Feature Current Insights

Recent Research in Science Teaching and Learning

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This feature is designed to point *CBE—Life Sciences Education* readers to current articles of interest in life sciences education as well as more general and noteworthy publications in education research. URLs are provided for the abstracts or full text of articles. For articles listed as “Abstract available,” full text may be accessible at the indicated URL for readers whose institutions subscribe to the corresponding journal. This themed issue focuses on recent studies about various aspects of authentic research activities experienced by undergraduate students and by primary and secondary school teachers. The authors discuss the implications of their findings with respect to the role of mentors, the participants’ perceptions about the scientific community of practice, and about the impact of mentored research on persistence and academic achievement in science.

1. Jones MT, Barlow AEL, Villarejo M (2010). Importance of undergraduate research for minority persistence and achievement in biology. *J High Educ* 81, 82–115.

[Abstract available: <http://muse.jhu.edu/journals/jhe/summary/v081/81.1.jones.html>]

The existence of well-established, federally funded education intervention programs for underrepresented minority students at the authors’ institution provided the opportunity to conduct a longitudinal study to examine the association between timing and extent of students’ participation in authentic research and their academic success and persistence as science majors (particularly in the biological sciences). The authors performed statistical analyses on transcript and admissions data collected and aggregated from 6834 freshmen who matriculated at their institution dur-

ing a 4-yr period with a declared major in biology or in a related, biology-intensive major. The authors used the analyses to address the following research questions: 1) Is participation in undergraduate research (UR) positively associated with academic performance in biological sciences and with persistence to degree completion (of any degree, and specifically in biological sciences)? 2) If so, how do these associations compare when students from various underrepresented racial/ethnic minority groups are disaggregated from white and Asian students? 3) Does any association that is found vary with timing and duration of the research experiences?

For the analyses, the authors used logistic regression to estimate dichotomous dependent variables: graduation versus no graduation; graduation in biological sciences (vs. another degree program); and graduation in biology with a grade point average (GPA) of 3.0 or above (vs. below 3.0), which is a GPA considered to be a qualifier for graduate school admission. They used two major sets of independent variables: individual characteristics of the students (gender, race/ethnicity, socioeconomic status, indices of prior academic achievement) and research participation (timing and duration), with students’ GPAs in the introductory biology course sequence as an additional variable.

The major findings were that across all individual characteristics and differences in academic success prior to college, UR experience in this institutional context is positively associated with persistence to degree completion in any degree (including the biological sciences) and to academic success in biology. These findings persisted when the authors used conservative (highly restrictive) models for testing the associations. The increase in the probability of obtaining a degree between students who had research experiences and those who did not was largest for Hispanic and African-American students, indicating to the authors that research participation may be particularly helpful in preparing minority students for graduate study and careers in science. Additionally, the analyses revealed that participation in research more than once, or during or after the third year, was strongly associated with persistence toward degree completion; in some of the statistical analysis models, participation during the first 2 yr had either as strong or stronger associations. The analyses

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did not detect interactions between racial/ethnic status and the timing and duration of the research experiences, a result that the authors attributed to the relatively small number of participants with these personal characteristics (i.e., a small cell size in the analysis).

Thus, in the context of this institution (a large, fairly selective research institution), the implicit assumption is that federally funded goals of programs aimed at providing research opportunities for underrepresented minorities ("to increase the number of underrepresented minority students who are credible candidates for post-graduate study," p. 83) appear to be met. The authors interpret their results as providing evidence that making research experiences more available to undergraduates could serve to counteract the high attrition rates from science majors and to foster interest in science careers for more diverse student populations.

2. Thiry H, Laursen SL (2011). The role of student-advisor interactions in apprenticing undergraduate researchers into a scientific community of practice. *J Sci Educ Technol* 20, 771–784.

[Abstract available: <http://rd.springer.com/article/10.1007/s10956-010-9271-2>]

The authors examined the role that interactions between students and their research advisors play in acculturating UR apprentices to the community of science and shaping their scientist identities, as viewed through the lens of situated learning theory (Lave and Wenger, 1991). They interviewed 73 students (54% of whom were biosciences or bio-engineering majors) participating in four UR programs from two research-intensive universities in geographically distinct locations, with the goal of informing the science community about how experienced researchers successfully foster the growth and development of undergraduates along the path toward becoming a scientist. Two of the sampled programs served large numbers of students from groups that are underrepresented in the sciences, resulting in a relatively diverse sample population in which 23% of the participants were African American and 12% were Hispanic; 48% were women). Fifty-six percent of the study participants had completed at least three semesters and a summer of prior UR experience, and 44% of the interviewees were classified as being research novices (two semesters or fewer of UR experience).

The participants were interviewed once for a 40- to 80-min period; the authors used a semistructured protocol that allowed for follow-up probing and further exploration of participants' comments. The interview questions focused on eliciting students' perceptions of the value of participating in UR, their interactions with various laboratory personnel (research advisors, including graduate students and postdoctoral fellows, principal investigators, and other research group members), and the role that the experience was playing in shaping their identities as scientists.

Data analysis consisted of identification of coding themes under which the student comments fell (including a taxonomic analysis that clustered these into domains and subcategories), which the authors initially carried out using a qualitative software program, then discussed and refined. They used componential analysis to cluster comments for relevant

group comparisons and also determined the frequency of student observations in each category.

An important finding from the study is that there were few identifiable significant differences between gender, race/ethnicity, and the type of UR program and institution with respect to students' perceptions of the behaviors and practices of their advisors that best fostered their development as researchers. The variable that mattered, as revealed by intergroup statistical comparisons, was the extent of the interviewees' prior UR experience. Novice students expressed needs that were different in major respects from those of the experienced students in all three of the domains articulated by the authors to categorize the practices by which advisors support undergraduate scientists-in-training. These three domains were professional socialization (transmission of norms and values, disciplinary knowledge, and skills), intellectual support (with problem solving and strategizing), and personal/emotional support (providing support by expressing interest and being friendly and accessible). In general, novices valued 1) clearly stated expectations and guidelines, 2) more extensive orientation to the concepts underlying their specific projects and the related language and tools, 3) understanding how the project fit into the "big picture," and 4) getting past the intellectual frustrations and barriers of learning to think analytically and apply their knowledge to the specifics of the project. More experienced students expressed a greater need for support in areas related to their socialization, such as how scientific researchers think and act, on both a personal and professional level (e.g., how to deal with failures and setbacks and operate with intellectual independence).

The authors discuss the importance of the mentoring interactions for undergraduates from underrepresented groups, highlighting the strong potential of mentoring for building students' confidence and interest in pursuing scientific careers. In discussing the implications of their findings with respect to informing use of successful practices, the authors also note the importance of increasing the awareness of graduate students and postdoctoral fellows (who commonly serve as UR mentors) of the educational role they also play as part of their everyday work as scientists.

3. Eagan MK, Jr., Sharkness J, Hurtado S, Mosqueda CM, Chang MJ (2011). Engaging undergraduates in science research: not just about faculty willingness. *Res High Educ* 52, 151–177.

[Full text available: www.ncbi.nlm.nih.gov/pmc/articles/PMC3284472/?tool=pubmed]

A model of organizational citizenship behavior (Organ and Ryan, 1995; McManus and Russell, 1997) and social exchange theory (Emerson, 1981) provided the conceptual framework for this study, which used analysis of data from a national faculty survey (DeAngelo *et al.*, 2009) to predict individual characteristics and institutional contexts that influence faculty members' decisions whether to sponsor authentic research experiences for undergraduates. These conceptual frameworks provided lenses for understanding why faculty may choose to include undergraduates in their research programs despite the many potential disincentives for doing so (including the way that institutional and departmental faculty reward systems are typically structured). The organizational citizenship lens would allow for the prediction that

a strong commitment to their institution and its mission, or a more positive perspective on undergraduates and the time they spend with them, for example, would motivate faculty to extend themselves beyond their official job responsibilities and obligations to sponsor undergraduate researchers. Social exchange theory would suggest such motivations as the belief that the relative benefits of playing this role in the professional development of young scholars outweigh the relatively high costs (in terms of the reward structure that influences how faculty distribute their workload time and allocate other resources).

The data source for the study was the University of California, Los Angeles, Higher Education Research Institute's 2007–2008 Faculty Survey, which was administered to a national sample of faculty across institutional types and disciplines. The study also utilized an additional sampling of science, technology, engineering, and mathematics (STEM) faculty from institutions that confer relatively large numbers of STEM undergraduate degrees. The final analytical sample population consisted of 4832 STEM faculty survey respondents representing 194 colleges and universities. The authors used hierarchical generalized linear modeling (HGLM) as the main analytical technique, with a clustered design that nested faculty within institutions. The sole dependent variable for the analysis was the dichotomous issue of engagement versus nonengagement of undergraduates in faculty research projects. The authors grouped the study's independent variables into eight blocks of faculty-level factors (predictors), as follows: 1) demographic characteristics of respondents; 2–3) aspects of faculty members' careers (e.g., tenure status, rank, discipline, etc.); 4–5) various scholarly and teaching activities that might place constraints on faculty time (e.g., teaching interdisciplinary courses, collaboration with local community in teaching and/or research activities); 6) faculty research productivity; 7) indicators of faculty members' goals for undergraduate education; and 8) faculty perceptions about the institutional climate for engaging undergraduates in their research. An additional block in the analysis consisted of institution-level measures, such as workload and mentorship activities, along with dichotomous measures that corresponded to different aspects of institutional type (e.g., private, doctoral/research university, or historically black college or university [HBCU], etc.). As part of the analysis, the investigators calculated factor scores in each of these blocks.

The HGLM analysis findings indicate that institutional context is strongly associated with faculty members' likelihood of including undergraduates in their research programs, with faculty who teach at HBCUs, liberal arts colleges, and more selective institutions having the greatest likelihood. In particular, the results suggested a large gap (17 percentage points) between HBCUs and primarily white institutions with respect to the inclusion of undergraduates in faculty research. Faculty members who teach in the life sciences were more likely to include undergraduates in their research projects; for example, 20 percentage points more likely than faculty in the physical sciences, and 35 points more likely than faculty in the health sciences. Receipt of foundation or grant support and publication of a greater number of journal articles also had a strong positive association with decision to sponsor UR. While goals related to undergraduate education generally

yielded mixed results, the factor that measured faculty members' commitment to fostering scholarly habits of mind had a significant positive association with the outcome. Although the block of predictors related to faculty members' perceptions of institutional climate also yielded mixed results, the results did suggest that faculty who expressed belief in three of the six categories (students at the institution were well-prepared academically, faculty at the institution are strongly interested in students' academic problems, and departmental colleagues valued their research) were more likely to include undergraduates in their research programs.

The authors go on to discuss the implications of their main findings, including implications for increasing faculty commitment to the institution, faculty hiring decisions, and reshaping the faculty reward structure. They conclude by highlighting the importance of creating effective incentives to develop and sustain a viable UR program.

4. Cartrette DP, Melroe-Lehrman B (2011). Describing changes in undergraduate students' preconceptions of research activities. *Res Sci Educ*, doi: 10.1007/s11165-011-9235-4.

[Abstract available: www.springerlink.com/content/awt18w8jq1522rn0]

This study contributes to existing knowledge about the affective and cognitive outcomes of students' participation in UR by exploring their preconceptions about the processes surrounding authentic science and how these beliefs might change over the course of a 10-wk research apprenticeship.

Study subjects were the 17 students selected from a 450-student applicant pool for participation in a federally funded, 10-wk summer research program with a chemistry focus at a public, research-intensive university. The sample population included roughly equal percentages of males and females of at least sophomore standing whose home institutional types varied; the students had no prior formal experiences with authentic research. Prior to the summer program, students were in electronic communication with their prospective mentors about the projects in which they would participate. At the end of a 1-d orientation program, students began interacting with their research groups, and after a short period of acclimation to their mentors' laboratories, began work on their project within the first week.

Sources of data for the study include a modified version of a survey instrument developed to elicit beliefs about the nature of science (Nature of Scientific Knowledge [NOSK] survey; Rubba *et al.*, 1981), periodic (at 2-wk intervals) structured interviews, directed journaling, and a follow-up questionnaire sent to participants several months following the summer research experience. The investigators administered the survey twice; the first administration informed interview protocols and assisted in the refinement of interview questions. The authors adjusted the interview questions to probe more deeply into students' experiences and beliefs as their participation in the program progressed. The participants submitted the journals weekly, with entries consisting of responses to questions aimed at capturing beliefs related to such topics as the process of science and knowledge construction in science. The authors independently and iteratively analyzed the data sources for identification of emergent unifying themes, and reanalyzed the data after the coding themes were determined. They

cross-referenced across the various data sources to compile themes for individual participants in order to focus on the most significant changes in students' beliefs that developed during the summer program.

To generalize broadly about the earliest preconceptions reported for the participants in this study: many thought that the authentic research would have major similarities to their laboratory courses—that it would be a well-planned and well-defined process governed by a single scientific method. Additional common preconceptions described by the authors include the notion that “everyday” research activity leads to groundbreaking results, and that it is a solitary activity guided by a quest for truth and understanding. Participants reported that the primary sources of these preconceptions were advisors, teachers, and friends who had participated in research projects, as well as textbooks and images from popular culture. Interviews conducted near the end of the summer research experience and responses to the follow-up questionnaire revealed that in many cases students considered their preconceptions to have been misconceptions and came to have what the authors considered to be slightly more mature understandings over the course of the 10-wk experience. Students came to appreciate the attention to detail and meticulousness needed in designing and conducting authentic research, particularly in the absence of the various fail-safe mechanisms of the standard laboratory course experience (laboratory manuals with step-by-step procedures, teaching assistants and professors as problem solvers), the relatively slow pace at which interpretable results emerged from the process, and the fact that successful research most often requires a team effort.

The authors conclude by discussing the implications of their results for how science laboratories are taught, suggesting that incorporation of strategies that more closely mirror authentic processes of science research might better shape students' conceptions about how science is practiced. They suggest that understanding of students' most likely preconceptions about how science progresses could play a key role in the design of effective learning experiences in the sciences, including UR programs.

5. Adedokun OA, Burgess WD (2011). Uncovering students' preconceptions of undergraduate research experiences. *J STEM Educ* 12, 12–22.

[Full text available: <http://ojs.jstem.org/index.php?journal=JSTEM&page=article&op=view&path%5B%5D=1523>]

Like the research of Cartrette and Melroe-Lehrman summarized above, this study explored the nature of the initial expectations, motivations, beliefs, and attitudes undergraduates have about research internships and how these were altered by an actual internship experience in an interdisciplinary STEM field. Although the number of study participants was slightly greater ($N = 25$), and the research internship was of longer duration (an entire semester), the data sources used in this study were more limited in nature than the Cartrette and Melroe-Lehrman study, consisting solely of students' guided journal entries made 3 wk after the start of the internship. Students were asked to reflect on their preconceptions and about whether their experience differed from these initial assumptions. The participating students, all of whom were

enrolled at the institution that sponsored the research program, had a minimum GPA of 3.0 and at least a sophomore standing.

The authors performed a content analysis of the journal entries (initially, independently of one another), sorting and coding them according to themes that emerged from the data. As in the study done by Cartrette and Melroe-Lehrman, several of the categories of preconceptions were related to beliefs about scientists, research environments, and the ease or difficulty of conducting research. That is, many of the participants initially viewed science as being a solitary endeavor, one conducted in a serious and stern environment that would require little use of communication and interpersonal relationship skills. Approximately half of the participants also thought that, like their course-embedded laboratory experiences, authentic science research projects would involve the following of set procedures, with mostly obstacle-free progress toward the expected results. As revealed in the journal entries, the actual internship experience enhanced these participants' awareness that unlike the familiar terrain of laboratory courses, authentic research has creative, challenging aspects and can lead to unexpected results. In contrast with the Cartrette and Melroe-Lehrman study, however, the content analysis revealed additional themes relating to the extent of an intern's involvement in research, and the nature of the mentor or supervisor's role. With respect to the latter, participants shared a fairly prevalent preconception that they would receive extensive supervision from their faculty mentors and valued the prospect of this one-on-one mentoring, but found that their supervision came mostly from graduate students and postdoctoral fellows. Perhaps because of the timing of the reflection and reporting on preconceptions (3 wk into the experience), the authors were able to conclude that most of the participants' preconceptions were contradicted by the actual internship experience.

The authors conclude by discussing implications from the study that could inform the faculty and staff who coordinate UR projects and programs. Largely, they highlight the value of incorporating an understanding of students' preconceptions and expectations into conversations with students or other orientation activities prior to their internships, particularly with regard to their expectations about the nature of the supervision they will receive.

The following are recent *CBE-LSE* articles on UR:

Fechheimer M, Webber K, Kleiber PB (2011). How well do undergraduate research programs promote engagement and success of students? *CBE Life Sci Educ* 10, 156–163.

Pacifici LB, Thomson N (2011). Undergraduate science research: a comparison of influences and experiences between premed and non-premed students. *CBE Life Sci Educ* 10, 199–208.

Wei CA, Woodin T (2011). Undergraduate research experiences in biology: alternatives to the apprenticeship model. *CBE Life Sci Educ* 10, 123–131.

Wiegant F, Scager K, Boonstra J (2011). An undergraduate course to bridge the gap between textbooks and scientific research. *CBE Life Sci Educ* 10, 83–94.

I invite readers to suggest current themes or articles of interest in life science education, as well as influential papers published in the more distant past or in the broader field of education research, to be featured in *Current Insights*. Please send any suggestions to Deborah Allen (deallen@udel.edu).

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