesis is acceptable to the faculty members in the appropriate discipline.

We currently house 1,277 undergraduate theses in the library system at Butler. Of the 1,277 theses, 392 (30.7 percent) are classified as science theses. These include theses from the STEM disciplines, as well as contributions from our College of Pharmacy and Health Sciences and a few from our psychology program. We accept hard copies and recently began to accept theses in electronic format, as is current practice at other institutions (Webster 1999; Nykanen 2011).

Since 1968, students have been required to submit a copy of their thesis to the library. A retrospective analysis of all of the undergraduate science theses from 1968 to 2013 was undertaken. Since 1968, 1,169 undergraduate theses were produced at Butler. Of these, 359 (30.7 percent) are classified as science theses, and 292 (25 percent) are in the STEM disciplines of biology (including botany, zoology, and environmental science), chemistry, computer science, mathematics, and physics.

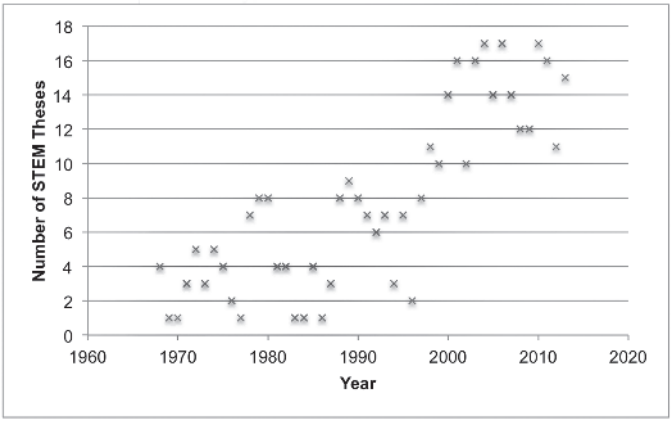
We also performed an analysis of the publication record that included Butler student co-authors in the STEM disciplines (biology, chemistry, mathematics, engineering, computer science, and physics) from 1968 to present. Many, but not all, of the student co-authors had written undergraduate theses. Below we report on our examination of the connections between these two activities, the faculty members involved, characteristics of the students, and what this suggests about undergraduate research in the sciences.

The Butler Case Study

Data Collection. For the purposes of this study, STEM disciplines were defined as biology (and sub-disciplines of biology), biochemistry, chemistry, computer science, engineering, mathematics, physics, and interdisciplinary areas that intersected any of the other disciplines. For comparative analysis with other campuses, we used online library catalogues to search for data on undergraduate senior theses and/or projects at other campuses. Relatively few academic institutions list undergraduate theses and/or projects in their library records. This significantly limited our institutional sample choice to Butler, Brandeis University, the College of William and Mary, Lawrence University, and Wittenberg University. These institutions represent a diverse sample of academic institutions, even though the sample is small.

The collection of peer-reviewed publications with undergraduate co-authors proved significantly more challenging. For each of the institutions above, a list of publications in the targeted time period was generated through the Web of Science database, searched by the "address" field. This list was compared to departmental web sites, institutional lists of undergraduate authors, the lists of undergraduate thesis authors, and individual faculty members' CVs (curricula vitae) to determine if co-authors were undergraduates. If a positive determination could not be made, it was assumed that the co-author was an undergraduate.

Figure 1. Number of Undergraduate STEM Theses Produced by Year, at Butler University, 1968-2013

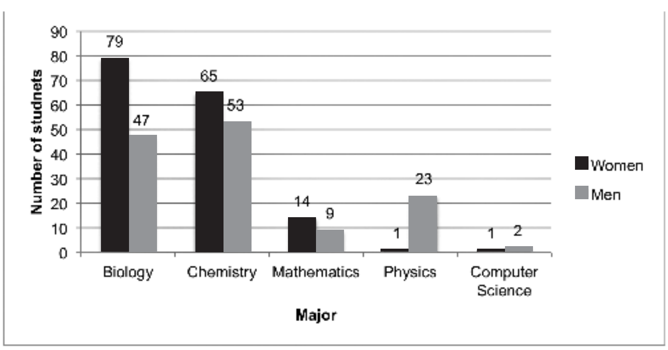


Data Analysis of Butler's Thesis Collection. An analysis of the 292 undergraduate STEM theses housed in the science library has revealed some very interesting findings. Over the 45 years covered by the study, the production of theses has shown a steady increase (see Figure 1). Between 1998 and 2013, an average of 11 theses were produced annually, compared to

3.9 theses per year from 1968 to 1997. This corresponds to an uptick in the expectations for research productivity at Butler and an increase in the undergraduate enrollment in the sciences.

Biology (including botany and zoology) and/or chemistry students produced 83 percent of the 292 theses. Women produced 158 (54 percent) of them (see Figure 2). Women produced more undergraduate theses in biology, chemistry, and mathematics than men over the 45-year period. For physics and computer science, men produced the majority of undergraduate theses. During the first ten years of this study (1968-1977), 30 theses were written with 14 (47 percent) produced by women. During the last ten years of this study (2004-2013), 145 theses were written, with 98 (68 percent) produced by women. Over the time period of this case study, we saw increases in the percentage of women undergraduates who wrote theses in the STEM disciplines; although women wrote few in physics and computer science, fields in which they were less represented, they did write a few.

Figure 2. Female and Male Thesis Writers, by Discipline, at Butler University, 1968-2013



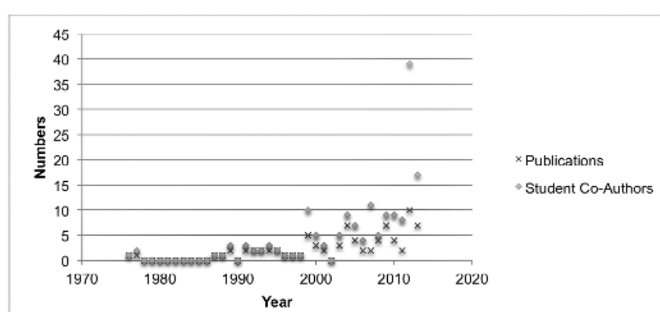
We found that 83 faculty members served as thesis advisors to undergraduates between 1968 and 2013. Of the 83, 34 are current faculty members. Thirty-five of the thesis advisors were expected to be "research active" as part of their position description at the time they served as a thesis advisor. Of the 83 thesis advisors, 24 have served as the thesis advisor for five or more undergraduate theses, and seven have served as the advisor to ten or more theses. All seven of these supportive individuals are in the biology or chemistry departments. There are currently 38 research-active faculty members in the STEM disciplines at Butler, and all of them are expected to serve as undergraduate thesis advisors. Of the 38, 30 have already served as thesis advisors, with an average of 5.6 theses per faculty member.

We believe this is a strong record of thesis production, especially in chemistry and biology, and indicates a long-term commitment by the university to undergraduate research and to the expectation of a concrete outcome (a thesis) from this activity. The College of Liberal Arts and Sciences offers an annual award to outstanding faculty members, and we believe that it is not a coincidence that all of the awardees from the STEM disciplines have served as an undergraduate thesis advisor. Given our recent data, it is reasonable to expect 10 to 14 undergraduate theses per year will be produced by undergraduates in the sciences, with at least seven of those theses produced in the STEM disciplines. We would also expect that research-active STEM faculty members would serve as a thesis advisor at least once every five years.

Publications by Undergraduate Co-Authors in STEM Disciplines

Since 1968, 81 publications with Butler undergraduates as co-authors have appeared in the peer-reviewed scientific literature. Publications by faculty members that do not list undergraduate co-authors, even if undergraduates performed a portion of the work, are not included in this analysis. Work that was performed while the Butler student was an undergraduate, either at Butler or off-campus, was included. Through the late 1980's, some of the STEM disciplines at Butler offered masters programs. Published work by master's students, even if they were also Butler undergraduates, was not considered.

Figure 3. Number of Peer-Reviewed Publications with Undergraduate Co-Authors by Year, at Butler University, 1968-2013

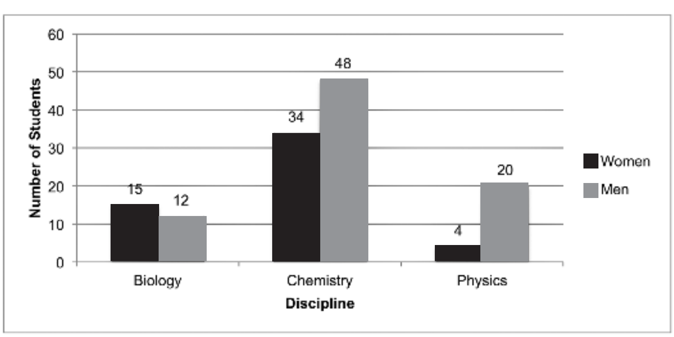


We could find no record of faculty publications with undergraduate coauthors between 1968 and 1975 (see Figure 3). Based on the available data, aside from two publications in 1976 and 1977, routine publication with undergraduate coauthors did not take place at Butler until 1987. Since 1987, an average of 2.8 publications per year with approximately six undergraduate co-authors became the norm. Faculty publications with student co-authors experienced a strong increase in the late 1990's, just as undergraduates' production of theses rose. Starting in 1999, approximately four publications per year with nine student co-authors became the average.

Since 1976, 133 individual undergraduate co-authors have appeared on the 81 peer-reviewed publications located. Of this group, 50 students also wrote undergraduate theses (36 percent). In addition, 20 of these student co-authors have appeared on two or more publications. Of these students, nine (41 percent) wrote undergraduate theses.

In this data set, 30 STEM faculty members are co-authors of the peer-reviewed publications with undergraduates. Eighteen of these faculty members appear on two or more publications with students, and all of these faculty members are from the College of Liberal Arts and Sciences. Of the 18 faculty, 4 are from biology, 11 from chemistry, and 3 from physics. Seven faculty members appear on more than five publications—two from biology, three from chemistry, and two from physics. Once again, all but two of the annual LAS award winners co-authored *at least one* publication with an undergraduate. This suggests that the college has a history of valuing, rewarding, and recognizing faculty who engage students in research. A large percentage, 83 percent of these faculty members, also have served as advisors on undergraduate theses.

Figure 4. Undergraduate Co-Authors by Gender and Discipline, 1976-2013



Of the 133 undergraduate co-authors, 53 (40 percent) are women (Figure 4). In addition, 36 of the 81 publications cited (44 percent) have a female undergraduate as co-author. In this regard, it is worth noting that 61 percent of the thesis writers are female. In addition, only four of the STEM faculty co-authors are female (13 percent), although 13 of the 81 publications (16 percent) have at least one female faculty member as a co-author. Taking into account both female students and faculty members, 53 percent (44/81) of the publications with an undergraduate co-author have a female co-author.

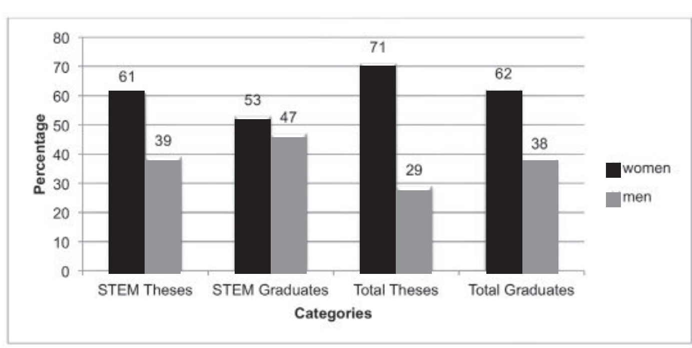
In 2007, 39 percent of undergraduate STEM degrees were awarded to women nationally (Hill, Corbett, and St. Rose 2010). Butler awarded 52 percent of the bachelor's degrees conferred in STEM fields that same year to women. While there is room for improvement, female faculty and students in STEM disciplines at Butler are doing remarkably well in terms of scholarly production. However, there is more to be done. While the majority of STEM undergraduates at Butler are female, the majority of undergraduate co-authors of scholarship in most STEM disciplines are male (Figure 4).

2003-2012 Data on Undergraduate Theses, Co-authored Publications

In order to provide a more accurate assessment of our current research productivity and expectations, we undertook a detailed examination of STEM undergraduate theses and co-authorship of publications between 2003 and 2012. This data was then compared to similar data from Brandeis University, the College of William & Mary, Lawrence University and Wittenberg University.

In the fall of 2013, Butler enrolled nearly 4,300 full-time undergraduates, with 1,282 in the College of Liberal Arts and Sciences (LAS). Students are encouraged to perform undergraduate research during the school year and/or during the summer months. Students who perform research often produce an undergraduate thesis.

Figure 5. Percentages of Undergraduate Theses and Graduates, by Gender, at Butler University, 2003-2012



During the 2003-2012 period, 113 undergraduate theses were produced in the STEM disciplines. During the same time period, a total of 495 undergraduate theses were produced at Butler. This means that 23 percent of the undergraduate theses were in the STEM disciplines. Almost 13 percent of STEM graduates (113/885) expended the effort to write an undergraduate thesis. Between 2003 and 2012, the 38,187 graduates from the rest of the university (the rest of LAS plus the other five other professional colleges at Butler) produced 382 undergraduate theses, meaning about one percent of all non-STEM graduates wrote theses.

Between 2003-2012, 53 percent of our STEM graduates were female (473/885). In this same time period, women wrote 69 of the 113 STEM theses (61 percent of the total). So during this period gender was not an obstacle to thesis production at Butler. For academic programs in which writing an undergraduate thesis is entirely elective, we believe this to be a high rate of production.

We also examined the rate of STEM students appearing as co-authors on peer-reviewed publications between 2003 and 2012 (Figure 6). During this time period, 45 co-authored publications appeared in the peer-reviewed literature, with 83 separate individuals as co-authors. Recognizing that publications lag behind graduation rates, this represents publications by about eight percent of the STEM graduates during the same time period. In addition, 12 of these students appeared on two or more publications. Women were co-authors of 21 of the 45 publications (47 percent). Undergraduate-thesis writers made up 35 percent of this cohort (29/82).

Of the 82 co-authors, 37 are female. This percentage, 45 percent, is an improvement upon the overall publication record of 42 percent since 1968, but still of concern given the thesis-production rate by women in STEM of 61 percent in the 2003-2012 time period. However, it is clear from Figure 6 that physics publications may be skewing the data. Excluding physics, women make up the majority of the undergraduate co-authors. In addition, the majority of publications with undergraduate co-authors from 2013 and early 2014 have at least one female co-author.

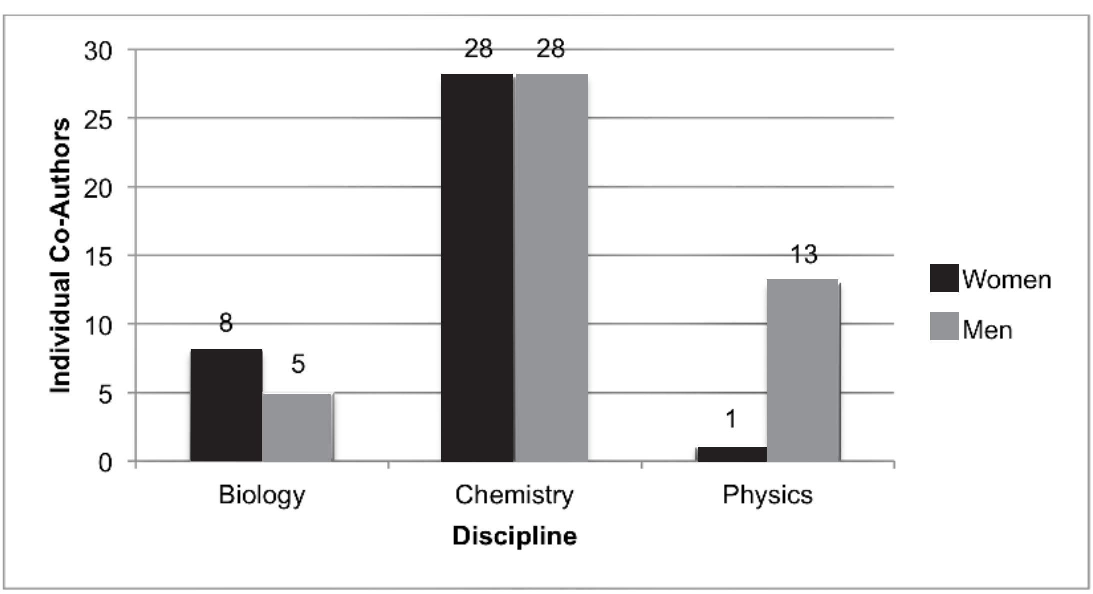
It is critical for us to know if the thesis production and publication rate of undergraduate STEM students at Butler University is appropriate. Are these numbers reasonable? Are they impressive? Are our students reaching their highest potential with their undergraduate research? Without comparisons to other institutions, it is not possible to answer those questions.

Comparative Data

Comparative data from other institutions are difficult to locate, as noted above. Several institutions house undergraduate theses in their library systems, but those programs *require* a senior project/thesis (as at Colby College) or provide support for nearly every student to perform research (MIT). Other institutions list undergraduate theses, but it is not clear if the library has a complete collection (Tufts, Carroll College). Still other institutions have publications by undergraduate co-authors listed by departments or programs, like the University of Virginia's chemistry department. But few campuses have searchable online databases of undergraduate senior theses or have shown an inclination to list undergraduate publications.

We found, however, that Brandeis University, a private research university with high research activ-

Figure 6. Publication Record of Butler Undergraduates, by Discipline, 2003-2012



ity, had both a searchable database for undergraduate theses and a list of undergraduate publications maintained by its College of Science. The College of William & Mary allowed for library searching of undergraduate theses, and most of its STEM departments listed undergraduate publications. These larger lists could be checked against the Web of Science listings of publications. Lawrence University lists honors projects in the library's files, and Wittenberg University listed honors theses in its library catalogue. As the numbers were smaller, utilizing the Web of Science data, each listing could be evaluated for undergraduate co-authorship.

Brandeis University offers PhDs in biology, chemistry, computer science, mathematics, and physics. However, it also has a long record of undergraduate involvement in research, as well as an optional undergraduate thesis for honors students. The undergraduate enrollment at Brandeis is 3,559, all in the College of Liberal Arts and Sciences.

The College of William & Mary is a self-described "research-intensive" undergraduate institution, although it offers masters of science in biology and chemistry and PhDs in computer science, mathematics, and physics, as well as a joint PhD program in applied science. William & Mary also has a long record of undergraduates' involvement in research and offers an optional undergraduate thesis. The undergraduate enrollment in its College of Liberal Arts and Sciences is 6,271, and the graduate enrollment is 2,105, making William & Mary a large master's-level university.

Lawrence University is an undergraduate arts and sciences institution with a College of Arts and Sciences and a Conservatory of Music. It enrolls 1,500 undergraduates and encourages undergraduate research, especially during the winter term. Students have the option of producing undergraduate honors projects, which are searchable through the library catalogue.

Table 1. Thesis, Publication Comparisons among Five Institutions, 2003-2012

Institution	Number of Arts & Sciences Undergraduates*	STEM Theses	Individual STEM Co-Authors	Overall Number of Publications
William & Mary	6,271	347	341	230
Brandeis	3,559	176	159	158
Wittenberg	1,784	20	45	34
Lawrence	1,500	73	15	15
Butler	1,282	113	82	45

*2013 data as reported on institutional websites

Wittenberg University is a self-described premier liberal arts college. It enrolls approximately 1,800 full-time undergraduates. Both BA and BS degrees are offered in the STEM disciplines. Students are encouraged to undertake independent study and summer research, and their projects often become honors theses.

Table 2. Theses and Publications by Gender Among Five Institutions, 2003-2013

Institution	Overall Female to Male Enrolment Ratio*	Numbers of STEM Theses by Females, Males	Numbers of Individual Female, Male STEM Co-Authors	Overall Number of Publications by Females, Males
William & Mary	55:45	151 F, 196 M (44:56)	178 F, 163 M (52:48)	129 F, 101 M (56:44)
Brandeis	57:43	103 F, 73 M (59:41)	84 F, 75 M (53:47)	88 F, 70 M (56:44)
Wittenberg	55:45	14 F, 6 M (70:30)	25 F, 20 M (56:44)	20 F, 14 M (59:41)
Lawrence	54:46	33 F, 40 M (45:55)	7 F, 8 M (47:53)	6 F, 9 M (40:60)
Butler	61:39	69 F, 44 M (61:39)	37 F, 45 M (45:55)	21 F, 23 M (47:53)

*2013 data as reported on institutional websites.

We felt that this diversity of institutions should give a broad sense of thesis production and publication by undergraduates in STEM disciplines. The general institutional data from the five institutions in our study is shown in Table 1.

From the data shown in Table 2, at Brandeis, Butler, and Wittenberg, more female undergraduates produced theses than did male undergraduates. At Brandeis, William & Mary, and Wittenberg, a larger number of undergraduate women were co-authors on publications as compared to men. These three institutions, Brandeis, William & Mary, and Wittenberg, also cite the majority of their faculty publications with undergraduates as having *at least one* female undergraduate co-author.

To control for size of programs, the data were normalized to the number of undergraduate arts and sciences students in 2013 at each of the institutions (Table 3). This does not fully account for variations in percentages of STEM students at each of the different institutions. It also penalizes institutions that have grown during the relevant time period, including Butler. However, this normalization does provide interesting findings.

Table 3. Institutional Comparison Data Normalized to the Number of Undergraduate Arts and Sciences Students at Each Institution, 2003-2012

Institution	STEM Thesis[a]	Individual Co-Authors[b]	Number of Publications[c]
William & Mary	5.5	5.4	3.7
Brandeis	4.9	4.5	4.4
Wittenberg	1.1	2.5	1.9
Lawrence	4.9	1.0	1.0
Butler	8.8	6.4	3.4

a. Number of STEM theses between 2003-2012, divided by the number of undergraduate arts & sciences students at the institution in 2013 X 100.

b. Number of individual undergraduate co-authors between 2003-2012, divided by the number of undergraduate arts and sciences students at the institution in 2013 X 100.

c. Number of co-authored publications between 2003-2012, divided by number of undergraduate arts and sciences students at the institution in 2013.

Accounting for institutional size, STEM students at William & Mary, Brandeis, and Butler are producing undergraduate theses and including students as co-authors on publications at a high rate. William & Mary's high rate was expected given its research emphasis. Brandeis, which cited the largest overall number of publications, also excelled at production of undergraduate theses. This could be expected for a PhD institution with high research expectations. It is refreshing to see undergraduate participation at Brandeis at such a high rate, which speaks to its commitment to undergraduates in the STEM disciplines. Lawrence University produced senior projects at a high rate, comparable to the thesis production at William & Mary, Brandeis, and Butler. Wittenberg had a slightly higher rate of undergraduate co-authorship than Lawrence. However, the relatively lower publication rate for Wittenberg may be a more appropriate benchmark for liberal arts institutions.

Overall, comprehensive universities, research-intensive undergraduate institutions, and PhD-granting institutions with a strong commitment to undergraduates in the STEM disciplines can be reasonably compared if enrollment size is taken into account. The production of undergraduate theses and publications with undergraduate co-authors is comparable at these institutions. Liberal arts colleges, while having smaller datasets, have similar production rates in our sample.

Conclusions

This examination of undergraduate-thesis production and undergraduate coauthors of peer-reviewed publications at Butler from 1968 to the present has outlined the final products of undergraduate research. In addition, the detailed study of data for the period between 2003 and 2012 and the comparison to other institutions has provided a first pass at benchmarks for undergraduate research. There is a strong synergy between thesis production and publications by student co-authors at all the institutions. These tangible outputs of undergraduate research have provided a robust assessment of the undergraduate research efforts in the STEM disciplines at Butler University compared to other institutions. Areas for further exploration include the production of theses and publications in other academic areas, completion of post-graduate degrees by thesis writers and student co-authors, and analysis of the publication record of undergraduate co-authors after they leave their undergraduate institution.

We hope that our examination of thesis production and publications with undergraduates as co-authors will allow other institutions to undertake their own assessment of research outcomes. As many institutions are now carefully tracking senior theses and projects, as well as undergraduate publications, data from other institutions should be available to help create further benchmarks.

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CURQ Vignettes

Sustaining a Culture of Undergraduate Research Through Robust Faculty Evaluation Processes

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Undergraduate research (UR) is the cornerstone of the chemistry program at Georgia College, Georgia's public liberal arts university. The chemistry major, anchored by a well-rounded curriculum in chemistry and the liberal arts, is supported by a three-credit-hour requirement for supervised research (CHEM 4999) and a defense of a research project in the senior year, in addition to scholarships that support undergraduate research as early as the first year. Students present their research annually at local, regional, and national disciplinary conferences and are frequent recipients of prestigious research awards. In a recent revision of our student-learning goals, the chemistry faculty elevated UR as a critical component of student success. Assessments of students indicate that those engaged in UR are better able to communicate chemical concepts and demonstrate higher-order, problem-solving skills. Students also report great satisfaction with the research experience, as well as strong gains in the application of chemical knowledge and attainment of professional dispositions.

A first-year chemistry major, Macy Polk (right), practices laboratory techniques under the guidance of her faculty research mentor, Chavonda Mills (left).

Supervised UR and related activities (research exhibitions, award ceremonies, travel planning, grant writing, assessment, etc.) are conducted by faculty without personnel support or compensation. This challenge is compounded by the fact that faculty do not receive teaching credit for students registered in CHEM 4999. In lieu of a focus on scarce resources, a faculty reward structure valuing UR evolved as a creative solution for sustaining the robust UR program. The annual faculty performance evaluation includes peer review, using criteria that place high value on UR activities. The evaluation criteria were developed inclusively by all faculty and were formalized in the form of rubrics for teaching, scholarship, and service. In a process that is both summative and formative, faculty are required to provide evidence of active and engaging UR in two of the three rubrics—teaching and scholarship. Subcommittees of chemistry-faculty peers provide review and feedback, and the process includes an option to appeal. The annual evaluations form the basis for merit-pay decisions and review for promotion and tenure. Most importantly, the evaluation criteria map seamlessly to our chemistry program's goals, creating a cyclical systemic model for sustaining the UR culture.

In 2014, the authors published a chapter in *Addressing the Millennial Student in Undergraduate Chemistry* (DOI:10.1021/bk-2014-1180) exploring the impact of undergraduate research on student and faculty culture.

Using YouTube to Assess Undergraduate Research in the Communication Capstone Course

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YouTube and the creation/presentation of research posters are used for assessment of undergraduate research in the capstone course in communication at California State University Channel Islands. For the course, students are given two options: completion of a 90-hour service-learning project or the completion of a semester-long research project. Approximately 10 to 20 percent of students choose the latter option, which involves choosing a communication topic and conducting research for a paper of 23 to 25 pages. In the second option, students are mentored over the course of the semester as they decide on a research question, theoretical construct, and methodology for analysis. Then they execute the research project, write up their results, and create a research poster.

In addition to displaying their poster to a diverse audience of family, faculty, and community members at an formal, end-of-the-semester consortium, students are also required to prepare a five-minute presentation for upload to YouTube. In the presentation, students are asked to detail the content of their research poster in a professional manner. Additionally, they are asked to describe how their research project and subsequent poster met the learning outcomes set for the communication program, including creating oral and written messages, demonstrating an understanding of communication theory, and engaging in a variety of research methods. Program faculty developed a rubric for assessing the reflective presentation that covered issues of delivery (structure, voice) and content (meaningful reflection on outcomes).

Preliminary results suggest that the use of YouTube has increased both the quality of the posters' design and the students' ability to coherently summarize and present their academic work to audiences. Further, the quality of students' reflections on the learning outcomes of the communication program has increased, compared to previous semesters when such presentations were not required. Therefore, the faculty has recommended that programs requiring undergraduate research include a requirement for upload of a formal poster presentation to YouTube or to a similar service.

Using Student Learning Agreements in Assessing an Undergraduate Research Program

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Concordia College students complete a learning agreement prior to beginning their paid undergraduate research (UR). The learning agreement includes expected weekly hours, project duration, and source and amount of funding, along with examples of broad learning outcomes that might be met during the research experience (e.g., demonstrate proficiency in the use of tools/instruments in the area of study; analyze and interpret literature and/or results). These examples guide mentors in developing specific learning outcomes and in articulating how outcomes will be evaluated during the research project. We have found that learning agreements can contribute to the assessment of UR. Students and mentors use a Likert scale to indicate how well students met the goals of the learning agreement, and they are given an opportunity to provide an open-ended explanation about the rating given. Open-ended responses have been useful in understanding the experience of students and in interpreting the quantitative data.

For example, students have demonstrated a sophisticated understanding of the flexible nature of research and have reflected on the importance of mentors' availability in achieving their learning goals. Faculty have commented that the students' prior research experience impacts how much students report gaining from the experience. Focus groups reveal that some faculty find the agreements are a useful tool in setting initial expectations for students and having students reflect on what they will achieve in the research experience. However, others felt that completing the learning agreements did not add to the process of goal setting and that since agreements are completed at the start of the experience, it is difficult to tailor expected outcomes to individual students. Given this feedback, changes could be made to improve the utility of the learning agreements. Nonetheless, using learning agreements for summative assessment, combined with their use in formative assessment of student progress, can be useful in improving the research experience.

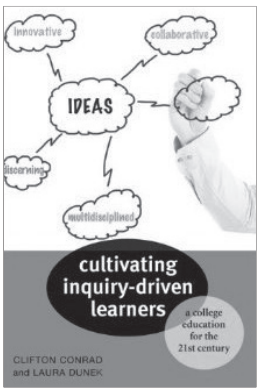
Undergraduate researcher, Gaya Shivega working in the lab at Concordia College. (Photo credit: Paige Borst)

CUR Book Review

Cultivating Inquiry-Driven Learners: A College Education for the 21st Century

By Clifton Conrad and Laura Dunek

Reviewed by Megan E. Cannella, Joliet Junior College, megan.cannella@gmail.com



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ISBN 10: 1-42140599-7

With the growing popularity of MOOCs (massive open online courses) and other online classes and universities the cultural value of education in America for students and potential employers, is increasingly being determined by educational access and consumption. However, as Clifton Conrad and Laura Dunek explore in their call-to-action text, *Cultivating Inquiry-Driven Learners*, undergraduate education cannot exist based on a knowledge-absorption model alone. It is not enough to merely teach students the information and theories currently available; students must be taught to engage and think critically, not because that is what is needed to pass a course, but rather because that is what is needed to cultivate their humanity. That in turn will allow them to succeed most effectively in the 21st century workplace. The emphasis on "knowledge acquisition fails to recognize that in the uncertain world in which we live, individuals must first and foremost be prepared to develop ideas that will prepare them to meet the rapid and constant change that awaits them over the course of their lives" (ix). In keeping with their call for inquiry-driven learners, throughout the four sections of their book, Conrad and Dunek skillfully set the ground work for the cultivation of inquiry-driven educators.

Part One is dedicated to discussing and exploring the current discourse regarding the very purpose of undergraduate education. By exploring what currently exists and the needs for reform, Conrad and Dunek challenge the purpose of the current purposes of American undergraduate education, which is increasingly, and not entirely incorrectly, criticized as providing little more than the knowledge formerly represented by a high school diploma, due to the perfunctory way in which the American undergraduate education is being pursued and consumed (30). This first section is focused on highlighting the perspective that situates undergraduate education as merely the next step in a chain of calculated, socially acceptable decisions. Conrad and Dunek write, "From our perspective, these dualisms–intellectual mastery versus personal development, breadth of knowledge versus depth of knowledge, knowledge versus skills, canonical knowledge versus character development, affective versus cognitive, professional/vocational versus liberal, science versus the humanities–all militate against a robust and inclusive definition of a college education" (22). Delineating the challenges facing the academy today, the text elucidates the urgent need for change that Conrad and Dunek see as patently evident and necessary.

The socio-economic realities of the 21st century undergraduate education are presented in Part Two, titled "A Rapidly Changing World and the Need for a Response." The need for new skillsets is made clear by Conrad and Dunek as they state: "The U.S. economy is rapidly shifting away from a national economy driven by industrial production to a global economy driven by knowledge and innovation: [...] in a knowledge and innovation economy, value is generated through the commodification of human intellect [and its thoughts] … which are, in turn, modified and inserted into the global marketplace as a commodity for sale" (27). They lament the absence of a coherent educational perspective that will produce graduates prepared for the "knowledge and innovation economy" that has emerged. By focusing on the importance of developing the human potential of students, institutions of higher education give students the agency to apply what is learned in the classroom in more tangible, meaningful ways.

Motivating students to be excited and engaged in their education, beyond rote assignments, grades, and the walls of the classroom, is the dream of many educators. Developing one person's human potential is daunting, let alone developing the potential of an entire undergraduate population. Conrad and Dunek are not proposing a utopian system or classroom, and they are careful to identify the realities that are hindering this transition into what must become the twenty-first century classroom. In Parts Three and Four, the definition of an inquiry-driven learner is outlined and how to create inquiry-driven programs and institutions is discussed. The authors write: "An inquiry-driven learner has four signature capabilities: (1) core qualities of the mind, (2) critical thinking skills, (3) expertise in divergent modes of inquiry, and (4) the capacity to express and communicate ideas" (61). While identifying necessary capabilities is vital, determining how best to develop those skills is the challenge that faculties and institutions are grappling with today.

Conrad and Dunek profile several institutions that have implemented such an inquiry-driven curriculum. With examples of colleges and universities, public and private, small and large, the authors illustrate inquiry-driven education is a realistic transition for higher education. Across the institutions they investigate, they identify three clusters of practices "that can be used to cultivate inquiry-driven learners: (1) the teaching and learning that occurs in classroom discussions, online interactions, and research endeavors, (2) the structure of courses, and (3) missions, policies, and strategic planning" (104). The authors show that just as each institution they discuss has taken its own approach to implementing these pedagogical revisions, each campus community can create an inquiry-driven environment that fits their needs.

Ultimately, the authors see the goal as an inquiry-driven learning that encourages students to "engage in ongoing dialogue and actively challenge the subject matter they encounter" (107). While acknowledging students' career goals, Conrad and Dundek remind us that it is an engaged education that will help students develop the "inquiry, creativity, and innovation" that are so vitally needed today. *Cultivating Inquiry-Driven Learners* is a call to action for higher education to rise to this challenge.

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