Integrating Undergraduate Research in STEM with Civic Engagement

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Abstract

Undergraduate research experiences (UREs) are part of an expanding toolkit of experiential learning experiences that can help students engage with the practices and processes of STEM. Civic engagement is another type of experiential learning experience that can offer students meaningful interactions in the wider community, thus leading to greater relevance and application of their work. Research studies suggest that both civic engagement and UREs are high-impact practices.

Much of the work to date on experiential learning has been discipline based. This may be due to challenges in getting faculty members from different disciplines to work together, or because of issues with infrastructure, budget policies, credit hours, incentives, and/or the reward systems in higher education. This paper aims to help readers better understand the potential for UREs that integrate civic engagement to enhance learning. To illustrate how the obstacles might be surmounted, an example of an interdisciplinary URE that is coupled with civic engagement is provided.

Introduction

Undergraduate Research Experiences (UREs)

> *Traditional introductory laboratory courses at the undergraduate level generally do not capture the creativity of STEM disciplines. They often involve repeating classical experiments to reproduce known results, rather than engaging students in experiments with the possibility of true discovery. … Engineering curricula in the first two years have long made use of design courses that engage student creativity. Recently, research courses in STEM subjects have been implemented at diverse institutions, including universities with large introductory course enrollments. These courses make individual ownership of projects and discovery feasible in a classroom setting, engaging students in authentic STEM experiences and enhancing learning and, therefore, they provide models for what should be more widely implemented.*
>
> *President's Council of Advisors on Science and Technology, 2012, pp. iv–v*

This statement precedes a recommendation from a 2012 report from the President's Council of Advisors on Science and Technology (PCAST, 2012), which urges the science, technology, engineering, and mathematics (STEM) higher education community and funding agencies to "advocate and provide support for replacing standard laboratory courses with discovery-based research courses." When the report was published, limited but potentially promising evidence was emerging about their value to enhance learning and understanding of the processes and nature of STEM. Much of the research on undergraduate research experiences (UREs) has focused primarily on STEM. The purposes of this paper are to

1. Provide an overview of some of the evidence for the efficacy of using both apprentice- and classroom-based research experiences to enhance, broaden, and deepen student learning.
2. Discuss how UREs have great potential to enhance learning about science and other disciplines and how integrating STEM learning with civic engagement may enhance the efficacy of student learning in both areas.
3. Introduce readers to resources about UREs that are freely available and help readers to better appreciate some of the opportunities and challenges that individual faculty, departments, and institutions may encounter when attempting to introduce or expand UREs, especially those which are classroom based.

STEM Learning and Evidence for the Efficacy of UREs

There have been many efforts to improve undergraduate STEM education. Research about the science of learning provides extensive and robust information on how people learn as well as the teaching practices, strategies, and approaches that have been shown to be most effective (Blumenfeld et al., 2000; Handelsman, Miller, and Pfund, 2007; National Academies of Sciences, Engineering, and Medicine [NASEM], 2015, 2017a, 2018a; National Research Council [NRC], 2012 a,b; President's Council of Advisors on Science and Technology, 2012). When students are engaged in experiential learning that piques their curiosity, they are motivated to investigate the world around them and improve their understanding of scientific concepts (Cook and Artino, 2016). However, these student-centered approaches are not always applied in the college classroom. Partly in response to this research, increasing numbers of courses and other learning experiences are now incorporating aspects of active learning, which research has demonstrated can significantly improve learning and academic achievement (e.g., Freeman et al., 2014), and high-impact practices, which serve as specific manifestations of active learning (Kuh, 2008; Brownell and Swaner, 2010; Kuh and O'Donnell, 2013).

An important example of active learning has been the increasingly widespread use of UREs to increase interest in science and engineering, to help students understand the processes and nature of science, and to empower students to "do" science and engineering rather than just reading about it or listening to others provide instruction. UREs can provide students with some combination of experience in designing and conducting research, troubleshooting, analyzing and writing the results and implications of their work, and presenting their projects to the scientific community through publication, or oral or poster presentations at professional meetings. They can help students internalize and accept that failure is often a normal component of the process of science and engineering research and that such failure often leads to new questions and sometimes to new insights, advancements, and breakthroughs. There also is evidence that learning gains can be similar for both STEM majors and non-majors who undertake UREs early in their college careers (Stanford, Rocheleau, Smith, and Mohan, 2017).

While undergraduates have long had opportunities to pursue research by working with faculty at their home institutions or through various kinds of apprenticeships or internships off-campus, relatively few students have been able to take advantage of such opportunities. Associated with limited access are the problems of which students are selected and how they are chosen. Much has been written about the tendency to offer these experiences primarily to certain types of students to the exclusion of others. For example, faculty may be inclined to seek students with the best grades (but who may not necessarily be best suited to undertaking original research). Students whose families have research or other scientific backgrounds may be more attuned to the kinds of URE opportunities that exist on their campus and thus may be better poised to pursue them. Students who attend institutions where faculty are not expected to undertake research and thus may not have the equipment and financial support to make such opportunities apparent or be readily available to them will be at a distinct disadvantage compared with their counterparts at research-intensive institutions. Thus, issues of equity and access become paramount when considering institutional policies for instituting, maintaining, or expanding these kinds of undergraduate research experiences (Laursen, Hunter, Seymour, Thiry, and Melton, 2010; NASEM, 2015; Hernandez, Woodcock, Estrada, and Schultz, 2018; see also the recent literature review in McDonald, Martin, Watters, and Landerholm, 2019).

More recently, increasing numbers of individual faculty, academic departments, and institutions have attempted to assuage these issues through the promotion and development of course-based undergraduate research experiences (CUREs). When appropriately structured and implemented, CUREs can provide research experiences of varying lengths and levels of sophistication to much larger numbers of undergraduates than is possible with apprentice- or internship-based UREs (Dolan, 2016; Frantz et al., 2017); many CUREs are targeted to first- and second-year students (e.g., Harrison, Dunbar, Ratmansky, Boyd, and Lopatto, 2011; Rodenbusch, Hernandez, Simmons, and Dolan, 2016) in addition to juniors and seniors. Such experiences may help non-traditional and underrepresented students (Bangera and Brownell, 2014), especially in community colleges (e.g., NRC, 2012a; Hensel and Cejda, 2014), better engage with science and engineering and increase their chances of transferring to a four-year institution and becoming part of the STEM workforce (Felts, 2017). Indeed, some institutions have opted to use CUREs as an important tool toward improving retention in STEM (e.g., Locks and Gregerman, 2008).

Importantly, education researchers have followed the development of many types of CUREs from their inception. Some researchers have attempted to measure their efficacy in various dimensions and combinations, examining potential impacts on students' understanding of the processes and nature of science, development of specific research skills, increased interest in STEM, and viewing themselves as contributors to the STEM community. Others have focused on effects of CUREs on retention of students in STEM degree programs, especially students from populations that historically have been underrepresented in these disciplines. It has become increasingly clear that when there are clear goals and expectations for CUREs coupled with departmental and institutional support, these approaches to active learning can have profound effects on student learning, affective behaviors, and deeper connections with and greater appreciation of STEM (Laursen et al., 2010; Peteroy-Kelly et al., 2017; although see cautions expressed by Linn, Palmer, Baranger, Gerard, and Stone, 2015).

The National Academies of Sciences, Engineering, and Medicine has published two reports about UREs. One report summarizes a convocation that considered the roles, structure, opportunities, and challenges of CUREs (NASEM, 2015; see also Elgin et al., 2016). The second report is based on the work of a committee that for almost two years examined the evidence base for the efficacy of both CUREs and apprentice-based research experiences in STEM and which produced its findings in a consensus report (NASEM, 2017a). Two of the coauthors of this paper served as the staff directors for these projects (Labov for NASEM 2015, Brenner for NASEM

2017a), and each worked as support staff on the other project. The third coauthor (Middlecamp) was invited to give a presentation at the convocation to describe her efforts to offer a CURE at the University of Wisconsin-Madison, because of its emphasis on and integration of both scientific research and civic engagement; that course is described in greater detail below.

Additional overviews of the efficacy of CUREs are available in NASEM, 2015. In addition, an important online resource (CUREnet, http://curenet.org) offers invaluable assistance to faculty who are seeking to engage their undergraduate students in research experiences through courses, especially in the life sciences. Many of the ideas on CUREnet are evidence based, with some of the preeminent education researchers in this realm contributing. Table 1 provides along with other selected resources that offer guidance to instructors who are looking to initiate or expand opportunities for UREs.

The report from the National Academies' convocation (NASEM, 2015) provides an array of examples and descriptions of different types of CUREs, including several national consortia in different STEM disciplines. Brief descriptions of all of these examples along with links to the original sources can be found in Table 1 of Elgin et al., 2016 (reprinted here as Table 2).

TABLE 1: Selected Resources for Instructors

Instructors planning to implement or improve experiential experiences for undergraduates may benefit from the following resources:
The Council on Undergraduate Research (CUR) document Characteristics of Excellence in Undergraduate Research (2012) outlines several best practices for apprentice-style UREs based on the extensive experiences and expertise of the Council's members. It suggests that undergraduate research should be a normal part of the undergraduate experience regardless of the type of institution. It also identifies changes necessary to include UREs as part of the curriculum and culture changes necessary to support curricular reform, co-curricular activities, and modifications to the incentives and rewards for faculty to engage with undergraduate research. In addition, professional development opportunities specifically designed to help improve the pedagogical and mentoring skills of instructional staff in using evidence-based practices can be important for a supportive learning culture. CUR also offers an extensive collection of reports on all aspects of undergraduate research, ranging from inclusion of underrepresented students to institutional management of research, all of which can be purchased at https://myaccount.cur.org/bookstore.
Campus Compact is a national higher education association of over one thousand colleges dedicated to campus-based civic engagement. Campus Compact enables campuses to develop students' citizenship skills and forge effective community partnerships. Their resources are designed to support administrators, faculty, staff, and students as they pursue community-based teaching, scholarship, and action in the service of public good (https://compact.org).
Community College Undergraduate Research Initiative (CCURI) "…uses an inquiry-based teaching model where students are exposed to real-world science through a case study in an introductory course followed by a hands-on research experience resulting from questions about or related to the case." CCURI currently includes 44 partnering institutions and offers introductory workshops/conferences that are building regional and national collaborations, start-up supplies, and a wide variety of faculty development opportunities (https://www.ccuri.org/).
CURENet: Course-Based Undergraduate Research Experience supports networking among faculty who are developing, teaching, and assessing CUREs, to share CURE projects and resources, and to develop new tools and strategies for CURE instruction and assessment (https://serc.carleton.edu/curenet/index.html).
Learning Through Citizen Science: Enhancing Opportunities by Design, a recent report of the Board on Science Education of the National Academies of Sciences, Engineering, and Medicine (NASEM, 2018b), identifies ways that citizen science projects can be designed to effectively support learning. Citizen science has blossomed as a way to engage a broad range of individuals in doing science and can be incorporated into undergraduate curriculum in ways that promote both learning and civic engagement (http://sites.nationalacademies.org/DBASSE/BOSE/Citizen_Science/index.htm).

TABLE 2(A): Reprinted from "Insights from a convocation: Integrating discovery-based research into the undergraduate curriculum," by S. C. R Elgin, G. Bangera, S. M. Decatur, E. L. Dolan, L. Guertin, W. C. Newstetter, . . . and J. B. Labov, 2016, CBE—Life Sciences Education, 15, pp. 1-7. Copyright 2016 by The American Society of Cell Biology.

Initiative (page numbers in convocation report)	Discipline(s) targeted	Local or national in scope?	Brief comments
Freshman Research Initiative (pp. 52–53)	Multiple disciplines	University of Texas–Austin	Offers first-year students in the College of Natural Sciences an opportunity to conduct original research under the guidance of a research faculty member and graduate students through a three-semester sequence of courses and laboratory work. https://cns.utexas.edu/fri
Community College Undergraduate Research Initiative (pp. 56–57)	Multiple disciplines	National	Exposes community college students to real-world science through hands-on research experiences. Students take an introductory course in which they are taught basic scientific procedures while investigating a specific case study and then work together to investigate questions developed from a case study. www.ccuri.org/content/home
Discovery-Enriched Curriculum (pp. 61–63)	All disciplines	City University of Hong Kong	Institution-wide program that requires all 11,000 students who matriculate to make an original discovery or create intellectual property. www.cityu.edu.hk/provost/dec
Interdisciplinary Science Learning Labs (pp. 63–65)	All disciplines	University of Delaware	Engages undergraduates in all phases of scientific research through the development of facilities that foster the integration of teaching, learning, and research in a holistic learning environment. www.udel.edu/iselab
Center for Interdisciplinary Biological Inspiration in Education and Research (CIBER) (p. 64)	Engineering design inspired by biological structures and functions	University of California–Berkeley	Creates a community of next-generation scientists and engineers who can work together to conceive and execute innovative multidisciplinary work by engaging undergraduates to formulate and execute novel designs in engineering that are informed and inspired by biological principles and phenomena. http://ciber.berkeley.edu
First-Year Innovation and Research Experience (FIRE) (pp. 65–68)	All disciplines	University of Maryland–College Park	Modeled after the Freshman Research Initiative at the University of Texas (see description above), FIRE provides first-year students with authentic research experiences, broad mentorship, and institutional connections, but with an expansion to disciplines beyond the STEM fields. http://fire.umd.edu
Dynamic Genome Project (pp. 66–67)	Genomics and molecular biology	University of California–Riverside	Provides undergraduates with the same types of experimental activities as graduate students while they learn fundamental concepts in genomics and molecular biology in a two-course sequence that is required for biology majors. http://dynamicgenome.ucr.edu

research, can help meet the expanding need for workers trained in STEM fields. These points served as the basis for recommendation 2 in the PCAST report.

Assessment and Evaluation of CUREs

A plenary session focused on what emerging research indicates about the efficacy of CUREs on several levels.[6] Student and faculty enthusiasm for CUREs is, at present, largely based on student reports of learning gains and satisfaction with the experience (Auchincloss *et al*., 2014; Corwin *et al*., 2015; Linn *et al*., 2015). However, there are some well-documented studies showing that research experiences improve retention in the sciences (e.g., Locks and Gregerman, 2008; Estrada *et al*., 2011; Schultz *et al*., 2011; Eagan *et al*., 2013; summarized in Corwin *et al*., 2015), and several case studies presented at the convocation reported positive impacts. CURE assessments that use multiple indicators of student learning and program efficacy can provide greater insights concerning achievement of desired learning goals and affective behaviors of students and can offer guidance when starting new courses (Corwin *et al*., 2015; Linn *et al*., 2015); more research of this type is needed.

Many CUREs are designed by individual faculty to align with their own research interests, an approach that has many benefits but results in assessments that are idiosyncratic and difficult to compare (Lopatto, 2010; Linn *et al*., 2015). In contrast, a group of coordinated national efforts (Table 1) have attempted to address these issues by using common assessments, and some positive results have been reported (Jordan *et al*., 2014; Shaffer *et al*., 2014). Speakers pointed out that collaborative projects and/or cooperatives of schools with common program goals and common sets of activities can develop a common set of metrics, providing unique opportunities for assessing their efforts. Moreover, speakers noted the potential for partnerships among state systems of higher education and public and private consortia for fostering the acceptance and institutionalization of research-based courses.

[6]Given the limited amount of time to address many topics during the convocation, no topic was explored in detail. The consensus study now underway at the National Academies of Sciences, Engineering, and Medicine will address many of these issues more deeply. A primary charge to that committee is to examine the robustness of the research literature on assessment of CUREs and other types of undergraduate research experiences.

TABLE 2(B): Continued from prevous page.

Initiative (page numbers in convocation report)	Discipline(s) targeted	Local or national in scope?	Brief comments
Freshman Research Initiative (pp. 52–53)	Multiple disciplines	University of Texas–Austin	Offers first-year students in the College of Natural Sciences an opportunity to conduct original research under the guidance of a research faculty member and graduate students through a three-semester sequence of courses and laboratory work. https://cns.utexas.edu/fri
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Center for Interdisciplinary Biological Inspiration in Education and Research (CIBER) (p. 64)	Engineering design inspired by biological structures and functions	University of California–Berkeley	Creates a community of next-generation scientists and engineers who can work together to conceive and execute innovative multidisciplinary work by engaging undergraduates to formulate and execute novel designs in engineering that are informed and inspired by biological principles and phenomena. http://ciber.berkeley.edu
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Synergistic Benefits of Integrating UREs and Civic Engagement

Readers of this journal understand well the mission as well as many of the dimensions and logistics of civic engagement, so we will not focus in this essay on the basics of this approach to teaching and learning. Rather, the purpose of this section of the paper is to emphasize how combining and integrating more traditional aspects of UREs with practices of civic engagement can enhance the breadth, depth, and value of teaching and learning experiences in both dimensions.

The first quote from Ehrlich defines the nature and dimensions of civic engagement. The second quote describes the characteristics of people who are civically engaged.

Civic engagement means working to make a difference in the civic life of our communities and developing the combination of knowledge, skills, values and motivation to make that difference. It means promoting the quality of life in a community, through both political and non-political processes.

Ehrlich, 2000, p. vi.

A morally and civically responsible individual recognizes himself or herself as a member of a larger social fabric and therefore considers social problems to be at least partly his or her own; such an individual is willing to see the moral and civic dimensions of issues, to make and justify informed moral and civic judgments, and to take action when appropriate.

Ehrlich, 2000, p. xxvi

The definition of civic engagement emphasizes that it encompasses "…developing the combination of knowledge, skills, and values" that can make a difference in the vitality, health, and vibrancy of communities. Research questions directed toward the improvement of communities and the skills needed to provide answers and insights to critical questions that a community faces can all become critical components of UREs.

This definition of a civically engaged person can also be applied to ethical researchers. Thus, civic engagement can help undergraduate researchers better appreciate the need for both basic and applied research, to approach both kinds of research with integrity, and to follow up on important questions both as scientists and as citizens (e.g., Clements et al., 2013). The final sentence in this definition (". . . to make and justify informed moral and civic judgments, and to take action when appropriate") also suggests the need for the development of empirical questions and experiments to evaluate those questions as a critical component of civic policy- and decision-making.

Too often community-based decision-making and actions may be based on finances, emotion, and conventional wisdom about ways to address a given set of challenges. It is here where UREs can be especially effective by helping students as well as the other members of a community with whom they interact to appreciate the roles of scientific inquiry and processes and the importance of bringing data to the table when decisions are being made. CUREs especially can be used as an opportunity for larger numbers of undergraduates working collectively to learn practices and approaches of science and can be designed to provide an opportunity for civic engagement, making them more interesting and relevant to students.

Taken from the website of SENCER (Science Education for New Civic Engagements and Responsibilities), Table 3 provides an additional set of rationales for instructors to consider when developing UREs that integrate civic engagement and for helping to convince departmental and campus faculty colleagues and other academic leaders about the importance of initiating interdisciplinary experiential learning experiences for undergraduates.

The research literature suggests that, to date, much of the development of UREs, both apprentice-based and course-based, has focused on individual disciplines in STEM (including the social sciences) and the humanities. The National Academies symposium on CUREs

TABLE 3

The SENCER Ideals Illustrate the Principles and Philosophies That Guide SENCER's Approach to Educational Practice
SENCER robustly connects science and civic engagement by teaching "through" complex, contested, capacious, current, and unresolved public issues "to" basic science.
SENCER invites students to put scientific knowledge and the scientific method to immediate use on matters of immediate interest to students.
SENCER helps reveal the limits of science by identifying the elements of public issues where science does not offer a clear resolution.
SENCER shows the power of science by identifying the dimensions of a public issue that can be better understood with certain mathematical and scientific ways of knowing.
SENCER conceives the intellectual project as practical and engaged from the start, as opposed to science education models that view the mind as a kind of "storage shed" where abstract knowledge may be secreted for vague potential uses.
SENCER seeks to extract from the immediate issues the larger, common lessons about scientific processes and methods.
SENCER locates the responsibilities (the burdens and the pleasures) of discovery as the work of the student.
SENCER, by focusing on contested issues, encourages student engagement with "multidisciplinary trouble" and with civic questions that require attention now. By doing so, SENCER hopes to help students overcome both unfounded fears and unquestioning awe of science.

(NASEM, 2015) featured several models of research-based courses that have promoted interdisciplinary teaching and learning, both across STEM disciplines and between STEM disciplines and the arts and humanities (see Table 2). Integrating civic engagement either with apprentice- or course-based research would add an important additional impetus for some students (especially non-STEM majors) to engage with research and for faculty from different academic departments to work with each other in developing such opportunities.

UREs that integrate STEM with civic engagement can also benefit institutions of higher education in the following ways:

1. Research can be directed toward addressing problems on the campus itself. For example, "The Campus as a Living Laboratory" developed into a system-wide initiative at the California State University, has provided small grants to faculty who engaged their students with addressing campus-based issues after funding from the state was severely restricted. Since then, many campuses have embraced this concept in a variety of ways. For additional information, see https://scholar.google.com/scholar?hl=en&as_sdt=0,47&q=campus+as+a+living+laboratory. See also (Lindstrom and Middlecamp, 2017, and Lindstrom and Middlecamp, 2018 below)
2. Civic engagement can be integrated with UREs into programs that help communities surrounding the campus address local issues. Focused attention to community-based issues can help improve relationships between a campus and the community in which it resides.
3. The integration of civic engagement and UREs may help with recruitment and retention of students from populations that historically have been underrepresented in various STEM disciplines. For example, research on improving retention of women and underrepresented minorities in engineering has indicated that many of these students are seeking to solve real-world problems that help their communities (National Academy of Engineering [NAE], 2008, 2013a). Based on this research, the NAE has helped lead a campaign to change messaging about and images of engineers and engineering (NAE, 2012, 2013b, 2014).
4. Interdisciplinary education is becoming more widespread in higher education. Importantly, there is increasing evidence that interdisciplinary approaches, combined with various forms of active engagement, can enhance student learning in multiple dimensions (NASEM, 2018c). UREs that involve civic engagement can serve as both a lens and a catalyst for institutions to encourage greater interdisciplinary cooperation across academic departments or clusters of faculty with differing but complementary areas of expertise.

While the benefits of integrating UREs in STEM with civic engagement are apparent, there are fewer examples and exemplars of these kinds of programs than for disciplinary UREs, and actually implementing such integrated programs may seem daunting. Thus, the next section of this paper provides details about one such URE that has successfully encompassed this kind of integration. Readers also may be able to seek assistance and resources from on-campus offices that focus on research opportunities for undergraduates (e.g., Kinkead and Blockus, 2012).

Research on Campus Waste: An Experiential Learning Experience That Integrates URE with Civic Engagement

> *Trash audits determine what is being thrown away, allow auditors to assess whether or not waste is properly sorted, and help to pinpoint incorrectly recycled items. Ultimately, audits are powerful tools for helping other entities to analyze the results from their facilities and provide feedback on areas of improvement. (La Susa, 2018)*

Almost a decade ago, one of the authors of this article (Middlecamp) accepted the assignment of teaching a large introductory environmental science course at her state's flagship research university where she is a member of the faculty, the University of Wisconsin-Madison. The 4-credit course included both weekly lectures and a 3-hour laboratory period and counted toward fulfilling a requirement for both the environmental studies major and certificate. For the past four years, the course has counted toward the sustainability certificate as well.

Seizing the opportunity, she designed a new course that was place-based, drawing its content from the campus on which students studied, lived, worked, and played. Although officially titled "Principles of Environmental Science," the course quickly earned the nickname of "Energy, Food, and Trash" because it addressed these three topics using campus data sets, food supply chains, and waste protocols. The course used the university campus as a "living laboratory" for sustainability (Lindstrom and Middlecamp, 2017; Lindstrom and Middlecamp, 2018).

By design, the new course was interdisciplinary from its inception. Not only do the topics of energy, food, and trash draw from the natural sciences, but they also touch on topics from the social sciences and humanities, including social psychology and environmental history. The sustainability-related course content includes dimensions that are environmental, social, and economic. The laboratory activities for this course are interdisciplinary as well.

This section describes the use of trash audits as a URE that connects to civic engagement. In essence, a trash audit is research to learn something about what is in the garbage. For example, some audits are of the contents of "general" trash bins to determine which or how many items are heading to the landfill that could have been composted or recycled instead. Other audits are of "specialty" bins, such as plastic recycling bins, to determine to what extent the recycled items are contaminated. Still other audits might determine what is in the trash that should not be there, such as silverware, cups, or plates. The use of trash audits at UW-Madison was reported in NASEM 2015:

> *At first, the projects may not appear to be "real" research. A trash audit, however, gives students the opportunity to follow a protocol, collect data, and ask research questions of their own. For example, an unexpected finding in the study described above was that this trash also included 20 pounds of cups, dishes, silverware, and even a tray from a campus dining hall. This finding in turn catalyzed a future research agenda for the undergraduate students. (p. 32)*

The rationale for the use of trash audits in an undergraduate course that integrates scientific research with civic engagement is threefold. First, trash audits are a low-cost way to involve large groups of students in a meaningful research project. Required is an enclosed space (i.e., an enclosed loading dock) to carry out the audit, protective gear for students who dig in the trash (i.e., Tyvek suits, Kevlar gloves, safety goggles), and some nearby safety equipment (i.e., a portable eyewash) for the use of all. Second, this type of research is a form of civic engagement because it provides useful data to campus officials, including those in charge of dining halls, athletics, hospitals, and residence halls. And third, this type of research engages students.

Trash audits typically are carried out by a team, with each student performing a different role. For example, in a team of four, one person may open the bags and sort the trash. This person wears protective gear. Two other people might hold bags to receive trash items, perhaps one for recyclables and another for landfill. A fourth person records the data and receives "unusual" items found in the trash, e.g., money, plates from the cafeteria, or medical records.

Trash audits also need to be conducted with proper safety protocols. Students and staff need proper training, appropriate personal protective equipment, and clear

TABLE 4

Safety Precautions for Students in the 4-Credit Course, Principles of Environmental Science
Sort through the waste carefully and cautiously.
Sort the waste in a space with adequate ventilation and light.
Work in a space free of obstacles or slippery surfaces.
Dress sensibly. Tie back your hair, wear close-toed shoes, and remove any jewelry or clothing that is loose fitting.
Do not eat or drink while sorting waste.
Do not rub your eyes or touch your face or mouth while sorting waste.
Be on the lookout for sharp objects, syringes, household chemicals, and pathogenic substances.
Find another person to help move a waste bag too heavy for one person.
If you notice any risks or hazards, immediately report these to your TA.
If an incident or an accident occurs, immediately report this to your TA.
After sorting waste, wash your hands well.

guidelines for emergency procedures. Table 4 lists the safety precautions given to students.

Finally, and most important to this article, trash audits couple undergraduate research with civic engagement. Here are four possible ways for a campus to utilize the data that students obtain, thus opening avenues for civic engagement by a broad range of stakeholders:

Cost saving – Some items may be found in the trash that do not belong there (and have value), signaling the need for a change in the policies at campus eateries. Examples include knives, forks, spoons, dishes, and plates.

Recycling protocols – An audit of a recycling bin can show the degree of contamination; similarly, an audit of a trash bin may show items that should have been recycled. Examples include food and trash in recycling bins and aluminum cans in trash bins.

Student life issues – If items that connect to student health and well-being are found in residence hall trash, these items may signal the need to reassess campus policies. Examples include alcohol bottles and cans.

Environmental issues – If prescription drugs are found in audits of residence hall trash, this may signal the need to set up collection stations or to change the protocols for existing ones, thus providing proper disposal instead of releasing drugs into the local environment.

Each of these can serve as the start of a campus conversation involving different stakeholders. In addition, if students or campus staff design and implement an intervention, each of these can serve as the impetus for future audits to assess the success of the intervention.

Over the years, some students have chosen to continue their research projects after their course ended. For example, Figure 1 shows a new recycling sign displayed at a campus library where the food items brought in by student produce a lot of waste. The project was run by a team of staff and students who had completed a course in life science communications (Jandl, 2018). Again, UREs can not only benefit the students but can also serve their campus and the local communities in which they live.

FIGURE 1: Informational poster from the #RecycleRight campaign at the College Library, UW-Madison.

Image courtesy of Carrie Kruse.

Policy Issues and System Challenges

Development, implementation, or expansion of UREs presents opportunities as well as challenges at the levels of individual facuty, teams of faculty, academic departments and programs, and institutions. Much has already been written about how to address and surmount many of these issues, and it is beyond the scope of this paper to provide a comprehensive review of the literature. For such summaries we recommend that readers consult NASEM, 2015 and 2017a and Dolan, 2016.

Integrating civic engagement with UREs adds additional layers of complexity to an already complex system because such research necessarily will be more applied than basic, will likely involve multiple faculty or departments, and may also require collaboration with organizations outside the college or university. Thus, we conclude this section with several points that initiators of UREs that include civic engagement may wish to consider.

Assessment

The good news about the development of UREs in STEM is that they have attracted the attention of the STEM education research community. Many such references are cited in this paper. Thus, there is a great deal of guidance in the literature about how to assess the efficacy of UREs and how to incorporate various kinds of assessments into program design from the beginning (e.g., Shortlidge and Brownell, 2016). However, there is greater debate about what to assess and whether or not those criteria should be standardized to facilitate comparisons across programs.

These issues, and especially what variables to measure, are compounded when interdisciplinary UREs or those that involve civic engagement are attempted. At a minimum, faculty who are planning such programs need to discuss openly, as critical components of the initial planning stages, what they value and what they expect their students to learn and be able to do, as well as the methods they will use for assessment.

Professional Development and Departmental Support

Many faculty, postdoctoral fellows, and graduate students, especially at research-focused institutions, have experience in providing individualized or small group UREs to students in their laboratories. Adapting these kinds of experiences to CUREs can present challenges to faculty who have little teaching experience or who have not engaged in various kinds of active, high-impact practices in their courses. Here again, an additional layer of complexity is added when either apprentice- or course-based UREs involve interdisciplinary foci such as civic engagement. Thus, providing these kinds of experiences to undergraduates will require investment of time and departmental or institutional funds for programs as well as professional development for instructors (faculty of all ranks and career paths as well as postbaccalaureate assistants). Such departmental and institutional investments could significantly enhance the quality and efficacy of such programs (e.g., NASEM 2018; McDonald et al., 2019; Huffmeyer and Lemus, 2019). The institution's teaching and learning center may be able to offer such programs. Many professional development workshops and other programs are currently offered by disciplinary and professional societies as well as other national organizations that can help faculty and other instructors become more comfortable with and adept at initiating more active, high-impact practices. Given the large increase in the number of adjunct faculty who are now involved with undergraduate instruction, including them in on-campus professional development programs or supporting their registration and travel to attend off-campus offerings could also greatly enhance the capacity of the institution to offer UREs. Providing these opportunities to adjunct faculty could also allow them to undertake original or applied research with students in their courses to enhance their own publication record, thereby offering a path toward professional advancement in academia.

Financial and Other Incentives

Much has been written about how incentives drive faculty productivity, retention, and motivation. It is difficult enough to address these issues within individual disciplines. Extending the discussion to include multiple departments makes the required discussions and actions that much more difficult. Money is not the only consideration. Faculty time to develop UREs, sufficient space, equipment and expendables, and professional recognition and credit for such participation (including serious consideration during decisions about tenure and promotion) are all essential if UREs involving civic engagement are to be successful. Who "owns" the course? How are FTEs assigned to what are still unconventional approaches in many academic settings? Who should be responsible (and appropriately compensated) for seeking out and engaging off-campus community organizations?

Student Considerations

The demographics of undergraduate student populations have changed a great deal during the past two decades (summarized in NASEM, 2016). These changing demographics can pose challenges to the successful development of integrated UREs. For example, the age of the average undergraduate is now in the mid-twenties. Many of these students are working at full- or part-time jobs. Increasing numbers of students have children, and a significant component of these students may be single parents. Today's students are also much more likely to complete their degrees across multiple institutions and take much longer than four years to complete their degrees, often due to the aforementioned contingencies (NASEM, 2016).

If UREs are to be successful, then they must account for these kinds of exigencies. Even within disciplines, if a URE requires additional fees, many students may be unable or unwilling to pay them. Due to high interest rates on student loans, those undergraduates who pay tuition and fees actually end up paying much more to enroll in these courses than students who do not have these kinds of financial burdens. If a URE requires students to be engaged with research outside of class time such as in the evenings or on weekends, students who are parents may be excluded from taking advantage of such opportunities. (For additional student considerations related to the designing of CUREs, see NASEM, 2015).

If UREs are to incorporate civic engagement, then additional barriers and challenges may ensue. For example, while such experiences could greatly benefit both STEM majors and non-majors, non-STEM students may not be willing to participate if they have to pay any additional lab or equipment fees, since many majors outside of STEM don't require them.

Finally, the issue of assessment and evaluation of student learning is germane to this discussion. Because many students' choices for courses during college are driven both by requirements and by the need to maintain a high grade point average, they will often opt to enroll in courses where standards and expectations for grading are clear. Thus, for example, instructors need to consider as part of their approaches to grading how they will assess students when their data are ambiguous or they don't obtain experimental results that match the hypotheses that they've originally proposed. Unless such expectations are established well in advance, agreed upon by all instructors, and conveyed clearly to students in the college catalog and course syllabi, some students who might benefit most from challenging themselves through undertaking a URE may opt to instead enroll in courses with more traditional approaches to grading. Of course, this challenge becomes magnified when instructors from different disciplines or academic traditions are working together on courses or other programs that integrate more traditional disciplines with civic engagement.

Conclusions

Efforts to expand participation in UREs have shown promise, and the strongest evidence for their benefit comes from studies of students from groups historically underrepresented in scientific fields (NASEM, 2017a, 2017b). Additional expansion of opportunities for students to participate in traditional formats of UREs are likely to benefit their learning. CUREs can bring research experiences to classrooms, transform more traditional laboratory and field venues into broader learning and discovery experiences, and decrease the importance of requiring students to bring prior knowledge and connections to a course, which also increases opportunities of access and equity for a broader array of students (NASEM, 2015). Other types of experiential learning can be obtained from service-learning projects and internships in industry or the community (NASEM, 2017b, 2018b).

The potential for engaging a broader spectrum of students, instructors, departments, institutions, and communities in the support of UREs may also be enhanced by integrating learning in the STEM disciplines with civic engagement. This melding of learning can help students better understand and appreciate the importance of challenging themselves, sometimes failing at what they are trying to do, and seeing how the subjects they learn can be applied to real problems that face society and the planet. We encourage readers who care about and currently involve their students in civic engagement to work with colleagues from the STEM disciplines (both on- and off- campus) to develop richer learning and more exciting teaching experiences through the integration of these approaches. As we have tried to articulate, the challenges for successful integration are many and may be more difficult to address than when we seek to improve teaching and learning within a discipline. However, the rewards can be many. The SENCER Guidelines (Table 3), coupled with serious consideration of an institution's mission statement, can become valuable guides for proceeding. Given the challenges that the current generation of students will face during their lifetimes and the critical need for using evidence to address problems, the importance of integrating STEM and civic engagement through undergraduate research experiences has never been greater.

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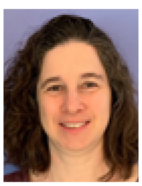

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