

Adapting to Change: Studying Undergraduate Research in the Current Education Environment

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Abstract

Given that science and science education are undergoing a climate change, the author suggests a re-envisioning of undergraduate research assessment. He argues that continuation of research into the processes and benefits of undergraduate research opportunities for undergraduates will need to decrease focus on student dispositions and increase attention to the external validity of programs. Common dispositional terms such as persistence and identity should give way to the study of student decision making, judgment, and communication. Student adaptability to diverse academic and personal pressures will aid in the understanding of student success.

Keywords: *undergraduate research, external validity, student outcomes, student success, adaptability*

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Science and science education are undergoing a climate change. As recently as the PCAST report (2012), it appeared that science was valued nationally, and discussions centered on the production of more science degrees through the prevention of attrition. More recently, faith in the support of the American government for science and science education has been subject to scrutiny. The PCAST theme of increasing science education may be supplanted by retrenchment to cope with reduced federal support (Mervis 2017) and enhanced federal criticism of science (and arts and humanities; Kington 2017). In this angst-driven world, the intended outcomes of education may change. For instance, now it will be increasingly important to teach “ensuring scientific integrity” (Goldman

et al. 2017), and for science at least, instructors may face a generation of students who attended secondary school during a time of decreasing public faith in science.

What to do? This essay suggests that now is the time to re-envision how we go about the assessment of undergraduate research, especially in the sciences. In early developments in undergraduate research, it was useful to survey and interview students for the purpose of uncovering the full taxonomy of the benefits of the dedicated undergraduate experience in science research (e.g., Lopatto 2003, 2004a; Seymour et al. 2004) and to examine the generalization of this taxonomy to the social sciences and humanities (Lopatto 2004b). As the study of undergraduate research experiences matured, research efforts branched both vertically, diving into specific features of student characteristics or outcomes of instructional activities (e.g., Hoskins et al. 2011), and horizontally, extending the research program to course-embedded research activities in disciplinary and interdisciplinary courses (Lopatto 2010). Along the way, there have been efforts to tie together various research methodologies to triangulate student learning outcomes (e.g., Shaffer et al. 2014) and calls for a road map of best practices. Fueling some of the research was an attitude, natural to many scientists turned science educators, that the methodology of science would yield significant information about the effects of undergraduate research program features on learning outcomes. Our attention has focused on the relation of teaching and mentoring practices, mediated by student dispositions, to learning outcomes. In considering our next steps, practitioners and program directors may value field research that casts more light on external validity—the generalization from

findings about one program to other programs. Research on student behavior should take on the challenge of understanding student decision making and adaptability.

Research on undergraduate research includes a focus on the participants (undergraduate students), the program, and the outcomes of the program. In pursuit of knowledge about students, work has proliferated on student dispositions (for example, grit, persistence, identity, ownership, and a sense of belonging). Typically a survey or scale has been developed, statistical credibility has been achieved, and the disposition is cited as important for the successful undergraduate research experience. Going forward, however, it is unlikely that practitioners will gain much more by the study of these isolated traits. The overarching philosophy of offering the undergraduate research experience is that it permits greater inclusion of diverse students. This valuing of inclusion means that student dispositional information cannot be employed in the traditional sense to select some students but not others for programs. Practitioners will work with all students (Awong-Taylor et al. 2016). Rather than focus on dispositional measures, mentors and program directors will need an omnibus instrument to alert them to program strengths and weaknesses. We could help practitioners assess programs by employing what medical researchers call a *clinimetric measure* (Feinstein 1987). A clinimetric measure is one that permits the practitioner to diagnose the condition of the client or, in this case, the program. A clinimetric measure is not necessarily constrained to one latent variable or construct. One candidate for such a measure is the Survey of Undergraduate Research Experiences (SURE; see Table 1).

The SURE includes a series of student-reported gains that cover many of the critical areas of a successful program. Although the items on this list of gains demonstrate inter-item reliability and differential validity, they do not reflect just one dimension of the experience. Practitioners who have used the SURE, which permits individual programs using small samples to benchmark their results with a larger national data set, often attend to the differences between the item means within their program. Thus, one program enhances its effectiveness in ethical training, whereas another allocates more time to scientific writing. SURE self-report data are unlike the more familiar knowledge measures common in the sciences, and so occasionally reservations about these instruments are raised. First, some educators mistrust student self-report. One useful response to the mistrust of self-report is to implement an assessment plan incorporating a multiple-operational approach that demonstrates agreement in the conclusions drawn from more than one measure (Shaffer et al. 2014). A more significant point is that “direct” measures of learning gains in disciplinary content or method do not show us the attitudes and motives of the student who may be navigating toward a science career. We need to

know how students are processing their experience. Thus, clinimetric measures that probe readiness for more research, tolerance for obstacles, and self-confidence are of value to the undergraduate research practitioner. Perhaps the hesitancy to accept student self-report of attitude and motivation is due to researchers’ continued use of convenient folk language to describe student behavior—language that suggests that students build up a kind of inertia that carries them forward in their careers. One popular term, *persistence*, can mean the dogged determination with which a student works out a small problem during research; the obsessive nature with which the student completes a course or program despite recommendations to quit; or the sequence of events that lead to graduation, postgraduate education, and a career. As has been stated elsewhere (Lopatto 2015), *persistence* is a word fraught with negative connotation. People report persistent coughs and persistent rashes, not persistent joy about doing research. *Identity* is another term often used, as in helping the student develop a scientific identity. This term is especially problematic, as it competes with powerful discourse on dimensions of identity such as a gender, race, and socioeconomic background. Although there are proffered measures of persistence (Hanauer et al. 2016) and identity (Robnett et al. 2015), it may be more useful to set aside these terms in favor of a decision-making approach. Through the lens of this approach, *persistence* is not a disposition but a set of circumstances that influence a student’s decision to continue or stop. *Identity* is a set of cognitive strategies that include “thinking like a scientist” or developing “scientific habits of mind.” As opposed to the inertia model, the decision-making model permits an understanding of how students decide to continue or not continue on a career trajectory, and it suggests a fresh line of research on student behavior—namely, investigations of adaptability.

Practitioners of undergraduate research ask for evidence-based practices to employ in their design of programs. *Evidence based* is not the same as *experiment based* (Cartwright and Hardie 2012). Many scientists are trained in the methodology of controlled experiments but have a more modest understanding for phenomena that occur in open, uncontrolled settings. Fortunately, the work of methodologist Donald Campbell on quasi-experiments (Campbell and Stanley 1966; Campbell 1969, 1982) and more recently the work of Nancy Cartwright on policy implementation (Cartwright and Hardie 2012) provide frameworks for performing and interpreting the sorts of studies that analyze the process and benefits of undergraduate research. Campbell’s work provides remedies for the problem of a lack of randomly assigned control groups, whereas Cartwright’s work helps us understand how a program that “worked there” may “work here”—that is, how it achieves external validity. In the context of undergraduate research programs, the view shared by these writers indicates that the external validity of programs, the generalizability of practices across programs and

TABLE 1. Self-Evaluation Items for Student Respondents on the SURE Survey

Item	Continuing	Leaving
Clarification of a career path	3.60	3.04
Skill in the interpretation of results	3.75	3.32
Tolerance for obstacles faced in the research process	3.95	3.52
Readiness for more demanding research	3.94	3.41
Understanding how knowledge is constructed	3.69	3.23
Understanding of the research process in your field	3.96	3.63
Ability to integrate theory and practice	3.70	3.23
Understanding how scientists work on real problems	3.91	3.58
Understanding that scientific assertions require supporting evidence	3.66	3.18
Ability to analyze data and other information	3.77	3.50
Understanding science	3.67	3.26
Learning ethical conduct in your field	3.37	3.01
Learning laboratory techniques	3.85	3.15
Ability to read and understand primary literature	3.64	3.20
Skill in how to give an effective oral presentation	3.55	2.95
Skill in science writing	3.30	2.86
Self-confidence	3.62	3.17
Understanding of how scientists think	3.64	3.10
Learn to work independently	3.83	3.46
Becoming part of a learning community	3.68	3.29
Confidence in potential to be a teacher of science	3.40	2.71

Note: Responses are scaled from 1 (no or very small gain) to 5 (very large gain). The means shown above are from a comparison of students (N = 1469) who, at the conclusion of their undergraduate research experience, continued to plan for an advanced degree in the field and students (N = 136) who, at the conclusion of the research experience, decided to leave the path to an advanced science degree. The instructions ask students to consider how much they benefited from their research experience. These sample results show how the survey may highlight relevant differences between continuing and leaving students on career path clarification, readiness for more demanding research, understanding of how scientists think, and confidence in science teaching potential.

institutions, yields valuable insights into the core features and outcomes of undergraduate research.

We can learn more about the nature of undergraduate research by studying groups of programs than by analyzing individual programs. One such collaborative is the Genomics Education Partnership (GEP), founded by

Sarah Elgin (Washington University in St. Louis). The GEP includes about 100 institutions of higher learning. Its collective success brings to mind a classic method of discovery, often attributed to the philosopher John Stuart Mill, called the *method of agreement* (Cook and Campbell 1979). If two or more instances (programs) of a phenomenon under investigation (learning genomics) have

only one circumstance in common (the features of the GEP), then the circumstance shared by all the instances is the cause of the given phenomenon. The GEP comprises diverse instances of the phenomenon of teaching genomics in the context of undergraduate research. These instances are institutions: universities, small liberal arts colleges, and community colleges with highly varied student populations. The overall success of the consortium has been attributed to its distinct, shared features that represent one model for undergraduate research in science education. These shared features include program goals, lab activities, common training of instructors, and a central support site, whereas the institutions differ in myriad ways, including size, mission, and admission selectivity (Shaffer et al. 2010).

One relatively unexplored environmental feature of individual and groups or programs is the extent to which a program, nominally dedicated to undergraduate research, is supported by other features of the learning environment. On most campuses, there are resources external to the specific course or research experience that influence student success. Many institutions have developed academic support services to facilitate student success, including teaching and learning centers, writing centers, peer education programs, and the like. Future studies of undergraduate research and its influence on student learning will need to take these moderating influences into account. What is the influence of these support services? How do they impact student decisions? Do they ameliorate problems that may interfere with student success? Support services are one source of the broader “support factors” discussed by Cartwright (Cartwright and Hardie 2012) that we need to study in order to understand how successful undergraduate research programs may generalize to new institutions and students.

Topics Deserving Increased Attention

Judgment and Communication

With current techniques and instrumentation, even novice students may make contributions to the catalog of scientific knowledge (e.g., Jordan et al. 2014). With improvements in technology, it is likely that contributions to a global encyclopedia of knowledge, the identification of objects from phage to exoplanets, will accelerate. What has not declined, however, is the student’s challenge to learn the provisional nature of knowledge and the influence of the researcher on the material being researched. From bioinformatics to statistics, there is a moment in which human judgment plays a critical role, and this role has not been replaced by automated systems. The outcome of a scientific investigation (as well as investigations in social science and humanities) does not end with a “correct” answer but rather with a conclusion that has been well thought out, well communicated, and well received. This ability to communicate, to express that outcome of

trained human judgment, is precisely what will emerge as a key component of scientific influence in the current political climate. Communication skills will need to expand out from the internal exhibitions of posters and papers that are nested inside the disciplinary community. The ability to communicate science to a broader audience should come to the increased attention of program directors and assessment experts. A moment’s reflection on public confusion over global climate change should convince us that this broader communication is important. There are some examples of learning scientific communication in the context of service learning (e.g., Harrison et al. 2013), and the topic deserves more scrutiny.

Student Adaptability

The optimal description of the undergraduate research experience is the summer in the lab or field, an experience of 8–10 weeks in which the student has no concerns except to focus on his or her research under the guidance of a mentor. This immersive experience may mislead us to think that the student is developing into a specialist, prioritizing his or her research interest above other considerations. During the academic year, however, the student must learn to balance the pressures of multiple courses and laboratories, as well as working and social life. We may wonder how a student develops an interest, for example, in a science, within an environment where the student must attend other courses and attend to other challenges. How is the promising biology major behaving in sociology class? History? Art? The students we see as promising scientists may also be promising social scientists and humanists. They may have learned to adapt, to “think like a scientist” in a science ecosystem, and to shift to “think like a historian” in a different ecosystem. This adaptability may carry on to later decision points in a student’s life, accounting for decisions to attend graduate school, to apply for a job in the STEM workforce, to continue a STEM career, and so on. Recent political events have highlighted the lack of public understanding of science, which in turn may lead the promising science student to change career trajectory. Similarly, social science, humanities, and art are facing lack of public understanding and institutional support (Fallon 2017; Wermund 2016). At the institutional level, “student success” is frequently defined as a graduation rate without regard to major or program. Decisions to change a major or program may be neglected by administrators who are satisfied with overall graduation rates, but we need to know the patterns of student decision making within the institution. It may be that the Council on Undergraduate Research is well positioned to encourage studies of student adaptability, as its members include many scholarly disciplines.

Conclusion

The most insistent motivation for studying undergraduate research and its effects is to learn how to replicate the successful features of the process. The PCAST (2012) report

invoked the need for 1 million new science degrees, and in the current political climate the need for science education seems more pressing than ever. Campbell (1986) suggested that focusing on the external validity of programs is the optimal strategy for understanding the validity of the construct itself. In principle, then, our continued attention to successful undergraduate research programs should teach us what works. But undergraduate research programs, whether stand-alone or embedded in a course, are not experiments in which initial conditions are prepared and then the experiment allowed to run its course with no further interventions, nor are they closed systems immune to exogenous variables. No responsible research mentor or course instructor would watch with disinterest as students failed to learn due to faulty experimental program conditions; and no program runs in a vacuum devoid of family or financial events affecting students. One study (Lopatto 2015) reported on undergraduates who reversed their decision to commit to a two-year research program and on alumnae who stopped pursuing science after graduation, despite experience with undergraduate research. These cases did not represent program failure. They demonstrated the influence of exogenous factors beyond the control of the program. They also represented the decision making continuously undertaken by people as they journey through life events.

Finally, there is a problem inherent to theories about research experiences and the students they affect. Theories concerning persistence, identity, ownership, efficacy, self-confidence, grit, or belonging are not exclusive to each other when being employed to make sense of student success. That is, there will always be more than one way to account for the data. Practitioners will likely remain eclectic in their approach to program design. This eclecticism may be a useful strategy in an era of changing climate for undergraduate research.

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