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About the Journal

Science Education and Civic Engagement: An International Journal is an online, peer-reviewed journal. It publishes articles that examine how to use important civic issues as a context to engage students, stimulate their interest, and promote their success in mathematics and science. By exploring civic questions, we seek to empower students to become active participants in their learning, as well as engaged members of their communities. The journal publishes the following types of articles:

- *Book & Media Reports*
- *Point of View*
- *Project Reports*
- *Research*
- *Review*
- *Science Education & Public Policy*
- *Teaching & Learning*

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SCIENCE EDUCATION & CIVIC ENGAGEMENT
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From the Editors

We are pleased to announce the Winter 2019 issue of *Science Education and Civic Engagement: An International Journal.*

This issue focuses on undergraduate research and civic engagement, which readers will see reflected in three articles. **Jay Labov** (retired, National Academies of Science, Engineering, and Medicine), **Kerry Brenner** (National Academies of Science, Engineering, and Medicine), and **Cathy H. Middlecamp** (University of Wisconsin-Madison) contribute a review that summarizes the work to date on undergraduate research experiences (UREs), much of which is discipline based. The authors then explore the potential for UREs which integrate civic engagement, both from the perspective of challenges and potential benefits. An interdisciplinary URE coupled with civic engagement that has operated for several years at the University of Wisconsin-Madison is used as an illustrative example by the authors.

Drew Sieg (Truman State University), **Joshua Sabatini** (Passaic County Community College), **Davida Smyth** (New School), and several faculty from Mercy College—**Nancy Beverly, Madhavan Narayanan,** and **Geetha Surendran**—collaborate on an article that describes their efforts and experiences at two liberal arts institutions to promote civic and scientific engagement through undergraduate research and project-based learning. This article complements the one by Labov, Brenner, and Middlecamp in several different ways: the type of institutions involved and the contrasting approaches taken by faculty at two institutions on how to connect civic engagement with project-based learning and course-based undergraduate research.

Finally, **Jeffrey Olimpo, Jennifer Apodaca, Aimee Hernandez,** and **Yok-Fong Paat** (all at the University of Texas at El Paso) describe their work with "Health Disparities in the Border Region," a course-based undergraduate research experience with a clear civic engagement dimension. Their work focuses particularly on student development of public outreach skills, researcher self-efficacy, and understanding of research-community connections. Their mixed methods study showed evidence of significant improvement by the end of the semester in these different areas.

We are particularly happy to present all three articles in the same issue, as we feel this will provide readers of the journal with more opportunities for reflection. It is our hope that these three articles will contribute to the ongoing discussion of how the high-impact practices of undergraduate research and civic engagement can continue to be connected.

In addition to the above three articles that explore undergraduate research and civic engagement, we are also pleased to publish three different pieces. **Rebecca Mazumdar, Nadia Benakli,** and **Pamela Brown** (New York City College of Technology) describe how a virtual learning community involving freshmen students enrolled in chemistry, English, and math helped promote student engagement and persistence. The courses in the virtual learning community were linked by the impact of human activities on the environment, specifically the de-icing of roads with salt.

Alicia Wodika (Illinois State University) describes the Global Public Health course offered at her institution, which focuses on the complexity of communicable and non-communicable diseases, determinants of health, and delivery of health services. As part of a campus "International Education Week," groups of students in the course created posters on such topics as disease reduction, cash transfer programs, health systems comparisons, and emergency preparedness. The evidence collected indicated that students saw the project as helping them develop an appreciation for how vast the subject of global health is.

Finally**, Marisha Speights Atkins, Cheryl Seals,** and **Dallin Bailey** (all from Auburn University) describe the development of a computation tool that automatically grades the phonetic transcription assignments that constitute an important part of the speech pathology curriculum. The development of this particular tool provided a service learning opportunity for students in a User Design Interface course offered by Auburn's Department of Computer Science and Software Engineering to meet a real need of students and faculty in the Department of Communication Disorders.

We would like to thank all the authors for sharing their work with the readers of this journal.

Matt Fisher
Trace Jordan
Co-Editors-in-Chief

Teaching with Technology:

Using a Virtual Learning Community and Peer Mentoring to Create an Interdisciplinary Intervention

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Abstract

This paper describes the development and implementation of engaging and supportive experiences to promote student engagement, persistence, and success at a commuter, open enrollment, public, minority-serving institution. Project components included faculty development at the SENCER Summer Institute (SSI) 2016, attended by a team comprised of an academic administrator, full-time faculty from English and math, and part-time faculty in chemistry; creation of a virtual learning community of freshmen enrolled in chemistry, English, and math, linked by the specific theme of the environmental impacts of de-icing roads with salt and the overarching theme of the impacts of human activities on the environment; and peer mentoring in chemistry. Faculty reflections and grade distributions indicate this is a promising approach and suggest strategies for overcoming challenges.

Motivation

This project was designed to use evidence-based interdisciplinary tactics to support a student population that is underrepresented in STEM. New York City College of Technology (City Tech) is a minority-serving institution, enrolling 17,279 full- and part-time students (Fall 2017). Over a third of our students were born in any one of 110 countries other than the United States, and nearly three-quarters (73%) report that a language other than English is spoken in their homes. Students self-report as 33% Hispanic, 30% Black (non-Hispanic), 20% Asian and 11%

White; 61% report household income less than $30,000 (2017–2018 Fact Sheet).

Project Development

Participating math, English, and chemistry faculty and an administrator worked together, and with colleagues at other institutions with a similar charge of developing an interdisciplinary intervention, to develop this project. Team activities were formally launched through participation at the SENCER Summer Institute (SSI) 2016, in Chicago, Illinois. In addition to an opportunity for faculty professional development, we hoped that the shared experience of participating in SSI 2016 would help the team form a sense of community, similar to the one anticipated for the students. This was the first SSI for two faculty members and an introduction to the concept of integrating civic engagement into the curriculum and the resources available through SENCER, and it was one faculty member's first exposure to the idea of structuring a learning community. By attending several lectures on the subject, she was able to reflect on just how important this could be for our students, especially concerning the construction of a sense of belonging to a community. During project development, we continued to meet with other similar teams at other institutions to learn about their experiences and to share ideas.

Project components included an early intervention modeled on the successes of learning communities and integrated by a shared focus on civic engagement with peer mentoring for academic support. While our college has several resources in place to support such a project, including an interdisciplinary culture, an established Peer-Led Team Learning (PLTL) program, and an administration that supports curricular innovation, our project nonetheless met with some logistical challenges. As explained below, we used an extant technological resource, City Tech's OpenLab, to help us overcome these obstacles. We achieved several successful outcomes.

Why These Courses?

The three courses participating in the project represent foundational courses in their disciplines. English Composition I is the first semester of a two-semester composition requirement. It is the only class required of all students at City Tech. Its goals include ethical research methods and uses of source material, awareness of audience and of generic conventions, and the process of academic writing itself (drafting, peer review, revising). These skills are critical to success in STEM disciplines. English professor Rebecca Mazumdar chose to participate in this learning community, because she wanted students to see the importance of effective communication and the joy of curiosity. While this course is designed to deliver the former message, the latter is sometimes more of a stretch, especially since so many students do not self-identify as strong writers.

College Algebra and Trigonometry is part of the College's required STEM math sequence. Strong analytical skills are a must for success in STEM disciplines. Project participant Professor Nadia Benakli reported that students struggle to grasp algebra concepts and often fail to see the practical purpose of learning these concepts. They also have significant difficulties with trigonometry. While many of the students taking this course are STEM majors, they often do poorly on exams, with one-third of registered students typically not passing the course. Because this course acts as a gatekeeper of sorts, including it in this project potentially offered a greater likelihood of impact on student success.

General Chemistry I is an introduction to the principles of general chemistry for STEM majors. This course includes lecture and lab and has a pre- or co-requisite of College Algebra and Trigonometry or higher. Some of the enrolled chemistry students had already taken these English and Math classes in previous semesters. For this project, an adjunct instructor, Prof. Medialdea, taught the chemistry lecture and lab.

All three courses contribute important components to a successful college education. Moreover, all three often pose difficulties for students as shown by Fall 2017 pass rates (D or better).

TABLE 1: Pass rates (D or better), Fall 2017, in All Sections of Relevant Courses

Course	Pass rates (D or Better)	Number of Students (N)
English Composition I	73.6%	3127
College Algebra and Trigonometry	66.0%	896
General Chemistry I	82.0%	197

Why a Learning Community?

Research has demonstrated that learning communities are one of several high impact strategies that improve student success (Kuh, 2008). Participation in learning communities is positively linked to increased engagement, stronger relationships with instructors and peers, self-reported gains in academic skills and interpersonal development, higher grades, increased persistence, and overall satisfaction with the college, even at commuter campuses (Zhao and Kuh, 2004; MDRC, 2012). Learning communities can be used to target the problematic parts of the curriculum that act as gatekeepers for student progress (Lardner, 2005). While many models of learning communities exist, common features include co-enrolling students in two or more courses to promote community through shared intellectual activities (Zhao and Kuh, 2004; Tinto, 2003; MDRC, 2012; Ratcliff et al., 1995; Rao, n.d.). This model encourages students to connect ideas from diverse perspectives and different disciplines. Learning communities often include a common theme. Successful learning communities may also include additional academic and counseling support for students. Other common attributes include faculty professional development on effective pedagogical strategies that allow the development of assignments utilizing group work and joint or overlapping assignments. Because of their demonstrated success, learning communities often target at-risk groups with identified low persistence and low graduation rates (Zhao and Kuh, 2004; Tinto, 2003; MDRC, 2012; Ratcliff, 1995; Smith, 2001; Rao, n.d.).

Challenges to implementing successful learning communities include increased cost, staffing, and support structure needs (Smith, 2001). It may be difficult to recruit students willing to agree to block programming, particularly if they have family, employment, or other commitments. Sections with low enrollment risk cancellation. Enrollment Management may not want to link dual enrollment in courses with different class size limits, particularly at campuses where space is an issue, as the linked enrollment reduces the number of available seats in the larger class. Another challenge is that without deliberate faculty professional development to enhance the learning environment, learning communities can devolve into little more than block programming. Even at campuses with established learning communities there is also the challenge of sustaining them as initial champions move on or as resources become scarcer (MDRC, 2012; Smith, 2001).

Why Peer Mentoring?

We incorporated peer mentoring in chemistry. Peer-Led Team Learning (PLTL) is a national model of student support where more advanced, successful undergraduate students are trained as peer leaders to facilitate small group learning (Dreyfuss, 2013) Peer leaders do not provide answers, but instead ask leading questions to encourage students to work together to solve problems that are structured to help the students develop conceptual understanding and problem-solving skills. PLTL has been demonstrated to lead to increased student success, particularly among minority students (Snyder, Sloane, Dunk, and Wiles, 2016). We chose to include PLTL as an additional social and academic support structure to again promote social interactions and a community of learners. Peer meetings occurred during the chemistry lab sections after hands-on work was completed. Thus, students were already physically present, optimizing the opportunity for impact. We were able to take advantage of a peer mentor training course already established on campus: MEDU 2901 Peer Leader Training in Mathematics (MEDU 2901, 2019).

Using Technology to Overcome Initial Obstacles

City Tech has a long-standing robust learning community program for first-year students, and Professor Mazumdar in English had participated in those linked-enrollment learning communities for several years. We planned to link enrollment of the sections participating in the learning communities; however, student recruitment was difficult and the low enrollment resulted in cancellation of the LC. The Fall 2016 implementation of our project was thus delayed by a semester. The enrollment challenges motivated our decision to create a virtual online community, using the College's OpenLab, a "digital platform where students, faculty and staff can meet to learn, work, and share their ideas. Its goals are to support teaching and learning, enable connection and collaboration, and strengthen the intellectual and social life of the college community" (OpenLab, 2018). These sections would meet in person like traditional classes but would include a virtual learning component for students in all three courses, providing asynchronous social and intellectual connections. The delay allowed us to hone the civic focus of our learning community; inspired by the winter weather, we decided to focus on the environmental effects of the salt used to de-ice snowy roads. Students in each course would work on projects related to this theme.

Implementation

Our learning community was launched in Spring 2017. It was unique because it would not be a shared-enrollment LC; our three distinct classes would need to find ways to interact through OpenLab, a digital shared space in which our students could share their work and ideas with each other, while still fulfilling the goals of each course.

Before the semester began, we agreed that we would make OpenLab participation 5% of our students' semester grades. We included the same instructions in all three syllabi. Students were provided with a step-by-step explanation of how to set up their OpenLab accounts and join the project; they also received an explanation of what was expected of them. These expectations are quoted at length here:

Here's what's expected of you:

1. Each week, you'll comment on a post to the blog. These blog posts will be authored by the professors participating in the project (Prof. Devers [now Prof. Mazumdar], Prof. Benakli, and Prof. Medialdea), and occasionally by the students enrolled in those professors' classes. To receive credit for a comment, the comment must be around 100 words, and should be a thoughtful response to the ideas, issues, or problem contained within the original post. You can also respond thoughtfully to the comments other students have posted to the original item. By the end of the semester, you should have at least 13 comments, at least one a week. Multiple comments in a single week will be considered 1 comment. (In other words, don't leave all 13 for the final week of the semester!)

   "Thoughtful responses" include specific academic maneuvers, like the following:

   a. comparing/contrasting the ideas in the blog post to the ideas you're discussing in class;
   b. offering a solution to a potential problem;
   c. identifying complications to potential solutions;
   d. selecting a quotation from the original text with which you agree or disagree, and using interpretation and analysis to defend your position;
   e. providing a solution to a problem and explaining your work; and
   f. applying the ideas in the reading to a real world problem
2. Once this semester, you'll be asked to post to the blog yourself, so that others can comment on your post. Your post could be an article you've found in recent news media, or a problem you'd like help solving. Your professor can help you brainstorm the types of material that would be appropriate for a blog post.
3. A word about online etiquette: write as though you're face-to-face with other students and faculty. Present your ideas with confidence, while maintaining respect for the ideas of others. Check your work for grammar and typos before posting it. And have fun! This project will allow us to discuss big issues with students in multiple classes across disciplinary boundaries.

We began with most posts coming from the instructors, with the hope that students would begin to post on their own. As the learning community started in the winter, the first OpenLab posts were about the chemistry of snow, ice control methods, and the impact of these methods on the environment such as manhole explosions due to road salt corroding electric wires. Students discussed eco-friendly ice melt alternatives such as beet juice. The students then moved to examine a broader theme, "the degree and nature of humans' impact on the environment." They shared posts on air pollution, plastic pollution, and climate change. They discussed possible solutions such as wind energy. In the math class, they solved problems with applications related to the themes discussed on OpenLab. By the end of the semester, there were 77 published posts, and 523 comments. The project site had 69 members (plus the three administrators); 33 members posted at least once.

In English Composition I, an assignment asked students to perform light research to locate a recent news article about a topic related to human impact on the environment. They were to post a summary and a link to the article on our project blog on OpenLab. Since the blog allows for comments on posts, students were also assigned to comment on other students' articles, to begin to make connections. The assignment allowed them to practice essential skills important to composition (synthesis of ideas, clear communication, reading comprehension) and to participate in a community of learners discussing common ideas. The collection of articles on OpenLab also became a shared library of relevant sources for students' research projects.

Outcomes

Below, the grade distributions of students in the virtual learning community are compared to all students taking the course in Spring 2017. There is some evidence that the goal of promoting persistence was achieved, as the withdrawal rate in all three learning community courses was lower than the overall withdrawal rate for the course. The higher chemistry grades of students receiving PLTL in lab suggest this support did help students succeed (no separate lab grade is given—there is just a grade in lecture with 25% of the grade based on the lab). There were significant improvements in College Algebra and Trigonometry grades in the LC section compared to all students, suggesting that incorporating civic engagement and interdisciplinarity was particularly effective here.

Observations Successes and Challenges

English professor Mazumdar, who has worked with linked-enrollment Learning Communities before, compares this one to previous ones. In linked-enrollment LCs, students form peer bonds or cliques. Sometimes, that can hinder their ability to pay attention in class, but the benefits are that they have the chance to form supportive friendships with classmates. This can be hard to do on a non-residential campus where students are often present only for the duration of classes. However, she did not see that cross-course bonding happening this semester. Students could respond to each other on OpenLab, but they likely never saw those screen names IRL or in-real-life. As the project continues, she would like all three classes to meet, perhaps for some ice-breaker/meet-and-greet activities, and to give the three instructors the opportunity to deliver essential information about the project. She hopes that this would encourage OpenLab participation, since they would be interacting with recognizable peers.

Math professor Benakli noted that initially, many students expressed unwillingness to participate in the project. Some of them were not happy that they had to "write" in a math class. Others complained that writing was not something they "do in other classes." With some encouragement, and a reminder that 5% of their grades depended on their participation in the blog, Professor Benakli had almost 100% participation. Many students did enjoy sharing and having someone else (other than a friend) read, listen, and comment on their posts. Several students submitted more comments than the required weekly contributions. The end of the year feedback was very positive.

Professor Benakli also observed another benefit of the project. Sometimes, she and her students would spend the first five minutes in class discussing one of the recent posts. Using the blog as a "warm up" activity helped the students to feel relaxed (which is unusual in a math class) and mentally prepare to focus on the lesson. Professor Benakli notes that she found herself enjoying

TABLE 2: Pass Rates of Participating Sections (LC) vs. All Sections

Course	% A-C	% A-D	% F	% W/WU	N
General Chemistry I (LC)	73%	81%	5%	14%	37
General Chemistry I LAB (LC)	80%	88%	0%	12%	25
General Chemistry I (Fall—Spring 2017)	77.2%	80.5%	4.7%	14.9%	215
English Composition I (LC)	59%	65%	35%	0%	17
English Composition I (Fall—Spring 2017)	71.3%	67.8%	9.7%	18.5%	1160
College Algebra & Trigonometry (LC)	84%	92%	8%	0%	37
College Algebra & Trigonometry (Fall— Spring 2017)	50.1%	63.4%	21.3%	14.8%	894

teaching this section more than previous ones, and that students did much better on their exams. She admits that perhaps this had nothing to do with the virtual learning community, but it speaks to the benefit to both students and faculty of linking classroom activities to larger issues in the community. In the future, she hopes to recruit other colleagues to participate in such a virtual learning community.

Chemistry professor Medialdea was pleased that her students expressed a strong interest in learning more about the environmental impacts of human activities, which seemed to enhance their interest in chemistry. She also noted that several students commented on an increased appreciation for the value of learning math and English as well as enrolling in additional chemistry courses.

Responding to Challenges

Recommendations and Future Plans

Several aspects of the project showed promise and will be retained as we repeat the project in a future semester. The use of OpenLab was one of the project's successes. Students found confidence in the blog, as a safe environment for contributing to discussions and as a source of like-minded peers. Furthermore, the project's common thread (road salts and their environmental impact) expanded to the broader topic of human impact on the environment, which enhanced student interest in it. The OpenLab site allowed the project to be flexible enough to respond to this student interest. Several topics like climate change involve multiple academic disciplines and would work well with this type of shared learning environment. Future permutations of this project face no limitations on the possible civic issues that such an interdisciplinary approach can address.

The team looks forward to implementing the project again, and to revising some elements of the intervention. In our self-reflections on the project, team members have considered the possibility that a different math class, like statistics, may be better suited for the project, as well as the possibility that students in a more advanced chemistry class, General Chemistry II, may have a better grasp of basic concepts and may therefore be better prepared to engage with larger themes. A benefit of this virtual learning community model is that the shared class blog sidesteps logistical challenges presented in linked-enrollment situations. Participating classes aren't restricted by prerequisites.

One significant change we want to make moving forward is the implementation of a single, overarching project. We didn't have one in place when the semester began, and it proved impossible to establish it as the semester progressed. We believe a "traveling" project could fit nicely with this type of learning community. Students in chemistry could collect data through lab work, send those data to students in math who can determine the implications of the data and how best to present them. Then, that information can be sent to the English students who use it to write persuasive pieces to local community leaders. To complete the circle, students in chemistry could then act as peer reviewers to help the writers refine and edit their formal assignments. The success of such a project relies on starting the first step, data collection, early enough in the semester so that each student group will have ample time with the information and can produce discipline-specific work in response to it. Professor Mazumdar would like the students to meet each other in person in order to develop a sense of community and shared experience; this would also mean that students would have a better sense of whom they were accountable to when passing data and information along to the next class.

Related to that sense of community, participating faculty learned that it also invites some interesting pedagogical questions. Specifically, the OpenLab site, which operates like a blog on which students can publish both original posts and comments, became a venue for discussions that were not relevant to course content. One student in particular used it to advertise his band's events. This activity raised issues concerning the policing of this virtual world, one which we admittedly had hoped would be a safe and welcoming community space where students could create the sort of learning environment that can be so elusive on a commuter campus. To address this, the next iteration of the project will include a social page where students can share and comment on extracurricular topics. This will keep the academic blog focused on class topics but allow the overall project site to remain amenable to the community building that supports student retention.

To get a better sense of our impact, assessment of future iterations of the project could take place at both the beginning and end of the term, and—if possible—perhaps a year or more after students take the class. Students could answer questions or submit a writing sample on the first day of the semester, so that instructors can gauge their knowledge and skill levels. The same assessment instrument could then be used at the end of the term to collect comparative data (pre/post knowledge checks). Outcomes related to other items, such as critical thinking, abilities to integrate course content with real-world scenarios, and collaboration/teamwork improvements could also be evaluated. To compare this project with other sections of the same courses, the same assessment procedure would need to be used in those sections as well. Instructors can also use the SENCER-SALG to assess students' interest in STEM courses as well as in the larger project theme: human impact on the environment. Another option is adoption of reflection exercises that unify course goals, where students could write in a journal (or other medium) to demonstrate their thinking, learning, and personal growth. Instructors could also qualitatively code the student responses, and identify emergent themes within their responses as well as evidence of intellectual growth as the semester progressed; additional quantitative assessment of the blog posts could include the average number of posts per student and the overall percentage of student participation.

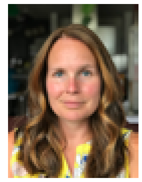
Longer-term assessment could be one or both of the following: another follow-up SALG to determine persistence of interest in STEM classes or themes, or the collection of retention and graduation rates for enrolled students (compared with those of students in other comparable sections, for example).

One of the biggest advantages of this form of learning community is scale-up; therefore, part of our continuing work on the project will include recruiting other faculty to participate.

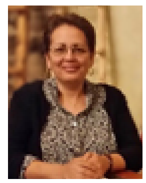
Broader Implications

By using OpenLab, or another platform such as BlackBoard, instructors of different courses across the campus can establish a virtual learning community without the logistical challenges of linked enrollment. This can even be expanded to cross-campus collaborations.

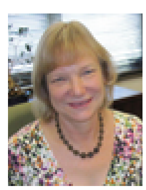
About the Authors



Rebecca Mazumdar, PhD, is Associate Professor of English at New York City College of Technology, as well as a Co-Coordinator for Writing Across the Curriculum. She earned her PhD at the University of Connecticut in 2010. Her research focuses on fictional domestic spaces in Cold War American literature and popular culture. At City Tech, she teaches courses in English composition, fiction, law through literature, and graphic novels.



Nadia Benakli, PhD, is Associate Professor of Mathematics at New York City College of Technology, the designated college of technology of the City University of New York (CUNY). She received her doctorate in Geometric Group Theory from Paris-Sud University in France. Her thesis advisor was M. Gromov. Before coming to City Tech, she taught at Columbia University and Princeton University. She was also a Postdoctoral Fellow at the Mathematical Sciences and Research Institute (MSRI), Berkeley. She organized the Group Theory Seminar, and the Trees and Related Topics Seminar at Columbia University, 1998. She was also the organizer of the Topology Seminar at Princeton University, 1993–1994. Benakli is the Quantitative Reasoning course coordinator, the Quantitative Reasoning Fellow program coordinator, and the Applied Mathematics and Computer Science internship programs coordinator. She has also participated in the READ, SENCER, and Learning Community programs. Benakli's research interests are in geometric group theory, graph theory, and in pedagogical issues in mathematics.



Pamela Brown, PhD, **PE**, is Associate Provost at New York City College of Technology of The City University of New York, a position she has held since 2012. Before assuming this position, Dr. Brown served for six years as dean of the School of Arts & Sciences and was a Program Director in the Division of Undergraduate Education at the National Science Foundation (NSF) in 2011-2012. She is a chemical engineer by training.

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Disease and the Environment:

A Health Disparities CURE Incorporating Civic Engagement Education

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Introduction

Course-based undergraduate research experiences (CUREs) offer a novel avenue for engaging students in the scientific process (Bangera and Brownell, 2014). In contrast to traditional laboratories, CUREs are designed to foster autonomy through student-driven hypothesis generation, experimentation, data analysis, and dissemination of findings (Auchincloss et al., 2014; Spell, Guinan, Miller, and Beck, 2014). Current evidence suggests that participation in CUREs in the biological sciences leads to significant increases in students' development of scientific process skills, ability to "think like a scientist," and affective dispositions in the domain (Brownell, Kloser, Fukami, and Shavelson, 2012; Brownell et al., 2015; Jordan et al., 2014; Olimpo, Fisher, and DeChenne-Peters, 2016). Despite the importance of these documented benefits, few studies (e.g., Ballen, Thompson, Blum, Newstrom, and Cotner, 2018) have examined the mechanisms for establishing connections between students' research and the larger community—what, in the CURE literature, is referred to as broader relevance—as well as the impact of those connections on cognitive and non-cognitive student outcomes. Review of published CUREs, including those cited in the CUREnet database (https://serc.carleton.edu/curenet/index.html), further suggest that this is especially true when considering civic engagement as a form of experiential learning and capacity building with the local community.

In this article, we describe the development and evaluation of the BIOL 1108: Health Disparities in the Border Region II CURE, which represents our efforts to address the aforementioned concerns through purposeful integration of civic engagement education into the CURE curriculum. A health disparities course theme was identified given the widespread health inequalities along the U.S.-Mexico border that have posed a challenge to the U.S. healthcare system (Bastida, Brown, and Pagán, 2008; Rosales, Carvajal, and de Zapien, 2016). In this context, civic engagement "encompasses actions wherein individuals participate in activities of personal and public concern that are both individually life-enriching and socially beneficial to the community" (AAC&U Civic Engagement VALUE Rubric, 2018). While the incorporation of civic engagement instruction into science, technology, engineering, and mathematics (STEM) pedagogy is not unique to our work, the research presented here is novel in several ways. First, the limited number of studies focusing on civic engagement within course-based research experiences have largely been conducted in inquiry- or discovery-oriented contexts (rather than in environments adopting a CURE model) (e.g., Ahmed et al., 2017; NASEM, 2015); conversely, the CURE may be structured such that it has public health implications, but students are not directly engaged with the public (e.g., Smyth, 2017). Secondly, our efforts and findings are responsive to recent work in the field (Ballen et al., 2018); we contend that this work provides a significant first step in examining broader relevance but that, due to methodological constraints, it misconstrues the level of importance of broader relevance in CUREs as being "insignificant," particularly for non-major (i.e., non-biology) populations. Finally, we present robust assessment of student outcomes following engagement in the BIOL 1108 CURE in a manner that serves to highlight the strength of civic engagement as an alternative mechanism for achieving broader relevance beyond commonly employed approaches within CUREs, such as student co-authored publications or presentations (e.g., Kloser, Brownell, Chiariello, and Fukami, 2011; Laungani et al., 2018).

Specifically, a quasi-experimental, mixed methods design was used to examine the following research questions:

1. What impact does engagement in the BIOL 1108 CURE have on students' development of public health outreach skills?
2. To what extent does participation in the BIOL 1108 CURE influence students' sense of project ownership, science identity and networking skills development, and researcher self-efficacy?
3. What perceptions do students hold of the BIOL 1108 CURE experience, particularly as it relates to their understanding of the relationship between science and society?

We hypothesized that student involvement in the BIOL 1108 CURE would lead to a significant increase in their public health outreach skills development and perceptions regarding the connections between science and the public, given the explicit focus on civic engagement within the context of the CURE. This assertion is supported by prior evidence in the field, which suggests that students highly value opportunities to engage with their community and report feeling equipped to do so following formal civic engagement instruction (Ahmed et al., 2017; Donovan and Schmitt, 2014). Furthermore, in concordance with empirical studies on the efficacy and benefits of CUREs in the biological sciences (e.g., Brownell et al., 2012; Fisher, Olimpo, McCabe, and Pevey, 2018; Mader et al., 2017; Olimpo et al., 2016), we anticipated that participation in the BIOL 1108 CURE would result in enhancement of students' science identity and researcher development.

Course Description: Health Disparities in the Border Region II (BIOL 1108)

Health Disparities in the Border Region II (BIOL 1108) is the second course in a year-long, research-driven sequence within the Department of Biological Sciences at the University of Texas at El Paso (UTEP). Eighteen two-semester CURE series exist within the department and university as part of the Freshman Year Research-Intensive Sequence (FYRIS; https://fyris.utep.edu), an NIH-funded program modeled after the University of Texas at Austin's Freshman Research Initiative (https://cns.utexas.edu/fri). Each course sequence possesses a distinct topical focus aligned with the lead faculty's area of scholarship and enrolls a maximum of twenty-four students per section per term, with the intent of retaining the same cohort of students throughout the duration of the experience. Building upon the structure of Health Disparities in the Border Region I (BIOL 1107), which emphasized development of technical skills and experimental design (see Appendix 1 for the course syllabus), BIOL 1108 was developed to meet six core course objectives, as described in Table 1. During the 15-week term, class sessions occurred twice weekly for an average of 120 minutes each session. Students predominantly spent class time continuing to iteratively and collaboratively engage in the research projects that they had initiated in BIOL 1107, receiving feedback from their peers and the course instructors (J.T.O. and J.A.) about their progress, and outlining and implementing their civic engagement initiative as deemed feasible. This latter component of the BIOL 1108 course is unique in comparison to all other CUREs at the institution and was purposefully designed to connect students and their research with the communities in which that research occurred and which that research, at least in part, was intended to benefit (see Table 2 for alignment of student research interests and their corresponding civic engagement component).

In order to increase the fidelity of implementation of student outreach initiatives, research teams first constructed a community engagement plan during week #11 of the course (see Appendix 2 for the BIOL 1108 course syllabus). Specifically, this plan required that each group: (a) identify the individuals within the community with whom they intended to interact during the initiative; (b)

TABLE 1: BIOL 1108 Course Objectives, Associated Activities, and Assessment.

Course Objectives	Course Activities*	Assessment
1. Students will utilize scientific process skills to make informed decisions throughout all aspects of the experimental process.	Weekly PI meetings with course team; engagement in authentic research projects (Table 2)	Formative monitoring of students' weekly research progress
2. Students will apply principles of scientific inquiry to conduct a descriptive and/or analytical study of their choosing within the fields of health disparities, environmental health, molecular epidemiology, and public health bioinformatics.	Iterative planning and implementation of authentic research projects (Table 2)	Formative monitoring of students' weekly research progress
3. Students will demonstrate an increased understanding of qualitative and quantitative research methods, as evidenced in written and oral deliverables.	Weekly entries in laboratory notebook; research roundtable presentations; data analysis workshop; end-of-semester outreach presentations	Summative evaluation of individual students' laboratory notebooks; summative evaluation of outreach presentations
4. Students will make meaningful empirical connections between diseases and the environment.	Engagement in authentic research projects (Table 2)	Formative monitoring of students' weekly research progress
5. Students will describe, succinctly, the results of their research to both lay and scientific audiences.	Biweekly research updates; professional development workshops (Appendix 2)	Formative feedback provided on biweekly research updates
6. Students will describe the impact of their research to communities of practice outside of the classroom.	Development and implementation of civic engagement initiatives (Table 2)	Summative evaluation of end-of-semester outreach presentations

* Please contact J. Olimpo (jtolimpo@utep.edu) if you are interested in obtaining course activities and/or assessments.

TABLE 2: Alignment of Student Research Projects and Civic Engagement Initiatives.

Research Project	Research Approaches	Civic Engagement
Agricultural Impacts of *Coccidioides* in the Southwestern United States	Molecular Epidemiology; Metagenomic Analysis	Development and Implementation of Public Awareness Events at Farmers Markets
Air Quality Monitoring and Prevention of Air Quality-Associated Illnesses on Campus and in the Region	Engineering (Monitor Development); Survey Methods; Air Quality Surveillance	Tabling Event at the UTEP Earth Day Celebration; Formation of the Student Society for Science and Civic Engagement; Contact with Local Government
Prevention of Hospital-Associated Infections (HAIs): A Study in Hygiene Practices	Survey and Semi-Structured Interview Methods	Nursing Student Workshop; HAI Community Awareness "Nerd Night"*
Metagenomic Analysis of Microbial Diversity on the Campus Bus System	Molecular Epidemiology; Metagenomic Analysis	Organization of a Student-Focused Mini-Symposium on Local Health Issues and Related Social Media Development

* Nerd Nights are hosted by the University as a means to bring science to the public in interactive ways.

describe what role those individuals would have in the outreach process; (c) articulate how contact would be made with external partners; and (d) generate an outline detailing how the outreach event would be organized, executed, and monitored. At the conclusion of the first session, students were invited to participate in a gallery walk, which allowed them to observe other team's engagement plans and to provide feedback on those plans. Similarly, this allowed the course instructors to formatively assess student progress and address any questions or concerns that emerged. Research teams then used the constructive criticism provided by their peers to revise their community engagement plans during the second weekly session.

Revised plans required subsequent approval from the course instructors, and, once finalized, teams could proceed to the implementation phase. In this context, it is important to note that the majority of research teams (n = 3) elected to initiate contact with community partners with minimal guidance and facilitation from the course instructors. For instance, members of the air quality monitoring team directly e-mailed the local organizer for the UTEP Earth Day Celebration to express their interest in the event and to request a table for their outreach activity, which included an "adverse effects of air pollution" matching activity for children and opportunities for adults to view and discuss existing air quality data for the region. Likewise, members of the HAI team identified and contacted a clinical professor in the UTEP School of Nursing, who provided them with access to collect data from and speak informally with nursing students who were currently participating in clinical rotations. Notably, all student groups were successful in executing one or more components of their outreach plan (see Table 2 for an overview).

We contend that this success is attributable to several factors. First, BIOL 1108 is a continuation of BIOL 1107. Accordingly, students have already established relationships with one another and are already invested in their research projects, with moderate to high levels of perceived project ownership reported (see Methods and Results sections below). Second, the BIOL 1108 CURE convened, on average, for four hours each week, which provided substantial time for peer-peer and peer-instructor discussion to occur with respect to each student team's research and outreach agendas. Course deliverables, including weekly updates and the final civic engagement presentation, likewise held students accountable for their efforts and promoted metareflective practices among both the students and the instructors. Lastly, the course's central focus on place-based health issues within the Paseo del Norte region likely encouraged students to formulate outreach plans that primarily necessitated interaction with individuals at UTEP or in the community, with whom they were already at least somewhat familiar.

Methods

Participant Recruitment

Participants (N = 16) represented a convenience sample consisting of all students enrolled in the BIOL 1108: Health Disparities in the Border Region II CURE at the University of Texas at El Paso in the Spring 2018 semester. As discussed previously, this course is a successor to BIOL 1107: Health Disparities in the Border Region I (Appendix 1) and is intentionally designed to provide students with opportunities to connect their independent research initiatives to the local community (see *Course Description: Health Disparities II [BIOL 1108]* and Appendix 2). The majority of the students (n = 13) completed BIOL 1107 prior to entering BIOL 1108; however, none of the participants had prior civic engagement or service-learning experience. Participants were predominantly female (62.5%) and majoring in STEM (93.8%), although the course was open to any individual whose degree requirements included BIOL 1108. Approval was received from the University of Texas at El Paso's Institutional Review Board prior to conducting research involving human subjects.

Public Health Outreach Flowchart (PHOF)

Given the explicit focus of BIOL 1108 on research and civic engagement, we sought to examine the degree to which students were successful at constructing public health outreach plans prior to and following their participation in the course. To accomplish this objective, a modified version of the Scientific Process Flowchart Assessment (SPFA; Wilson and Rigakos, 2016), the PHOF, was developed and validated (via expert-panel review). Specifically, the PHOF presented students with a hypothetical scenario in which two introductory biology students were tasked with creating an outreach program to address the high incidence of asthma in their community due to widespread public exposure to pesticides. Participants were prompted to create a flowchart diagramming their plan and could use any text, arrows, and objects to accomplish the task (Appendix 3). Responses were blinded and scored using a modified version of the SPFA rubric (Wilson and Rigakos, 2016), which was likewise subjected to expert-panel review for the purposes of content and construct validation (Appendix 3). Each response was evaluated by two individuals with expertise in the social sciences and bioeducation research. High interrater reliability was achieved (κ= 0.93; $p < 0.001$), with all disputes being resolved through discussion among the coders. Aggregate data were then entered into SPSS (v.23, IBM) and paired t-tests used to assess for pre-/post-semester shifts in performance.

Persistence in the Sciences (PITS) Survey

As a complement to the PHOF, the PITS (Hanauer, Graham, and Hatfull, 2016) was utilized to assess the impact of the BIOL 1108 CURE on students' sense of project ownership (content- and emotion-related), researcher self-efficacy, science identity development, scientific community values, and networking skills (post-only). An adapted version of the PITS was created for pre-semester utilization, in which the question stem was modified, where appropriate, to inquire about students' initial beliefs and expectations (e.g., "I believe that the research I conduct this semester will help to solve a problem in the world"). Psychometric analyses indicated a high degree of construct validity (as established via expert-panel review) and reliability for both the pre-test (Cronbach's α= 0.943) and post-test (Cronbach's α = 0.857) versions of the instrument (Cronbach's $\alpha \geq$ 0.754 for each individual subscale). Given that all students in the course intended to continue to engage in research in subsequent semesters (as indicated in an end-of-semester one-minute response paper assignment), we did not inquire about their interest in persisting in conducting scientific research on the post-semester PITS diagnostic. Data were entered into SPSS (v.23, IBM), and, with the exception of the Networking scale, a series of paired t-tests were used to examine pre-/post-semester shifts in response. Descriptive statistics were tabulated for all Networking items.

FIGURE 1: Examination of Student Performance on the PHOF Reveals a Significant Shift in Total Item Count, Total Rating, and Flowchart Structure Following Engagement in the CURE. Error Bars Represent +/- SEM. All Comparisons are Significant at $p \leq 0.039$.

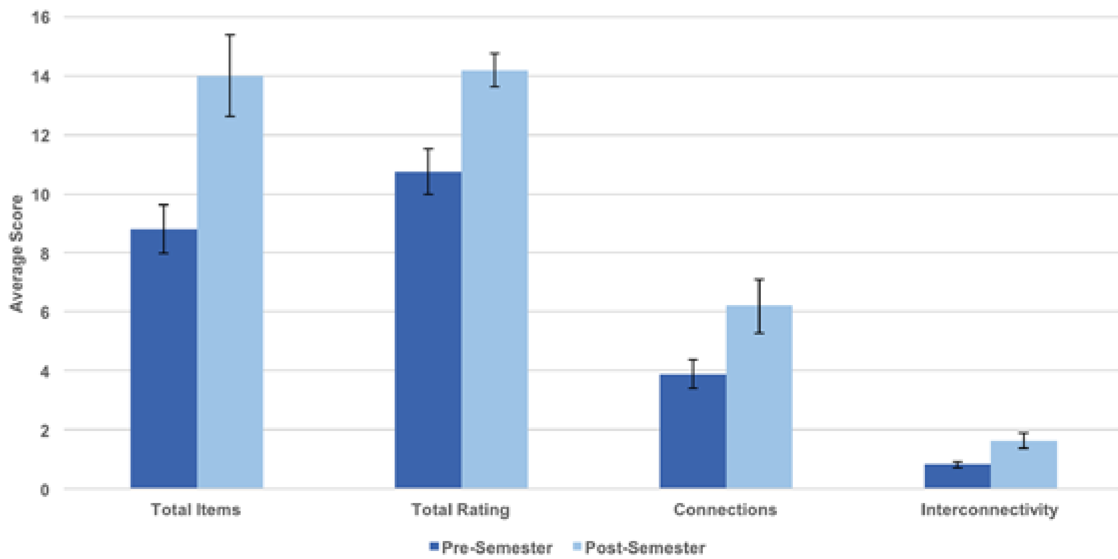
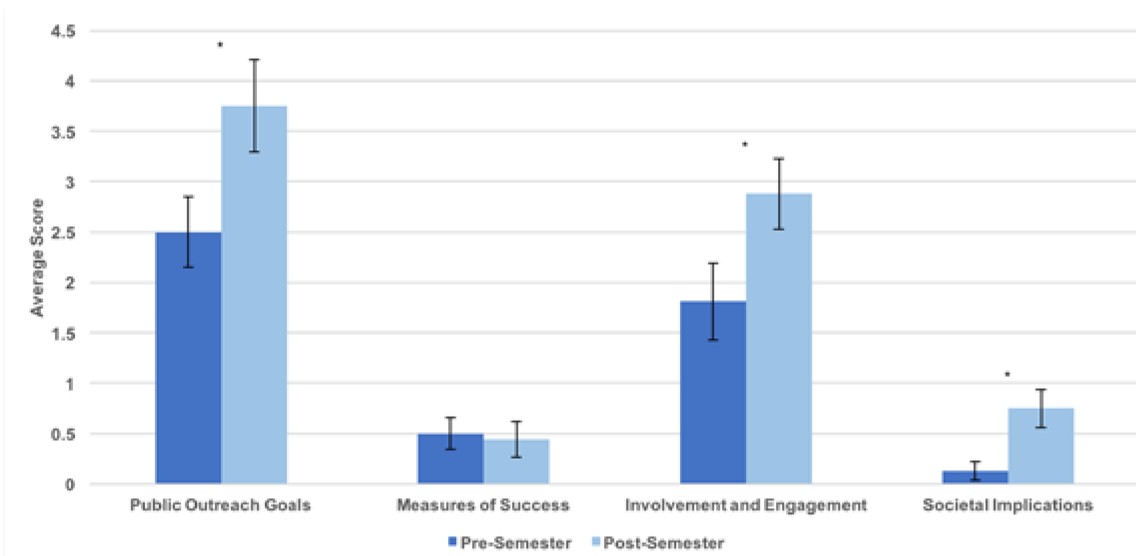


FIGURE 2: Examination of Student Performance on the PHOF Reveals a Significant Shift in Students' Understanding of Factors Impacting Public Health Outreach Initiatives Following Engagement in the CURE. Error Bars Represent +/- SEM. Flagged Comparisons (*) are Significant at $p \leq 0.020$.



Student Perceptions of the Course (SPC)

To better understand how the BIOL 1108 CURE impacted students' beliefs about the relationship between science and civic engagement, we asked participants to respond to three open-ended prompts at the end of the term (Appendix 4; adapted from Lancor and Schiebel, 2018). Responses were analyzed using a descriptive interpretive approach (Tesch, 2013), with emergent themes identified via iterative cycles of open and axial coding. Each response was scored by two individuals with expertise in the social sciences and bioeducation research. High interrater reliability was achieved ($K = 0.97$; $P < 0.001$), with all disputes being resolved through discussion among the coders.

Results

Participation in the CURE Results in a Significant Increase in Students' Development of Public Health Outreach Abilities.

A series of paired t-tests were performed to examine pre-/post-semester shifts in participants' PHOF responses with respect to the six rubric dimensions (Appendix 3). Results indicated a statistically significant increase in the total number of items reported ($t(15) = 3.463$; $p = 0.003$) and total flowchart rating ($t(15) = 3.218$; $p = 0.006$), as well as in the number of connections made between concepts ($t(15) = 2.259$; $p = 0.039$) and interconnectivity ($t(15) = 2.360$; $p = 0.032$), following engagement in the BIOL 1108 CURE (Figure 1). Significant increases in all other categories were likewise observed with the exception of the Measures of Success dimension (Figure 2).

TABLE 3: Analysis of Students' Pre-/Post-Semester Responses to the PITS.

Construct	Pre-Semester (M; SEM)*	Post-Semester (M; SEM)	p-value
Project Ownership (Content)	4.34 (0.12)	4.64 (0.10)	0.012
Project Ownership (Emotion)	4.27 (0.17)	4.17 (0.16)	0.409
Self-Efficacy	4.15 (0.13)	4.51 (0.11)	0.004
Science Community Values	4.48 (0.12)	4.69 (0.13)	0.201
Science Identity	3.94 (0.17)	4.16 (0.14)	0.913

Engagement in the CURE Enhances Students' Sense of Project Ownership and Researcher Self-Efficacy

Paired t-test analyses of student responses to the PITS revealed a significant, pre-/post-semester shift for both the Project Ownership (Content) scale ($t(15) = 2.841$; $p = 0.012$) and Researcher Self-Efficacy scale ($t(15) = 3.381$; $p = 0.004$) (Table 3). Remaining comparisons were not statistically significant. Descriptive analysis of networking data indicated that students engaged in research-related conversation most frequently with friends and least frequently with faculty external to the course (Figure 3).

Research-Civic Engagement Connections Are Evident in Students' Post-Semester Written Questionnaire Responses

In addition to examining the above cognitive and non-cognitive outcomes, we sought to understand the more globalized perceptions students possessed regarding connections between their research and the broader community. Qualitative analysis of SPC responses revealed, in a collective sense, that students valued the need for increasing community awareness of public health issues in the region and that this could be accomplished both through practical means (e.g., increased communication) and through professional means (e.g., students pursuing careers with

FIGURE 3: Descriptive Statistics Regarding Student Networking Practices.

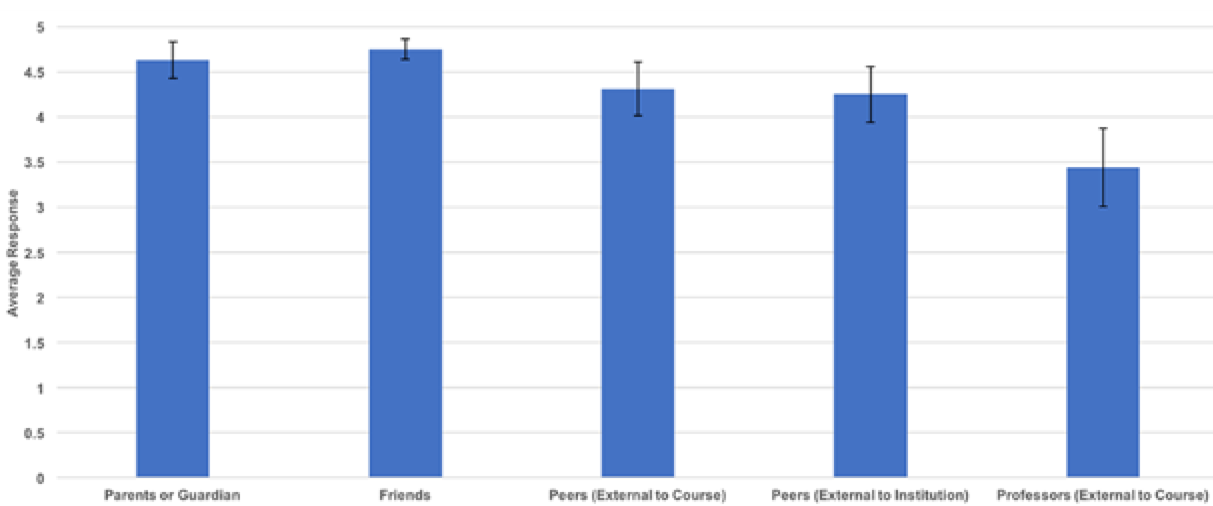


TABLE 4A: Student Responses to the Question "How Will You Continue to Engage with Science and the Public in Your Future Career?"

Theme: Research Engagement — **Number of Responses (%)**: 10 (62.5%)

Sample Student Responses:

"After my time in this lab, I plan to find professors who are doing research and request to participate, particularly research [that] has to do with public health."

"As I develop as a scientist, I would get involved in more on-campus research as well as internships pertaining to my field of interest in Environmental Science."

Theme: Increase Public Awareness/Outreach — **Number of Responses (%)**: 7 (43.8%)

Sample Student Responses:

"I would like to continue to participate in scientific organizations."

"In my research on air quality, [the public] will be able to build their own air sensors [to measure air quality], which will give them a sense of engagement in our research."

Theme: Career Advancement — **Number of Responses (%)**: 6 (37.5%)

Sample Student Responses:

"I intend to pursue professional school either in pharmacy or medicine (physician). In addition to this, I would like to pursue a double-degree that would allow me to have more direct contact with the community (e.g., MPH)."

"I am interested in possibly pursuing graduate work in the area of epidemiology/public health."

Theme: Academic Connectedness — **Number of Responses (%)**: 2 (12.5%)

Sample Student Responses:

"By belonging to the FYRIS program, I will have academic opportunities to continue to engage in science that impacts the public."

"As a BUILDing SCHOLAR, I am able to develop my scientific abilities and create networking opportunities for myself [and] my future endeavors."

TABLE 4B: Student Responses to the Question "In Your Opinion, What is Your Role as a Scientist in Communicating with the Public?"

Theme: Educate the Public — **Number of Responses (%):** 10 (62.5%)

Sample Student Responses:

"A scientist must be able to teach others what they have learned such that all of society's knowledge as a whole can improve."

"By communicating to the public, we are sharing our findings [with] the world."

Theme: Increase Public Awareness/Engagement — **Number of Responses (%):** 5 (31.3%)

Sample Student Responses:

"[My role] is to raise issues that are vital and that affect every human by spreading awareness."

"I have been working on my project for some time, and I want to share my findings."

Theme: Improve Quality of Life — **Number of Responses (%):** 5 (31.3%)

Sample Student Responses:

"We are the gatekeepers and facilitators for people to live a better quality of life."

"Whether it be public health, clinical research, or environmental public health, all people deserve the right to be informed about the many factors affecting their daily lives."

TABLE 4C: Student Responses to the Question "What Have You Learned in This Course That Will Equip You to Effectively Connect the Broader Community with Issues in Science?"

Theme: Increased Research Knowledge	**Number of Responses (%):** 5 (31.3%)
Sample Student Responses: "With the knowledge of research skills that I have learned in this class, I can better understand how [science and society] are connected and how to reach out [to community stakeholders]." "I have learned to obtain consent to acquire data, create engagement pieces (such as proposals), and create surveys that will obtain desired information for our research."	
Theme: Increased Public Outreach Knowledge	**Number of Responses (%):** 5 (31.3%)
Sample Student Responses: "With the knowledge of community outreach that I have learned in this class, I can better understand how scientific research and the community are connected and how to reach out." "I have learned how to address the community by increasing awareness of issues and incorporating citizen-science pieces [into my work]."	
Theme: Engagement with the Community	**Number of Responses (%):** 11 (68.8%)
Sample Student Responses: "Throughout our study, we incorporated the broader community in order to effectively reach everyone, not only our target community." "What makes science engaging and more meaningful from a community standpoint is specifically spreading awareness for scientific research that affects them."	
Theme: Professional Skills Development	**Number of Responses (%):** 4 (25.0%)
Sample Student Responses: "In this course, I have learned how to communicate; how to find resources; how to fully understand the goals/outcomes of my research; how to problem-solve; how to better manage my time; and how to become a better presenter." "I have improved in my communication and writing skills."	

a civic engagement focus). Furthermore, several students (n = 10; 62.5% of the participants) noted that the research projects that they initiated in the course could serve as a platform for engaging in future scholarship that served to "bring science to the public." One student stated, for instance, that she "wanted to become a primary care physician one day" and hoped she could "continue doing research in the field of public health so [she could] better advocate for [her] patients' lifelong health." Another, in documenting what he believed he learned in the course that could enable him to effectively connect the broader community with issues in science, wrote that "among all of the typical things [he] discovered in the course (e.g., how to write a research proposal; laboratory methods), [he] learned not to hesitate to communicate ideas about the direction of research and how to make progress." In doing so, he could then also "better communicate any possibility of something bad or beneficial [about his research] to the public in an effective manner." Comprehensive analysis of student responses, including identified themes, is presented in Tables 4A - C above. In interpreting these outcomes, it is important to note that across all open-ended prompts, more than 81% of responses were identified as belonging to two or more coding categories.

Discussion

Since their inception, CUREs have sought to extend the benefits of research to an increasing number of undergraduates at all academic levels (Bangera and Brownell, 2014). Indeed, efforts within the discipline indicate that CUREs have the potential to promote the development of cognitive and non-cognitive student outcomes ranging from increased science literacy to science identity formation and persistence in STEM (e.g., Brownell et al., 2012; Brownell et al., 2015; Jordan et al., 2014; Olimpo et al., ,2016). While this is the case, few studies (e.g., Ahmed et al., 2017; Ballen et al., 2018) have expounded upon the extent to which those outcomes are fostered by purposeful integration of civic engagement education into the CURE curriculum.

In this article, we describe the structure of the Health Disparities in the Border Region II CURE, highlighting connections between student-driven research that examines health challenges within the students' local community as well as the civic engagement/public outreach initiatives that course participants developed to connect their research to the broader society. Furthermore, we present both quantitative and qualitative evidence suggesting that participation in the CURE positively impacts students' development of public health outreach skills, researcher autonomy and self-efficacy, and affective dispositions toward the role of science in society. These findings are consistent with several prior studies, which note that targeted instruction that establishes tacit links between student research projects and the public good increases students' attitudes about the role of science in society, their understanding of the nature of science, and their appreciation and value for "doing" scientific work (e.g., Ahmed et al., 2017; Smyth, 2017).

In considering the outcomes reported here, we also wish to acknowledge the limitations associated with our work. Specifically, the structure of the FYRIS program and the resources allocated for the Health Disparities sequence (e.g., physical materials, financial incentives) were only intended to support a single implementation with a relatively finite population of students. There currently exists no opportunity to repeat the course sequence, although we are in the process of exploring alternate strategies to sustain and scale the CURE. In addition, although we believe it would be ideal to conduct a comparative examination of CURE and non-CURE courses with embedded civic engagement opportunities, no parallel non-CURE course presently exists within the department that incorporates direct outreach to the local community. While these caveats should be considered when evaluating reported outcomes both here and more broadly within the CURE literature (Brownell, Kloser, Fukami, and Shavelson, 2013), they also promote meaningful contemplation of future research directions in this area.

For instance, what factors are required to ensure that CUREs incorporating civic engagement education into the curriculum are both sustainable and scalable? Are these factors the same as those that are necessary to support sustainability and scalability of CUREs that do not integrate civic engagement experiences? In what ways do CUREs that promote civic engagement through science-society connections (ProCESS CUREs) allow us to examine as yet unexplored benefits of student participation in course-based research, and how do we effectively measure those outcomes?

With specific regard to our own work, and in response to those limitations cited above, we likewise seek to engage in future studies that: (a) examine the replicability of the findings reported here (e.g., through analysis of outcomes in course iterations with larger student sample sizes); (b) implement multiple sections of the course in the same semester and vary whether or not students participate in civic engagement experiences, which will afford us an opportunity to more closely understand the direct impact of such experiences; and (c) collaborate with other UTEP CURE faculty to promote incorporation of civic engagement into their curricula and to conduct CURE-CURE comparative studies using similar methods as those described in this article. Pursuing these and other relevant areas of inquiry is a critical step toward understanding how CUREs can continue to foster growth in the classroom and beyond.

About the Authors

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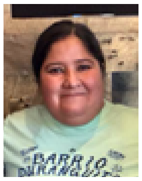
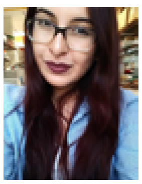


Jennifer Apodaca, Ph.D., is Lecturer and Lab Coordinator in the Department of Biological Sciences at the University of Texas at El Paso, where she teaches classes covering topics in introductory biology, microbiology, molecular biology, comparative genomics, animal physiology, animal behavior, and evolutionary biology. Her primary research interest in bioeducation involves curriculum development and evaluation of course-based undergraduate research experiences and civic engagement in science activities that employ genome-scale experimental and computational approaches to topics in public health, microbiology, and genetics.



Aimee A. Hernandez is an undergraduate Forensic Biology student at the University of Texas at El Paso, whose research experiences cover areas from virology to biology education. After completing her doctoral degree, she aspires to work as a forensic DNA analyst for the FBI. In addition to her interest in forensics, she plans to eventually teach at the high school or undergraduate level, ideally to inspire young scientists who are often underrepresented or underestimated to make a name for themselves in the scientific community.

Yok-Fong Paat, Ph.D., is Associate Professor in the Department of Social Work at the University of Texas at El Paso. Her interests focus on family well-being, community participatory based research, and social integration.

Acknowledgments

We wish to thank the undergraduate researchers in the Health Disparities course sequence for their diligence and willingness to participate in this study. This research was supported in part through the HHMI PERSIST initiative, award no. 52008125. The opinions and views expressed in this article are those of the authors and do not necessarily reflect the opinions and views of the Howard Hughes Medical Institute and/or its constituents.

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DISEASE AND THE ENVIRONMENT: HEALTH DISPARITIES IN THE BORDER REGION (BIOL 1107) – FALL 2017

Instructor: Drs. Jennifer Apodaca and Jeffrey Olimpo
Office: B226C Biology Building (Fri. 11:00am - noon)*
E-mail: japodaca15@utep.edu; jtolimpo@utep.edu

*These are hours when I am **guaranteed** to be in my office. If these times do not work for you, please send me an e-mail, and we can arrange another time to meet. I'm here to help!

COURSE DESCRIPTION

Welcome to *a study of life*! This course offers students a unique opportunity to explore the relationship between disease, the environment, and public health through an intensive, self-driven research experience. As opposed to traditional laboratory coursework, this means that *you* will be determining your own research questions, methods to use, types of experiments to perform, and "next steps" in the research process based on obtained conclusions. We (as your instructors) seek to promote an environment where (reasonable) risk is rewarded, overcoming failure is part of true scientific inquiry, and the contributions *you* make to science are invaluable.

COURSE OBJECTIVES

This course is designed to provide students with an authentic research opportunity in the biological sciences. Upon completion of the course, students will be able to:

- Compare and contrast the various descriptive and analytic study designs utilized in the fields of epidemiology, public health, and biological sciences
- Utilize scientific process skills to make informed decisions throughout all aspects of the experimental process
- Apply principles of scientific inquiry to conduct a descriptive and/or analytic study of their choosing within the fields of health disparities, environmental health, molecular epidemiology, and public health bioinformatics
- Demonstrate an increased understanding of qualitative and quantitative research methods, as evidenced in written and oral deliverables
- Make meaningful empirical connections between diseases and the environment
- Describe, succinctly, the results of their research to both lay and scientific audiences

1

COURSE MATERIALS & CO-REQUISITES

1. *Health Disparities in the Border Region* laboratory manual (available in PDF on our Blackboard site; Olimpo *et al.*, 2017)
2. Laboratory notebook (a *non*-spiral bound composition book will suffice) and pen
3. Personal Protective Equipment (PPE) needed: laboratory coat; goggles

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ACADEMIC INTEGRITY

As members of a scholarly community dedicated to healthy intellectual development, students and faculty are expected to share the responsibility of maintaining high standards of honesty and integrity in their academic work. All material for this course must be your work and no one else's. **Cheating or plagiarism in any form will not be tolerated.** This includes, but is not limited to, copying someone else's work on an assignment. Please note that all suspected instances of plagiarism or academic dishonesty will be referred to the Dean of Students' Office, in accordance with UTEP policies and procedures.

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COMMUNICATIONS

When you e-mail me, please include a proper subject, any message you are responding to, the course name and CRN, as well as your name. Please use your UTEP account to ensure the e-mail is not blocked by the university's spam filter. If you e-mail directly from the Blackboard course, essential information like the course name and section will automatically be included. I will do my best to respond to your e-mail within 24-48 hours. If you do not receive a response within this timeframe, I ask that you please re-send your e-mail. Please be sure to regularly check the e-mail account listed for you in Blackboard, as this is where all course correspondence will be sent.

CENTER FOR ACCOMMODATIONS AND SUPPORT SERVICES

Students needing special accommodations in this course must be registered with the Center for Accommodations and Support Services (CASS) Office in Room 106 of the Union East Bldg. You may contact them at (915) 747-5148 or cass@utep.edu for more information. Once you are registered with the CASS Office, please notify me as soon as possible so that we may meet to discuss appropriate accommodations, as recommended by CASS.

The IT Support Team can assist with Blackboard, password resets, and student e-mail accounts. Hours and other helpful information can be found at http://www.helpdesk.utep.edu.

COURSE GRADING & EXPECTATIONS

COURSE GRADING:

- Structured Homework Assignments 10%
- Participation/Attendance 5%
- Research Question 5%
- Preliminary Proposal 5%
- Rough Draft of Proposal 10%
- Final Draft of Proposal 15%
- Laboratory Notebook 10%
- Final Presentation 20%
- Final Laboratory Report 20%

A = 90 – 100%	D = 60 – 69%
B = 80 – 89%	F = <60%
C = 70 – 79%	

ATTENDANCE

Your attendance is **required** for all laboratories, unless otherwise noted. Class will begin promptly at **4:30pm** and will run no later than **6:50pm**. If, for whatever reason, you cannot make it to class on time, please do your best to enter quietly when you do arrive. More than two absences will result in an automatic grade of "F."

LABORATORY CONDUCT

Please make every effort to be courteous to your fellow students and myself. Policies regarding responsible conduct of research and ethics are expected to be adhered to (we will discuss these in class) and are essential not only in a "local" sense but in a broader, professional sense as well. Transparency and open lines of communication in the laboratory are critical. Therefore, please report all laboratory accidents, suspected instances of research misconduct, etc. to me ASAP.

BLACKBOARD

This course makes extensive use of Blackboard® (https://adminapps.utep.edu/blackboardlearn). You will use Blackboard to download the laboratory manual, submit assignments, download or print additional course materials, and check your grades. Please note that your login and password are the same as you would use to access your UTEP e-mail account.

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Structured Homework Assignments

In an effort to provide you with the necessary training and skills required for successful completion of your independent research projects, a series of ten (10) structured homework assignments will be administered this semester. These assignments correspond with the series of confirmatory laboratory exercises that occur at the start of the semester. All completed homework assignments are due at the beginning of the following class (see laboratory schedule below).

Research Proposal, Final Presentation/Report, and Notebook

Details regarding expectations and grading criteria for the research question and proposal, final research presentation/report, and notebook can be found as appendices within the laboratory manual. We will discuss these items in greater detail throughout the course.

Laboratory Schedule

Wk.		Date	Laboratory Topics	Assignment(s) Due
1	T/R	Aug. 29	-- NO LABS --	-
2	T	Sept. 5	Introduction to Laboratory	-
	R	Sept. 7	Lab #1: Scientific Inquiry	-
3	T	Sept. 12	Lab #2: Research Prop. Dev.	HW #1
	R	Sept. 14	Lab #3: Pop. Literature Lab #4: Eval. of Databases	Prelim. Prop.
4	T	Sept. 19	Lab #5: Qualitative Methods	HW #2
	R	Sept. 21	Lab #6: Quantitative Meths.	HW #3
5	T	Sept. 26	Lab #7: Peer Review + Ethics	HW #4
	R	Sept. 28	Lab #8: Biotechnology I	HW #5; Rough Draft
6	T	Oct. 3	Lab #9: Biotechnology II	HW #6
	R	Oct. 5	Lab #10: Microscopic World	HW #7
7	T	Oct. 10	Lab #11: Bioinformatics I	HW #8; Final Prop.
	R	Oct. 12	Lab #12: Bioinformatics II	HW #9
8	T	Oct. 17	Independent Research	HW #10
	R	Oct. 19	Independent Research	Notebook
9	T	Oct. 24	Independent Research	-
	R	Oct. 26	Independent Research	Notebook
10	T	Oct. 31	Independent Research	-
	R	Nov. 2	Independent Research	Notebook
11	T	Nov. 7	Independent Research	-
	R	Nov. 9	Independent Research	Notebook
12	T	Nov. 14	Independent Research	-
	R	Nov. 16	Independent Research	Notebook

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13	T	Nov. 21	Independent Research	-
	R	Nov. 23	*~~ THANKSGIVING ~~*	-
14	T	Nov. 28	Independent Research	Notebook
	R	Nov. 30	Analysis Workshop	-
15	T	Dec. 5	Final Presentations	Presentation
	R	Dec. 7	Wrap-Up + "Next Steps"	Final Lab Report

** **Please note that the course drop date is Nov. 3rd.***
*** Disclaimer: I reserve the right to change the contents of this syllabus due to unforeseen circumstances. Students will be given notice of relevant changes through Blackboard and e-mail. Assignment due dates will **NOT** change.*

5

DISEASE AND THE ENVIRONMENT: HEALTH DISPARITIES IN THE BORDER REGION II (BIOL 1108) – SPRING 2018

Instructor: Drs. Jeffrey Olimpo and Jennifer Apodaca
Office: B226 Biology Building (Fri. 11:00am - noon)*
E-mail: jtolimpo@utep.edu; japodaca15@utep.edu

*These are hours when I (Dr. Apodaca) am **guaranteed** to be in my office. If these times do not work for you, please send me an e-mail, and we can arrange another time to meet. I'm here to help!

COURSE DESCRIPTION

Welcome to *a study of life*! This course offers students a unique opportunity to explore the relationship between disease, the environment, and public health through an intensive, self-driven research experience. As opposed to traditional laboratory coursework, this means that *you* will be determining your own research questions, methods to use, types of experiments to perform, and "next steps" in the research process based on obtained conclusions. We (as your instructors) seek to promote an environment where (reasonable) risk is rewarded, overcoming failure is part of true scientific inquiry, and the contributions *you* make to science are invaluable.

COURSE OBJECTIVES

This course is designed to provide students with an authentic research opportunity in the biological sciences. Upon completion of the course, students will be able to:

- Utilize scientific process skills to make informed decisions throughout all aspects of the experimental process
- Apply principles of scientific inquiry to conduct a descriptive and/or analytic study of their choosing within the fields of health disparities, environmental health, molecular epidemiology, and public health bioinformatics
- Demonstrate an increased understanding of qualitative and quantitative research methods, as evidenced in written and oral deliverables
- Make meaningful empirical connections between diseases and the environment
- Describe, succinctly, the results of their research to both lay and scientific audiences
- Describe the impact of their research to communities of practice *outside* of the classroom

COURSE MATERIALS & CO-REQUISITES

1. Completion of BIOL 1107 *and* prior or concurrent enrollment in BIOL 1306
2. Laboratory notebook (a *non*-spiral bound composition book will suffice) and pen
3. Personal Protective Equipment (PPE) needed: laboratory coat; goggles

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ACADEMIC INTEGRITY

As members of a scholarly community dedicated to healthy intellectual development, students and faculty are expected to share the responsibility of maintaining high standards of honesty and integrity in their academic work. All material for this course must be your work and no one else's. **Cheating or plagiarism in any form will not be tolerated.** This includes, but is not limited to, copying someone else's work on an assignment. Please note that all suspected instances of plagiarism or academic dishonesty will be referred to the Dean of Students' Office, in accordance with UTEP policies and procedures.

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COURSE GRADING & EXPECTATIONS

COURSE GRADING:

- Weekly Research Updates 15%
- Participation/Attendance 15%
- Laboratory Notebook 10%
- Research Roundtable 20%
- Individual Development Plan (IDP) 5%
- Personal Statement 5%
- Résumé *or* Curriculum Vitae (CV) 5%
- Community Outreach Presentation 25%

A = 90 – 100%	D = 60 – 69%
B = 80 – 89%	F = <60%
C = 70 – 79%	

ATTENDANCE

Your attendance is **required** for all laboratories, unless otherwise noted. Class will begin promptly at **4:30pm** and will run no later than **6:45pm**. If, for whatever reason, you cannot make it to class on time, please do your best to enter quietly when you do arrive. More than two absences will result in an automatic grade of "F."

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Please make every effort to be courteous to your fellow students and myself. Policies regarding responsible conduct of research and ethics are expected to be adhered to (we will discuss these in class) and are essential not only in a "local" sense but in a broader, professional sense as well. Transparency and open lines of communication in the laboratory are critical. Therefore, please report all laboratory accidents, suspected instances of research misconduct, etc. to me ASAP.

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LABORATORY SCHEDULE

Wk.		Date	Laboratory Topics	Assignment(s) Due
1	T/R	Jan. 16	-- NO LABS --	-
2	T	Jan. 23	Orientation (Welcome)	-
	R	Jan. 25	Research Project "Reboot"	**Weekly Update**
3	T	Jan. 30	Independent Research	-
	R	Feb. 1	Independent Research	**Weekly Update**
4	T	Feb. 6	Independent Research	-
	R	Feb. 8	Independent Research	**Weekly Update**
5	T	Feb. 13	Independent Research	-
	R	Feb. 15	Independent Research	**Weekly Update**
6	T	Feb. 20	Independent Research	-
	R	Feb. 22	Independent Research	**Weekly Update**
7	T	Feb. 27	Independent Research	-
	R	Mar. 1	Research Roundtable Wkshp	-
8	T	Mar. 6	Research Roundtable Wkshp	-
	R	Mar. 8	**Research Roundtable**	**Roundtable; NB**
9	T	Mar. 13	~~ SPRING BREAK ~~	**-**
	R	Mar. 15	~~ SPRING BREAK ~~	-
10	T	Mar. 20	Careers in Science Wkshp	**IDP**
	R	Mar. 22	Research Internships	-
11	T	Mar. 27	Public Health Outreach (I)	**Résumé; Statement**
	R	Mar. 29	Public Health Outreach (II)	Outreach Plan
12	T	Apr. 3	Civic Engagement/Outreach	-
	R	Apr. 5	Civic Engagement/Outreach	**Weekly Update**
13	T	Apr. 10	Civic Engagement/Outreach	-
	R	Apr. 12	Civic Engagement/Outreach	**Weekly Update**
14	T	Apr. 17	Civic Engagement/Outreach	-
	R	Apr. 19	Civic Engagement/Outreach	**Weekly Update**
15	T	Apr. 24	Data Analysis Wkshop	-
	R	Apr. 26	Presentation Wkshop	-
16	T	May 1	Com. Outreach Presentations	**Presentation; NB**
	R	May 3	* End-of-Semester Potluck *	-

**** Please note that the course drop date is March 29th.***

*** Disclaimer: I reserve the right to change the contents of this syllabus due to unforeseen circumstances. Students will be given notice of relevant changes through Blackboard and e-mail.*

4

Public Health Outreach Flowchart (PHOF)

<u>Instructions</u>: Laura and Luis are undergraduate research assistants at a large, public university in Texas. They have observed, in their studies, a correlation between exposure to pesticides and increased incidence (i.e., number of cases) of asthma in their community. Resultant from this work, they now seek to create a public health outreach program that addresses this issue. **In the space below, draw a flowchart that, in YOUR opinion, best outlines the course of action that Luis and Laura should pursue in order to successfully implement all aspects of their outreach program.** You may use shapes (circles, squares, etc.) to separate ideas/terms and any arrows (→ OR ←→) to connect the ideas/terms. **Please be as complete and detailed as possible.**

Consider the Following:

- What goals are Laura and Luis trying to achieve, and how will they accomplish them?
- How will success be measured (i.e., how will they determine if their goals are achieved)?
- Who is involved in the process? Why?
- What are the societal implications of Laura's and Luis' efforts?

Public Health Outreach Flowchart (PHOF) Assessment Rubric

Connections
What type of connector is used to link ideas, concepts, etc. within the flowchart?

Public Outreach Goals
What is/are the purpose(s) of the outreach effort? Example items include: *increase public awareness*, *educate the public*, *increase community engagement*, *support ongoing or planned research efforts in the area of interest*, *etc.*

Measures of Success
How will you know if the outreach effort has been effectively implemented? Example items include: *qualitative research*, *quantitative research*, *mixed methods research*, *successful enactment of new policies*, *social media activity*, *etc.*

Involvement and Engagement
Who will be involved in the outreach effort? Example items include: *parents*, *children*, *local government officials*, *community foundations*, *students*, *research participants*, *etc.* NO CREDIT is given for mentioning either Laura or Luis!

Societal Implications
What are the impacts of the outreach effort on the broader community? Example items include: *Improved healthcare or quality of life*, *access to resources*, *increased awareness or knowledge among community stakeholders*, *etc.*

Interconnectivity
In what manner are ideas, concepts, etc. connected within the flowchart?

Dimension	#	Naïve (1)	Novice (2)	Intermediate (3)	Proficient (4)	Expert (5)
Items should only be counted once for any of the following.						
1. Connections						
Lines that connect ideas		Only	Some	None	None	None
Single-sided arrows		None	Some	Only	More	Less
Double-sided arrows		None	None	None	Less	More
2. Public Outreach Objectives/Goals		0 - 1	2	3	4	≥ 5
3. Determining Success of Public Outreach Efforts		0	1	2 - 3	4 -5	≥ 6
4. Involvement and Engagement		0	1	2 - 3	4 -5	≥ 6
5. Societal Implications		0	1	2 - 3	4 -5	≥ 6
6. Interconnectivity		Linear		Circular		Integrated
7. Counted Items and Total Ratings		**Total Items (Sum Items #1 - #5):**			**Total Rating (Sum Ratings #1 - #6):**	

Appendix 4: End of Semester SPC Prompts

1. How will you continue to engage with science and the public in your future career?
2. In your opinion, what is your role as a scientist in communicating with the public?
3. What have you learned in this course that will equip you to effectively connect the broader community with issues in science?

At the Intersection of Applied Sciences:

Integrated Learning Models in Computer Science and Software Engineering and Communication Disorders

MARISHA SPEIGHTS ATKINS
Auburn University

CHERYL SEALS
Auburn University

DALLIN BAILEY
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Abstract

The use of innovative technologies in speech-language pathology is revolutionizing diagnostic and treatment approaches for individuals with communication disorders. This evolution has required educators to integrate the use of technologies into the clinical training pedagogy. Phonetic transcription is a foundational skill presented early in the undergraduate speech-pathology curriculum and serves as the basis for advanced course work in clinical diagnostic decision-making. Mastery requires regular practice and performance feedback. One factor that impedes the provision of more practice opportunities is the widely agreed-upon problem of grading phonetic transcription assignments by hand. The development of a computational tool that automatically grades transcription assignments served as the mechanism for an integrated learning opportunity between the departments of Communication Disorders and Computer Science and Software Engineering at Auburn University.

Introduction

The use of innovative technologies for clinical practice in speech-language pathology is revolutionizing practices for diagnosis and treatment of communication-related disorders across the lifespan. This evolution has also required educators to integrate the use of technologies into the clinical training pedagogy. One such area is in the teaching of phonetic transcription (Abel et al., 2016; Mompeán, Ashby, and Fraser, 2011; Sullivan and Czigler, 2002; Titterington, and Bates, 2018; Vassière, 2003 Verhoeven and Davey, 2007). Phonetic transcription allows speech-language pathologists (SLPs) to (1) create a visual representation of the status of speech production skills and (2) to interpret the coded speech in order to make diagnostic decisions for individuals at risk for communication disorders.

Phonetic transcription is a foundational skill presented early in the undergraduate communication disorders curriculum (Howard and Heselwood, 2002; Randolph, 2015). Students of communication disorders must become experts in phonetic transcription, which involves capturing the sounds of speech in written form in order to create a transcript that represents how words were produced by an individual speaker (Knight, 2010). This written phonetic transcript is important for continued assessment and clinical diagnostics. However, phonetic transcription requires the development of the ability to categorize speech sounds perceptually into phonemic categories and to write what was perceived using the International Phonetic Alphabet (IPA) coding system (Howard and Heselwood, 2002, Ladefoged, 1990). The IPA coding system contains over 100 symbols representing consonants, vowels, diacritics, accents, and suprasegmentals. This is a substantial number of symbols to become familiar with, learn to identify, and use, within a single course. As in other scientific disciplines such as chemistry and computer science, a universal code allows for the standardization of the documentation, analysis, and interpretation of the code by specialists in the field, and just as the periodic table or JAVA Code may seem at first to be a foreign language to novices, the International Phonetic Alphabet (IPA) presents as a new language as well (Müller and Papakyritsis, 2011). Many students find this written code to be challenging, as it requires a cognitive shift from the standard written alphabetic code system to a perceptual system that captures the contrastive distinctions between the sounds in language (Knight, 2011). For example, although the words 'coat' and 'king' start with different letters in the standard written alphabet, phonetically, there is no distinction, and so the IPA characters are the same ('k'). Similarly, a single alphabetic character, such as the 's' in 'sing' and 'has,' may be represented by different IPA characters ('s' and 'z', respectively, in the previous example). In some cases, such as the words 'ball' and 'light,' the IPA characters have to be further notated with additional symbols (diacritic [ɫ] versus phoneme /l/, respectively) that describe the variation in how these two same sounds are produced in different places in the mouth although they are the same sound. This challenge is compounded as phonetic transcription tasks increase in complexity from individual sounds to full words and sentences. Advanced skills are required to transcribe using diacritics.

Students who want to become speech pathologists typically receive one semester of instruction in phonetics; however, recent attention has been drawn to whether this provides students with enough opportunities for learning (Randolph, 2015). Recent evidence supports the idea that additional opportunities for practice may positively affect student success (Hillenbrand, 2014; Hillenbrand, Gayvert, and Clark, 2015). Conversely, "the less experience students have in conducting phonetic transcriptions, the less apt they are at becoming proficient in this skill" (Randolph, 2015, p. 1). Surveyed practicing clinicians have also expressed the need for additional practice opportunities as students and for meaningful opportunities to extend their training further as practitioners (Knight, Bandali, Woodhead, and Vansadia, 2018).

The Real-World Issue

When learning methods for the transcription of disordered speech, it is beneficial for students to receive regular feedback on their progress and to have opportunities to collaborate with peers to understand the flexibility of speech perception during the transcription process. One factor that limits the provision of such experiences is the widely agreed-upon problem of grading phonetic transcription assignments (Heselwood, 2007). Traditionally, phonetic symbols are taught sequentially in a face-to-face instruction model, the students are assigned phonetic practice assignments on paper, and the assignments are graded later by hand. Students rarely get immediate feedback on transcriptions since grading by hand is time intensive. Additionally, when trying to provide timely feedback to students, it is often difficult for an instructor to get a clear picture of the overall types of mistakes students are frequently making and to utilize this feedback to inform instruction. The teaching of phonetic transcription therefore presents a unique pedagogical opportunity for enhancing student learning with the support of online learning platforms that could automate some of these processes (Titterington and Bates, 2018). The lack of an automated grading model for phonetic transcription assignments presents an important gap in the existing teaching tools. To address this gap, faculty from the Auburn University Department of Communication Disorders proposed the development of a computational tool, the Automated Phonetic Transcription Grading Tool, to automatically compare students' phonetic transcriptions of speech samples to their instructor's transcriptions.

Operationalizing and automating the phonetic transcription grading process through the implementation of such a computational tool has many benefits, including (1) decreasing instructor time and effort in grading phonetic transcription accuracy, (2) reducing scoring bias, (3) facilitating learning by providing students with immediate feedback, (4) informing the teaching process by providing data on student performance, and (5) increasing engagement and dynamic learning. Also, the ability to visualize summative class results allows students to see differences between their transcriptions and those of their peers. This visualization can promote discussion about differences in human speech production and perception and replicate real clinical cases where clinicians have differences in perception and clinical decision-making.

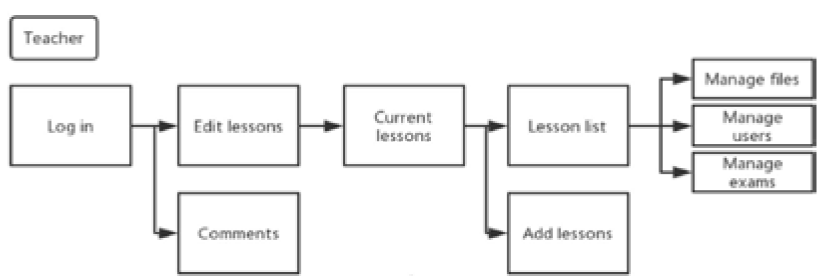
Interdisciplinary Learning Model

The development of the Automated Phonetic Transcription Grading Tool (APT-GT), served as a mechanism for an integrated learning opportunity between the departments of Communication Disorders (CMDS) and Computer Science and Software Engineering (CSSE) at Auburn University. Faculty in the CMDS department challenged the CSSE department to create a user-friendly, aesthetically pleasing web-based interface for practice transcription assignments (Norman, 2002), and to implement an algorithm to automatically grade the assignments. An answer to this challenge was the integration of student learning in CSSE and CMDS to inform the design and implementation. This service-learning opportunity allowed students in a User Interface Design course, a software engineering upper-level undergraduate and graduate course, to connect engineering science with the public issue of effective and efficient identification of individuals with communication disorders.

To design the APT-GT, the CSSE team first gathered requirements from the subject matter experts in the field (the CSDS team), then crafted user scenarios for the Student User, Teacher User, and Admin User of the system. The scenarios were captured utilizing Unified Modeling Language (UML) to capture a pictorial description of the system and cataloging roles, actors and their relationships, system interaction, and flow (Booch, Rumbaugh, and Jacobson, 2005; Rumbaugh, Booch, and Jacobson, 1998). Operation Logic was codified through simplified class diagrams to inform the design and describes the structure for the users of the system as illustrated in Figure 1 (Sparks, 1995).

Once the system scenarios were captured, software requirements created, software language identified, and environment identified, the software development team began iteratively developing software to instantiate this software system. The initial development began with the creation of low-fidelity drawings (i.e., paper prototypes) of our vision of the system and the creation of quick wire-frames of the envisioned system (Bailey, 1982; Shneiderman and Plaisant, 2010). In the second stage of prototyping, these images were refined to make them more detailed and to improve aesthetic appeal (Norman, 2002).

FIGURE 1: Operation Logic for the Teacher Role



Keyboard development

One special requirement of the system was the design of the IPA keyboard. Many of the other features that we have developed in the APT-GT system are available in existing course management systems, but one unique

FIGURE 2: Wire frames

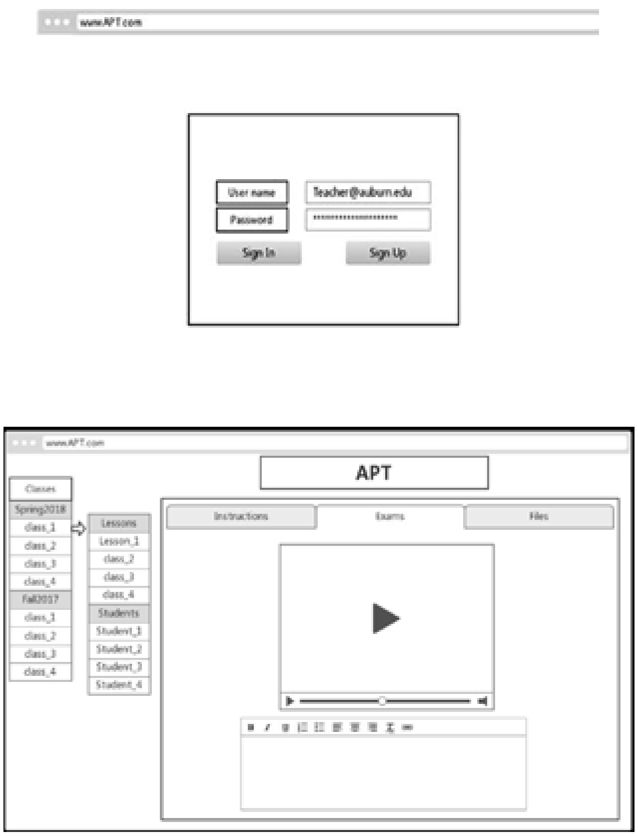


FIGURE 3: APT-GT Advanced Learner Keyboard Design

aspect was the development of an interactive IPA keyboard. Students typically are required to complete assignments by hand, download special fonts, or copy and paste symbols from websites (Small, 2005, p. 4–5). Students who are initially learning IPA may be additionally encumbered by the need to search for symbols in texts or online. In the design process, key placement and size were considered to reduce the time searching for keys. Multiple versions of the keyboard were implemented to engage students in basic American English broad transcription ("Keyboard 1"), advanced narrow transcription of disordered speech using diacritics ("Keyboard 2"), and a complete set for full IPA implementation for international and multilingual use ("Keyboard 3"). Scaffolding the keyboard complexity was considered in order to reduce confusion for the novice user and build confidence in the task incrementally.

Outcomes of the Integrated Learning Model

CMDS course

Implementation of the software tool was supported by the first and third authors' articulation and motor speech disorders courses in CMDS. CMDS students collaborated through the participatory design process (Bailey, 1982; Shneiderman and Plaisant, 2010) to aid in the development of the first version of APT-GT. Students (n=67) in undergraduate and graduate course work were used as beta testers to provide ease of use feedback to the student-led design team. Student feedback was used for refinement of the software to meet identified instructional needs. The students were surveyed at the beginning and end of the semesters to determine if the applied computer-supported learning environment with automated performance feedback increased confidence in their mastery of transcription when given additional practice. Students were asked the following: What is your greatest concern in transcribing disordered speech? What do you think you need to learn to be a more confident transcriber? If your level of confidence is different now compared to the beginning of the course, what aspects of the training modules do you think affected your level of confidence? What components of the transcription modules seemed helpful to you in learning phonetic transcription? The data were analyzed qualitatively to understand student sentiment following transcription practice modules. Open-ended responses were collapsed into themes independently by two research analysts. Themes were further collapsed into broad categories agreed upon by the two researchers.

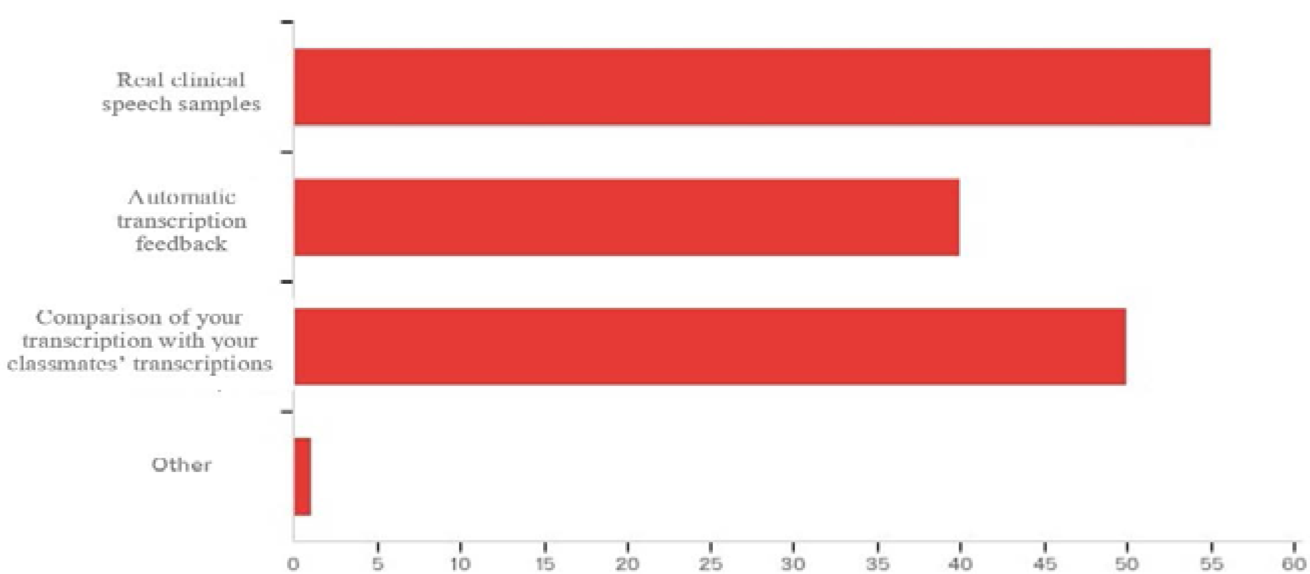
Results

Students' greatest areas of concern in transcribing disordered speech were in their ability to understand disordered speech (38%), to transcribe accurately (39%), to transcribe speech sounds (20%), to transcribe quickly (1%), and their general lack of experience (1%). To be a more confident transcriber, students expressed the need for increasing their knowledge of the phonetic symbols (39%) and additional opportunities for practice (35%). Levels of confidence were reported to have increased as a result of additional practice opportunities (32%), the variety of speech samples, which included talkers with different disorders (31%), automated feedback (13%), and comparison of peer results (13%). Others commented on the ease of use of the keyboard and the frequent opportunities for practice. When asked which components of the transcription modules were most helpful, students rank-ordered the following items (one being the highest): (1) access to real clinical speech samples, (2) the ability to compare transcriptions with those of classmates, and (3) obtaining automated transcription feedback (see Figure 4). A few (six) students indicated that they did not think the transcription modules increased their confidence, and one student did not feel that they benefited from the modules.

CSSE course

This User Interface Design course helped CSSE students integrate the theory of user interface design by engaging in practical software development projects through a fully elaborated real-world case study. This course model typically gives students a solid understanding of the user interface design process (Wolf, 2012; Holtzblatt and Beyer, 2014; Caristix, 2010). The current learning episode included the following components: gathering of requirements, task analysis, development, testing, and a project presentation of findings from preliminary user evaluations pertaining to the analysis of user satisfaction and system effectiveness. It also gave them real-world experience in teamwork, as they collaborated with a team of four to eight individuals, as well as additional practice in important programming skills.

FIGURE 4: Student Ranking of Transcription Modules Components Considered to Be Helpful



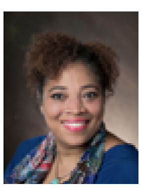
Conclusion

Through this collaborative and multifaceted effort, we aimed to create a rich learning experience for students in both departments to increase the efficiency of CMDS and CSSE instruction. Students in both classes had opportunities that increased engagement and interaction with science-based applied methodologies for addressing current public health issues. This marriage of computer software engineering and communication disorders learning objectives met two major goals: (1) to provide increased student engagement and (2) to increase applied science by addressing real-world problems. Instructors were able to close the theory-to-practice gap in two different disciplines through interdisciplinary collaboration.

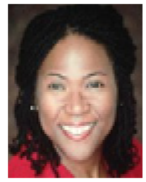
Future directions

We are currently working on making the learning management system more widely available to allow for testing by faculty at other institutions, particularly within the CSD profession, but also by teachers of linguistics and foreign languages and teachers of English to speakers of other languages. We also aim for further development and refinement to improve the user interaction experience and to improve technical support for usage with other languages.

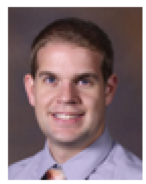
About the Authors



Dr. Marisha Speights Atkins is an assistant professor at Auburn University and Director of the Technologies for Speech-Language Research Lab. Her work focuses on the development of innovative technologies for diagnosis and treatment of speech disorders. Her research interests include child speech production and disorders, acoustic-based technologies for assessment and treatment of speech disorders, speech intelligibility, and remote assessment of speech disorders through telepractice.



Dr. Cheryl Seals is an associate professor in Auburn University's Department of Computer Science and Software Engineering. Dr. Seals directs the Auburn University Computer Human Interaction Lab, which develops computing applications to improve the usability of products for many different populations (4-H, K-12 Teacher Education, introductory computer programming, and mathematics education and reinforcement applications). Lab efforts include development of educational applications to support advanced personalized learning tools and testing applications to determine instructional potential and design usability for a population, with the goal of universal usability.



Dr. Dallin Bailey's clinical research efforts primarily involve using linguistic tools to enhance treatment outcomes and patient satisfaction for aphasia and apraxia of speech treatments. His research focuses on the development and testing of treatments and treatment outcome measures for aphasia and apraxia of speech, kinematic measurement of speech motor learning, abstract word processing, verb processing, and single-subject research design.

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Local to Global:

Civic Engagement with Education, Awareness, and Global Health

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Abstract

Global Public Health is a course that allows students to learn about the complexity of communicable and non-communicable diseases, determinants of health, and delivery of health services. The Global Public Health course partnered with the Center for International Students to co-host International Education Week in November 2017. Specifically, the course held a "global successes" poster presentation event highlighting various initiatives including disease reduction, cash transfer programs, health system comparisons, and emergency preparedness. The project encouraged a dissection of the biological aspects while also focusing on the socioeconomic contexts, geo-political partners, and advocacy efforts to determine the factors that played into successful health initiatives. Quantitative and qualitative data were collected to assess project outcomes. The reach of the event was with the campus and local communities. Students reported that the project allowed them to develop an appreciation for the vastness of global health, while also identifying the importance of sustainability.

Introduction

Global health courses offer excellent opportunities for students to learn about issues outside of their local, state, and national communities. By developing projects that allow them to transcend their texts and engage with the content, they can begin to step out of their local contexts and apply their learned global knowledge. Along with learning about global health issues, students often feel disengaged to such "wicked" or massive global problems that exist. Wicked problems, including climate change, gender inequality, famine, human trafficking, and complex humanitarian issues, are defined as such because there are many stakeholders with differing opinions, and ultimately, "each attempt to create a solution changes the problem" (Kreuter, De Rosa, Howze, and Baldwin, 2004, p. 443). Focusing on a massive problem like climate change, studies have demonstrated that students are disengaged with the science regardless of their knowledge about the topic, because they lack action and self-awareness about their roles with the issue (Wilson and Henson, 1993; Cordero and Abellera, 2008; Feldmann, Nisbet, Leiserowitz, and Maibach, 2010; Wachholz, Artz, and Chene, 2014; Pfautsch and Gray, 2017). According to Reimers (2017), leaders in multiple fields including business, diplomacy, and military science were interviewed regarding their views on student readiness to address challenges with a global mindset. It was consistently reported that gaps among students exist for awareness of global issues (National Research Council, 2007; Reimers, 2017). Using case studies in the classroom has been demonstrated to assist students in identifying the "solutions for real-world scenarios . . . to raise self-awareness and improve sustainability literacy" (Pfautsch and Gray, 2017, p. 1168; see also Remington-Doucette and Musgrove, 2015).

Although global challenges exist, successes in addressing these issues are evident as maternal and child mortality have continued to decrease along with a more pronounced focus on diseases such as HIV/AIDS, tuberculosis, and malaria (Centers for Disease Control and Prevention [CDC], 2011; Jacobsen, 2014; Merson, 2014; Glassman and Temin, 2016). New medications are being developed along with lifesaving technologies and vaccinations, and via enhanced surveillance and reporting efforts, preparedness for global threats continues to be strengthened (CDC, 2011; Jacobsen, 2014). By highlighting that achievements are possible, we can assist future generations in identifying how to harness their knowledge and incorporate moral and ethical reasoning to enhance their competency in addressing issues that need sustainable solutions (Pfautsch and Gray, 2017).

Identified in the texts, *Millions Saved: Proven Successes in Global Health* (Levine and Kinder, 2004) and *Millions Saved: New Cases of Proven Success in Global Health* (Glassman and Temin, 2016), are over 35 different examples of interventions that have lasting health education and promotion effects. Using these case studies, college students can embark on an educational journey to better identify the roots of disease, disability, and death from a global perspective. In the Global Public Health course, students were challenged to find a global health endeavor that was "successful" and define, using multiple lenses, what "success" means. Students had to go beyond reading a case study and dissect the topic to gain a better understanding of factors such as the physiology of disease and the impacts of economic policies on effective health measures.

Project Description

Six student groups, ranging from two to four students per group, researched case studies including neglected tropical diseases and successes of the Deworm the World Initiative (https://www.evidenceaction.org/dewormtheworld), global vaccination perspectives in Cameroon and Southern Ethiopia, and behavior modification to eradicate guinea worm. Incorporating an interdisciplinary approach to understanding their chosen case studies, students identified underlying causes of disease (or health issues) using an agent, host, environment model to better explain how the interventions and/or successes broke the chain of causation. Specifically, students focused on disciplines including public health, health education, epidemiology, and biology. To display their case study outcomes, students developed professional 3x4 posters. In a partnership to co-host International Education Week with the Center for International Students (November 2017), students in the Global Public Health course held a poster presentation focusing on global health successes. The event was the kick-off feature, and all of campus and the local community was invited. Goals of the event were to invite discussion about pertinent global health issues that transcend national borders. To encourage attendee participation, international coffee, tea, and food items were served. All materials and supplies were purchased with funds from the Missouri Campus Compact mini-grant. For project assessment, student groups were evaluated on the guiding research questions developed for their topic, the historical and health background, elements for success (including impact, sustainability, and cost-effectiveness), the organizations involved with continued efforts, policies in place to address the issue, and finally, ways for individuals to get involved locally. To evaluate the poster event, attendees completed a short survey with 5-point Likert-scale questions from strongly agree to strongly disagree regarding the presenter knowledge, enthusiasm, professionalism, and preparation. An open-ended question was added to seek what attendees learned from attending the poster event. At the end of the course, student feedback was obtained via a short survey with a 5-point Likert-scale regarding their development of the poster content, impacts of the project on their learning, and three open-ended reflection questions. Open-ended questions were analyzed using a content-analysis procedure for patterns and themes (Altheide, 1987; Merriam, 2009), and quantitative data were analyzed using IBM SPSS 25. IRB approval was obtained in Fall 2017 before any data were collected.

Project Outcomes

Six different posters were presented. Student presenters interacted with attendees (n=~40) including members of campus administration, faculty, staff, and students from various majors. Overall, feedback from presentation attendees (n=20) was positive, with 90% strongly agreeing that presenters were prepared and knowledgeable about the material. Regarding enthusiasm and professionalism, over 95% of attendees either agreed or strongly agreed that students were excited to present and were credible regarding the content. Attendees' comments for learning outcomes were positive and varied about what they gained from the experience. Themes from those outcomes included being unaware (n=9), identifying keys to health successes (n=8), and that successes have global outcomes (n=1). A sample of quotations for each theme is available in Table 1.

For project impacts for students in the course, 100% of students who completed an evaluation agreed or strongly agreed that focusing on global health successes was important, and over 90% agreed or strongly agreed that providing service-learning opportunities in global health was important. Overarching themes students reported focused on their surprise for the vastness of global health successes (n=5), different ways to measure success (n=4), personal gains acquired from the project (n=1), and that we are all global citizens (n=1) (Table 2).

Discussion and Suggestions for Future Practice

By engaging with the broader campus community, students participated in open discourse to identify the importance of partnership, science, sustainability, and global citizenship to address the issues. To promote the events of International Education Week, a local news station also attended the poster presentation to learn more about the topic and provide awareness. As previously stated, students may be disengaged in the classroom if lectures and assignments lack an action or self-awareness component (Wilson and Henson, 1993; Cordero and Abellera, 2008; Feldmann et al., 2010; Wachholz, Artz, and Chene, 2014; Pfautsch and Gray, 2017). This course project was an attempt to combine students' awareness for these massive problems and research the failures and successes of the efforts to address these real-world issues. An additional component for the case study was to suggest ways in which we can advocate for these topics. Students developed ideas including identifying NGOs that are continuing to work on the issues, specifying ongoing research studies and ideas for further research, and ways in which we can expand community-based programs.

With the knowledge gained from implementing this project, instructors should build in more class time for posters to be developed and for students to reflect and to determine their questions as they navigate the research process. Students should also engage in peer review frequently throughout the semester. Peer review only occurred one time, at the mid-point of the project, and everyone would have benefitted from hearing regularly about each other's topics, challenges, and strengths. Another interesting learning outcome would be to prepare students on how to present at a formal poster event and explain who might be in attendance. According to one student, "I was caught a little off guard when [the Vice President] and [Department Chair] showed up."

To broaden this type of project, as Merson (2014) demonstrates, universities can engage in global health endeavors by acting as springboards for interdisciplinary collaboration of faculty and students from various institutions. Next steps for more transformative student experiences and value-added projects would be to build existing projects by partnering with different disciplines and other institutions (domestic and international). According to Ehrlich (2000), civic engagement is defined as "working to make a difference in the civic life of our common unities and developing the combination of knowledge, skills, values, and motivation to make that difference" (p. vi). As this project started in the classroom and expanded to the campus and surrounding community, this definition of civic engagement was followed, demonstrating that global successes are evident and that we should celebrate them.

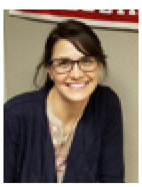
TABLE 1: Themes from Attendee Learning Outcomes

Themes	Unaware of Interesting Findings	Keys to Health Successes	Successes have Global Outcomes
Example quotations that fit each theme	"Underdeveloped nations are doing well with advancing public health." "There are many more successful programs than I thought!" "The healthcare presentation was my favorite. I had no idea the healthcare system in Brazil was so similar to the U.S." "I learned more about emergency preparedness." "Underdeveloped nations are doing well with advancing public health." "Worms are gross and water can be a terrible source of susceptibility for parasites." "Kenya seems to be leading African countries in successfully implementing vaccination and education programs. Indonesia was prepared for a natural disaster and other countries should look at their evacuation program."	"I learned that the amount of planning and preparation is so imperative to the success and that there is no one single solution which can be applied universally." "I learned that education and awareness is the best way to improve health quality for any country." "Government's corruption impacts a lot on health programs." "Variety of costs/benefits—every program faced different challenges and had different levels of success with different implications." "Education is important among communities for global health success!" "Kenya is very successful, and so is Rwanda. In addition, just because some programs did not work does not make them a failure. We can learn from that!"	"I learned about issues that may have large global effects, but that Americans do not know about."

TABLE 2: Themes from Student Project Outcomes

Themes	Vastness of Global Health Success	Different Ways to Measure Success	Global Citizens	Personal Gains
Example quotations that fit each theme	"Some of the aspects/ projects in global health I'd previously thought were unsuccessful actually do work." "Universal health care can be achieved." "Global partnerships and behavior modification strategies" "Kenya is doing a phenomenal job in public health."	"Continued progress leads to sustainability." "Sustainability and partnerships with local and national government helps a program be a successful one." "There are a lot of different ways to determine success, and people may have different opinions about that." "Communication and education delivered in a culturally competent way are very important to global health successes."	"We are all affected by what happens around the world."	"I learned so much about my topic—I knew nothing about helminths prior to this and now feel like an expert!"

About the Author



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Incubating the SENCER Ideals with Project-Based Learning and Undergraduate Research:

Perspectives from Two Liberal Arts Institutions

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Abstract

Maintaining undergraduate interest in STEM is a formidable challenge. Numerous studies have reported that structured, authentic research experiences in the classroom increase retention rates and introduce students to the skills needed to conduct independent research as upperclassmen and beyond. Most importantly, these strategies are inclusive, enabling all students, regardless of their backgrounds, to be exposed to and involved in research. However, few reports are available on the efforts of SENCER faculty to grow and support inclusive undergraduate research at small liberal arts institutions. Here we describe approaches being taken and challenges being faced by SENCER faculty at two liberal arts institutions while they strive to achieve the SENCER ideals and to promote civic and scientific engagement at their institutions through research and project-based learning.

Introduction

Classroom-based Undergraduate Research Experiences (CUREs) and Project-Based Learning (PBL) have been shown to enhance the career development and readiness of students and can substantially impact retention in STEM disciplines (e.g. Strobel and van Barneveld, 2009; Bangera and Brownell, 2014; Jordan et al., 2014). CUREs and PBL are inclusive, exposing a greater number of students to high-impact experiences (Bangera and Brownell, 2014). Projects can also be designed to generate meaningful data that can inform further student research projects as well as the research agenda of the faculty member (Shortlidge, Bangera, and Brownell, 2017).

At Mercy College and Young Harris College (YHC), the faculty define PBL as a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate an authentic, engaging, and complex question, problem, or challenge (Eberlein et al., 2008) and a CURE course is one in which students are expected to engage in science research with the aim of producing novel results that are of interest to the scientific community (Corwin, Graham, and Dolan, 2015). We use an inclusive definition of undergraduate research (UGR) here as being an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline.

With careful and thoughtful design, these experiences can help students gain exposure to research while enhancing their critical thinking, communication, and quantitative reasoning skills (Auchincloss et al., 2014). Providing authentic experiences also improves student confidence, motivation, and attitudes about research in comparison to "cookbook" labs (e.g. Brownell, Kloser, Fukami, and Shavelson, 2012; Brownell et al., 2015), which can prompt greater retention in traditionally challenging disciplines. For instance, students in an open-ended research laboratory course reported greater project ownership and a desire to discuss materials and collaborate with other students, in contrast with students who followed predetermined lab protocols from a manual (Brownell et al., 2012). A CURE approach also significantly increased the likelihood that undergraduates would want to pursue independent research (Brownell et al., 2012) and their ability to correctly analyze novel datasets during exams (Brownell et al., 2015). Numerous models and resources to implement CUREs and PBL have been described, and there are several faculty and institutional networks that encourage and foster collaborative experiences between students and faculty to tackle real-world problems. CUREnet: Course-Based Undergraduate Research Experiences (https://curenet.cns.utexas.edu) hosts a plethora of CURE examples and a detailed compendium of funded projects (with faculty contact information, objectives, and lab overviews). SEA-PHAGES: Science Education Alliance – Phage Hunters Advancing Genomics and Evolutionary Science (https://seaphages.org) is designed to isolate new viruses from soil samples and expose undergraduates to research methods in microbiology, genomics, bioinformatics, and evolutionary biology. Two antibiotic discovery networks, the Small World Initiative (http://www.smallworldinitiative.org) and Tiny Earth (http://tinyearth.wisc.edu) task students with isolating bacteria from soil samples to screen for antibiotic production and resistance while promoting science literacy and training in microbiology, molecular biology, and genetics lab techniques.

The learning outcomes of CUREs and PBL clearly overlap with SENCER ideals. Both invoke complex, open-ended problems that challenge students to recognize the limits of scientific knowledge and apply quantitative reasoning to address global issues. These key learning outcomes will help us improve civic and scientific literacy among our students, which we define as literacy that deals with accessing and assessing basic scientific constructs required to generate informed public policy decisions involving science and technology. By first understanding the relevance of wicked problems and then striving to solve them, students construct skills for independent learning, develop intrinsic motivation, and are prepared to be engaged 21st century citizens. At both institutions, we are scaffolding the experiences and approaches throughout our curricula so students gain relevant training that can be reinforced as they progress towards capstone courses and independent research. While students from Mercy College and YHC have not directly interacted, faculty from both institutions have recognized overlapping goals regarding the implementation of UGR at small liberal arts institutions. This has led to ongoing discussions during SENCER meetings between the schools to build on existing initiatives. Given their different demographics and mission statements, we felt that contrasting approaches undertaken by both institutions would illustrate unique strengths and challenges associated with implementing pedagogical reform within diverse liberal arts environments.

Leveraging SENCER at Two Small Liberal Arts Institutions

Mercy College is a federally designated Hispanic Serving Institution with about 6300 undergraduate students, 62% of whom are underrepresented ethnic minorities (UMs), with three main campuses in the Bronx, Manhattan, and Dobbs Ferry. Admission to Mercy is SAT/ACT optional. The biology program enrolls approximately 250 students and attracts a high percentage of UMs. Many are transfer students, of nontraditional age, and/or commuters, and the majority receive federal Pell grants. In the biology major, many students hail from high-needs high schools, are of first-generation college status, and/or care for a dependent.

National data trends show that the biology program has had a substantially higher attrition rate at Mercy than at colleges with similar admission standards. When asked, most often Mercy students have concerns regarding the biology major; worries about getting a job post graduation, about the impact of negative course outcomes on their GPAs, and about the workload associated with STEM courses (both the rigor and extent of work required). Analysis of our students has shown that they are most often transferring to majors that they perceive to be less arduous (psychology and health sciences), regardless of whether or not they are, in fact, less difficult. While there are great opportunities for students to engage in research in upper-division courses, we tend to lose students in their first year, since many students fail or fail to continue introductory biology and chemistry courses. This indicates that our efforts need to target the introductory sequence and improve our pedagogy and outcomes therein.

Our concerns about student success and retention in STEM majors like biology have led to major efforts within our college, our school, and the Natural Sciences Department. The Maverick Success Toolkit (a college-wide initiative of our President Timothy Hall is targeting "High-Impact Practices, including undergraduate research" (AAC&U, 2008). In Natural Sciences, the high-impact practices (HIPs) we are focused on includ CUREs and PBL, which address key program outcomes for the biology program at Mercy, include students being able to (a) critically examine basic, applied, and societal problems in the biological sciences and through the lens of life sciences professionals, (b) propose problem-solving strategies to address these problems, and (c) work as effective team members on collaborative projects. By engaging our students in collaborative projects and improving their problem-solving strategies with PBL and CUREs, we could reach our desired programmatic outcomes. Other initiatives and activities supporting the growth of UGR at Mercy include regular Faculty Seminar Days, when all faculty across the college participate in faculty development, a Council of Undergraduate Research (CUR) site visit, a monthly seminar series featuring local researchers, a yearly STEM day open to local high schools, and regularly co-hosting the Westchester Undergraduate Research Conference with Manhattanville College.

Young Harris College is a rural, residential, Methodist-affiliated liberal arts institution with just under 1,000 undergraduate students, over 80% of whom are white. The vast majority (93%) of students are Georgia residents, with an average SAT score of 1083 in 2017. Biology is consistently one of the top majors at the institution, comprising 15–18% of the total declared majors in a given year. As at Mercy, there is a drop in declared majors following the introductory biology and chemistry sequence, as they are perceived to be challenging courses.

YHC has a mixture of established initiatives in place to promote UGR and scholarship among upperclassmen. Biology majors are primed for research via a two-semester course sequence on experimental design and analyzing scientific literature. In their senior year, majors can choose between conducting an independent research project or a literature review. Only about a third of majors conduct research projects, and students who elect to do research typically spend one semester on the project before presenting it as a senior capstone. The college holds an annual campus-wide Undergraduate Research Day, which provides students the opportunity to present original research in a low-stakes environment. The Biology

Department also provides travel stipends to students who conduct UGR to present findings at the annual Georgia Academy of Sciences meeting, but travel by students to national conferences is less common.

YHC has had a minor SENCER connection since transitioning from a two- to a four-year institution in 2008, including a site visit and an interdepartmental team trip to a SENCER Summer Institute. However, campus-wide knowledge of SENCER is low, even though several faculty members actively promote civic engagement in their classrooms. Many of these initiatives are conducted independently, without extensive intra- or inter-departmental knowledge of the projects. This issue stems from a high teaching load and limited course release options, reducing the ability of faculty to apply for fellowships and grants.

What we have done at Mercy

Currently our efforts are focused on making UGR more inclusive. One approach is to integrate research across the curriculum, thereby serving more students. Particular focus has been placed on engaging students earlier on in the curriculum such as in introductory courses. Internal funding from Mercy has been directed towards the CURE project, to help the faculty attend professional development opportunities such as the PBL Institute at Worcester Polytechnic Institute (WPI) and to bring experts to the campus, including Dr. Monica Devanas of SENCER. A new position, the Undergraduate Research Coordinator, was created in the department to support UGR. Figure 1 shows our progress towards the incorporation of CUREs or PBL across the curriculum. To reach across the disciplines and to break down the discplinary silos, our approach to defining research has been broad and inclusive, and we have included aspects of the research process (literature reviews, poster presentations, designing experiments *in silico*) in our scaffolded approach. Here are some examples of our SENCERized efforts across the curriculum:

At the General Education level

Students in the Environmental Science class for non-science majors self-assign into teams and engage in student-chosen and student-driven projects aimed at solving environmental problems visible and meaningful to the Mercy community. At the end of the semester, they present proposals to solve a particular problem. In Fall 2016, students surveyed the college community on recycling, and generated an interdisciplinary proposal to reduce plastic use in the Mercy cafeteria. It was presented to the Mercy administration and helped make the case to reduce plastics in the cafeteria.

At the Introductory Level

In General Biology 1, students choose to research topics of civic and scientific importance relevant to the biology course (climate change, emerging infectious diseases, GMOs). The students generate posters, and learn how to cite and produce a bibliography. Librarians help us print and present the posters in the library and we hold poster sessions in public spaces, such as the corridor outside the labs, allowing the greater community to witness and engage with student work.

General Chemistry 1 also involves public poster presentations of the students' work. The projects are constructed around the theme of isotopes and nuclear chemistry, and students choose a project topic linking nuclear chemistry to societal issues such as radioactive accidents, global warming and evolution. As with biology, the students work in teams and are peer-assessed on their teamwork. The General Chemistry laboratory has also been redesigned to include a project, the theme of which centers on connecting acid-base chemistry to commercially available antacids. Antacids provide a perfect entry point for freshman students to understand the concepts of acids and bases and their relevance to health and biology. Students generate their own hypotheses to test, and in consultation with the instructor, design experiments, collect and analyze data, and submit a comprehensive lab report on their project.

Introductory Physics is a two-semester sequence, with embedded exploratory laboratory modules. It is project based, with students posing their own inquiries and making inferences based on analysis of their own data. Initially, student inquiries focus on biomechanics with emphasis on experimental design and collaborative execution. Then, inquiries expand to the physical mechanisms underlying biological processes, normal and impaired physiological functioning and/or medical diagnostics and treatment. Every student creates an ePortfolio of their final project work, which is viewable by the entire college community. Students self-assess and peer-assess their progress, and final projects are used to evaluate their competence in their inquiry, modeling, quantitative analysis, and communication skills.

At the Intermediate Level

We've previously reported on the development of a SENCERized elective CURE course called the "Microbiome of Urban Spaces" (Smyth, 2017), which began in Spring 2016. The microbiology lecture course was also redesigned to help students be more civically engaged using PBL. Students were instructed in aspects of policy and regulations (clean air and water acts, the EPA), health care disparities, and the rise of antibiotic resistance. They prepared educational materials (brochures, infographics, posters) that would be accessible and promote awareness of various topics of civic import in their communities, such as antibiotic-resistant bacteria in food, climate change, and emerging infectious diseases such as Zika.

PBL was introduced in the Organic II lab curriculum in the Fall of 2017. The topic chosen was sunscreens, as they are organic compounds that absorb solar radiation and can minimize UV damage or sunburn. Recently Hawaii banned sunscreens containing oxybenzone and octinoxate as active ingredients (these ingredients have a high sun protection factor). Divers use these on their faces, but the compounds are insoluble in water and can cause coral bleaching and disruption of marine ecosystems. The topic has societal implications and would appeal to students going into medical fields, as it links the study of organic chemistry to cancer, a topic usually restricted to biology students. Students chose to analyze the different active ingredients present in commercially available sunscreens to measure their UV absorbance/antioxidant properties. Currently the students are synthesizing organic compounds and are going to evaluate these for sunscreen properties.

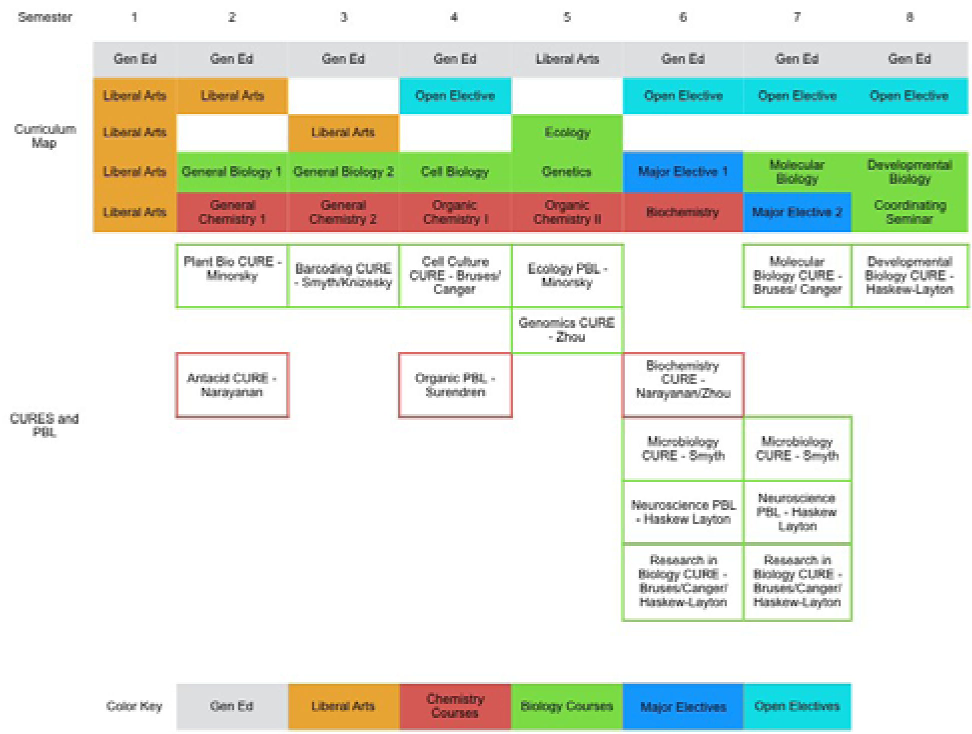
At the Advanced Level

Our efforts at the introductory and intermediate levels have prepared students for more advanced research experiences in developmental biology, neuroscience, and in a new "Research in Biology" course. The capstone course has also been redesigned from a literature review course to an authentic lab-based research course in which students can conduct independent projects. Faculty who work with students on independent projects have benefited from students progressing through the scaffolded curriculum, as these students are more confident, capable, and dependable in the lab. Their successes at conferences and meetings and acceptances to prestigious Research Experiences for Undergraduate programs (REUs) and internships support these observations. Student presentations at local conferences (such as the Westchester Undergraduate Research Conference, the SENCER SCI Mid-Atlantic Meeting, and the Metropolitan Association of College and University Biologists Conference) have increased from one in 2012/2013, two in 2013/2014, three in 2014/2015, nine in 2015/2016, six in 2016/2017, 28 in 2017/2018, and 11 in 2018/2019. There were no student presentations at national/international conferences (such as ABRCMS, ASM, SACNAS, and CSTEP) from 2013–2015, but there were eight student presentations in 2016/2017 and four in 2017/2018. Students have also increasingly been rewarded for their work with poster awards at CSTEP (in 2017 and 2018), travel awards to attend ABRCMS (in 2016), and an ASM Capstone award (in 2017), and they have been accepted to prestigious REUs for the first time in many years, such as SURP at Albert Einstein (in 2017), SURP at Rutgers (in 2018), and at SURP at NYU (in 2018). One of the most significant changes is the increase in chemistry-focused research involving undergraduates at Mercy, which had been stagnant for many years.

What We Have Done at YHC

The teaching load at YHC provides challenges and opportunities for incorporating SENCER ideals across the curriculum. In biology, most courses are developed without substantial input by other faculty. Faculty who choose to implement novel pedagogies are encouraged and have free rein to do so. However, the benefits of these designs can go unnoticed by administrators or colleagues unless explicitly promoted. In recent years, subsets of the division have applied for educational grants (e.g. NSF S-STEM) but have not received an award thus far. Therefore, although financial support for developing a cohesive departmental initiative is minimal at present, a scaffolded, SENCERized curriculum is certainly feasible in the future.

FIGURE 1



This figure is a representation of how PBL and CUREs have been integrated throughout the biology curriculum at Mercy College. These efforts are at various stages of completion and represent our commitment to scaffolding research across the curriculum to give as many students as possible an opportunity to engage in research. The color key indicates the category into which the courses fall (General Education, Liberal Arts, Major Electives, Biology, and Chemistry).

At the General Education and Introductory Levels

Arguably the area of greatest need for promoting civic engagement and scientific literacy at YHC is within non-majors courses, as these students generally fail to see the relevance of or are disinterested in biology. Similar trends have been observed at other institutions (e.g. Cotner, Thompson, and Wright, 2017). To combat this, one non-majors course (Exploring Life) was redesigned to promote the civic value of biological literacy in addition to content-related learning objectives. Instead of a traditional exploration of molecular biology, genetics, and evolution, these concepts were built into a modular approach. Each module was selected by students and used four weeks to explore a critical biological issue, such as epidemics, vaccinations, GMOs, or the antibiotic resistance crisis. Whenever possible, community connections were brought into each unit to promote a civic outlook in the topic, such as instilling awareness of disease agents on campus or considering the prevalence of GMOs in local markets. One unique element of the Exploring Life redesign was that students in the course were offered a choice between six potential modules at the beginning of the semester, of which the three topics with the highest number of votes were used as topics for the course. This design provides greater flexibility to other instructors, as they can select which six modules they are most comfortable offering each semester, or they can develop a new panel of modules to add to the course portfolio, provided that they meet established content guidelines.

During redesign for non-majors biology, a concerted effort was made to expose social challenges, embrace statistical analysis, and analyze peer-reviewed articles using established, student-centered teaching practices. Final projects for each theme were designed to promote scientific communication to non-scientists, such as designing a board game to illustrate how viruses spread through a community, or constructing a college flyer to highlight contributors to antibiotic resistance. Labs used an inquiry-based approach to demonstrate modern research techniques, although more structure was provided in comparison to recently redesigned open-ended labs in majors' introductory biology courses. Some lab modules were based on previously established CUREs (such as

Tiny Earth), while others were developed following workshops with Research Experiences in Introductory Laboratories (REIL)-Biology.

Our non-majors chemistry course also explores subjects that enhance student awareness of globally relevant topics, such as green chemistry. Introductory courses at the majors level are moving towards student-centered practices, but arguably lag behind efforts at the non-majors level. The degree of active learning within a section of introductory biology varies widely depending on the instructor of record; however, groups of faculty have collectively restructured lab activities to include inquiry elements, including a multi-week student-designed authentic research project for our introductory organismal biology course.

At the Intermediate and Advanced Level

In addition to department-wide initiatives to reinforce scientific literacy and training for biology majors (see examples in the institutional profile), most faculty promote a student-centered teaching environment to some degree, such as utilization of kinesthetic models in cellular biology, analysis of public environmental science data, preparing students for the workforce by utilizing discipline-relevant, open source statistical software (e.g. the R Project), and flipped classrooms. When possible, YHC faculty tie course content into their own research interests or connect topics to the rural, montane environment where our campus resides. Many YHC students hail from the Atlanta suburbs, and finding ways for them to connect to the YHC community is critical for retention.

Over the past five years, the majority of biology faculty teaching upper division courses have shifted from "cookbook" labs to incorporate greater inquiry-driven pedagogical approaches. The rationale for this is twofold. First, group-based projects prime sophomores and juniors for the rigors of independent research, and second, concepts illustrated in previous courses on experimental design and statistics can be reinforced. As an example, half of our Invertebrate Zoology labs were removed last year to make room for a student-designed project on chemoattractants to beehive pests. This project tied into the YHC community, as we have established beehives and an annual course on beekeeping that is among the most

TABLE 1: Synergies Between the Efforts at Mercy and YHC

Project Characteristics	At Mercy (Majors and Non-Majors)	At YHC (Non-Majors)
Projects are authentic and tied to wicked and capacious problems or issues.	Projects are based around themes such as climate change, antibiotic resistance, and cancer.	Course is based around themes such as GMOs, epidemics, and antibiotic resistance.
Student voice and choice	Students pick the topic and/or design the experiment.	Students vote on three themes from a list of six options.
Students reflect on their work	We use pre- and post-SALGs and the URSSA. Rubrics are used to assess their fellow team members. They review their peers and give feedback.	We use the SALG, CLASS-BIO, and TOSLS as pre- and post-assessments.
There is time for critique and revision	We use shared lab books, lab meeting discussions, and peer review. The posters are reviewed before the printing and presentation.	Each theme's project involves at least one class period for peer review. Students also assign peer grades during group projects.
A challenging problem/question	Questions are capacious: How can we design a better sunscreen? Can we find antibiotic-resistant bacteria on the campus? What will happen when there are no more fish?	Problems relate to real-world questions: Do common foods contain GMOs? How widespread are antibiotic-resistant bacteria? Why do diseases spread?
Inquiry or research is sustained	Across the curriculum, projects can last from 2 to 15 weeks.	Each lab/lecture theme lasts 4 weeks.
Students present publically	Students present their work orally, in posters or as ePortfolios. In some cases, proposals/brochures are generated to effect change on campus. Students present posters either on campus or at local conferences.	Students generate distributable final projects, such as board games, campus flyers, and infographics.

desirable courses on campus. Students wrote a proposal and budget, managed the project, designed a scientific poster, and orally defended their research one-on-one. The end product was of sufficient quality to be presented on campus during YHC's Undergraduate Research Day. Projects of similar complexity can be found among many upper-division science courses at YHC, but this is a bottom-up movement by faculty who see the value in reinforcing research methods and/or SENCER ideals in their courses. Table 1 demonstrates how these activities across the curriculum synergize between Mercy and YHC.

Student and Faculty Benefits and Successes

We've demonstrated that there are many ways to bring research to our students. By scaffolding research across the curriculum at Mercy, we enable our students to gain the skills and experiences they need at several stages throughout their academic careers, and across multiple disciplines including biology, chemistry and physics. This cross-disciplinary approach, spanning introductory to advanced courses, ensures that their learning is reinforced through multiple and varied exposures to research and authentic questions/projects that are of interest to them. At YHC, faculty are supportive of one another's efforts to incorporate research in the classroom. There has been minimal resistance to this approach, although greater communication and institutional support is needed at this time to transition from independent efforts to a cohesive, scaffolded approach that reaches across the curriculum.

What did we find at Mercy?

Feedback from our students enrolled in these modified courses has demonstrated that the students themselves feel that they have benefited in the areas of teamwork, communication, and in their appreciation of the course and of science in general. Many Mercy faculty have now adopted the SALG as a means of assessing student perceptions of their own learning. Students in microbiology reported "the projects were great, especially the microbe Digication project. I heard from past classes that they just wrote a paper for a project grade and I much preferred the Digication project that my class did." Digication is an online platform for electronic portfolios (DIGI[cation], n.d.). A chemistry student commented, "I think working as team with my peers and professor was great because we all learned from one another and each made great suggestions that contributed to the success of our project," and a physics student wrote, "Having the whole semester for a project of our choosing gave us the power to pursue our interests while learning physics instead of focusing on memorizing formulas and regurgitating ideas." Faculty themselves are enjoying teaching the courses and having more engaged students.

A barrier that remains for us is a means to assess the specific gains in the areas of civic engagement and scientific literacy. We are currently focused on developing assessment tools and metrics for determining our impact across the curriculum. Despite this we have demonstrable evidence of student successes both in the classroom, outside the classroom, and beyond, after graduation. Since Fall 2016, more than 40 students have participated in the Microbiome of Urban Spaces CURE, resulting in more than 27 posters and presentations at local, national, and international conferences by Mercy students. A pilot of the URSSA survey (Westin and Laursen, 2015) in Spring 2018 demonstrated that students are considering graduate school after participating in this CURE (Table 2). Additionally, participants have received honorary mentions, research fellowships, and travel awards from the Collegiate Science and Technology Entry Program (STEP), Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS), American Society for Microbiology (ASM), and Annual Biomedical Research Conference for Minority Students (ABRCMS), and several have been accepted to research-intensive internship programs such as at Albert Einstein, NYU, and Rutgers.

We've also increased the numbers of engaged and interested faculty. We started with eight engaged faculty and have grown to include more than 20, including visiting and adjunct faculty. While it is too soon to determine if we are affecting the graduation or retention rate, the number of students enrolling in the biology major has increased to 236 in Fall 2017 (3.5% of total Mercy College enrollment, 22.8% of the School of Health and Natural Sciences) compared with 216 in 2017 (3% of total Mercy College enrollment, 20% of the School of Health and Natural Sciences) and 213 in 2016 (2.7% of total Mercy College enrollment, 18.8% of the School of Health and Natural Sciences).

TABLE 2: Responses to the URSSA in the Spring 2018 Section of the Microbiome of Urban Spaces

Spring 2018 - How did your research experience influence your thinking about future career and graduate school plans? (n=9, 100%)
At first I did not want to go to a medical school that is big on research, but now I would love to go to one. I loved my experience doing research with Dr. Smyth.
My research experience has made me want to get creative as a future physician assistant and help people to learn things in a way they may have not thought of before.
It made me look into research projects currently going on campus to see what they are doing. I have learned to look at current research papers and research the information being provided.
It gave me a stronger vision on research in general.
Very much! I fell in love with microbiology. I never thought about getting a PhD until I participated in this research class.
My research experience has made me more confident going towards Clinical Laboratory Sciences.
It made me decide I want to go to graduate school and get a PhD.
My research experience definitely influenced me positively in pursuing my master's degree.
This was my first research experience in a lab. After studying staph so much, I became more interested in dermatology because of the different ways staph infects someone's skin.

What Did We Find at YHC?

Early feedback from the redesigned non-majors biology course is encouraging. We are using the Student Assessment of their Learning Gains (SALG), Test of Scientific Literacy Skills (TOSLS; Gormally, Brickman, and Lutz, 2012), and the Colorado Learning Attitudes about Science Survey for Biology (CLASS-BIO; Semsar, Knight, Birol, and Smith, 2011) instruments to track whether the redesign has affected non-majors' views on their ability to conduct scientific research, interpret it, and apply it to their lives, although post-implementation data are still being generated. Informal feedback confirms that students (a) appreciate that course material is relevant to non-scientists, (b) overcome misconceptions about the scientific method, and (c) apply a global outlook regarding solutions to the challenges associated with each topic.

One assignment clearly illustrated that the SENCER approach promotes biology as a globally relevant topic to non-majors. Pre-course surveys suggested that most students had not considered the socioeconomic or biological challenges associated with disease. While discussing HIV/AIDS, Dr. Sheryl Broverman's work with WISER was used as an example of an initiative that grew to have a huge impact. Students were tasked with writing a reflective response after investigating the WISER NGO. Their submissions illustrated how their perceptions of the world had changed over just a few months. As two examples:

> *"People like Dr. Broverman are impressive and can make a big difference…what would happen if all of the privileged people could help all of the non-privileged people?"* and *"I am so impressed by the efforts [of WISER] that I plan to pitch this NPO as my sorority's next philanthropy. While I am aware that the dent that a small-town sorority is able to make may not be huge…I have held steadfast to the idea that small changes can be monumental."*

As the course has progressed, these sorts of reflections have become more commonplace. What is needed at this stage is to expand on this vision for non-majors and apply it to majors-level courses. If students can be motivated early on and if faculty receive support for classroom initiatives, YHC could promote active research opportunities continuously throughout the major.

Recently, several STEM faculty have engaged in pedagogical research and civic engagement endeavors, resulting in travel awards and presentations at national educational conferences, including the SENCER Summer Institute (SSI), Association for Biology Laboratory

Education (ABLE), American Society for Biochemistry and Molecular Biology (ASBMB), and National Association of Biology Teachers (NABT), where two faculty were trained on CURE development through the Research Experiences in Introductory Laboratory in Biology (REIL) program. These faculty represent a minority at YHC, but there is a growing interest in building interdisciplinary connections among disparate majors.

Future Directions

While we have been able to champion "SENCERized" CUREs and PBL at our respective institutions, for many faculty, there remain several considerable barriers and challenges. What these challenges are, and where and when they arise, can often impede buy-in among reluctant faculty and administration. Despite the challenges, there are several strategies that we have used to achieve buy-in:

- **Show the data** – One of the most successful strategies to encourage your colleagues to participate or gather administrative and financial support is to show the results of your efforts. Take every chance to present your efforts at departmental meetings, school meetings, conferences, and in journals such as this one. Even preliminary data can serve to bolster your argument for your efforts and can greatly serve to encourage others to join you. We have presented our ongoing efforts to the broader community at SENCER meetings and at Project Kaleidoscope (PKAL) and Quantitative Undergraduate Biology Education and Synthesis (QUBES) meetings. These efforts not only help us identify allies at other schools and institutions, but also help our colleagues who may be struggling to find ideas, methods, and strategies for success. Communication between faculty at Mercy and YHC is one such example of the community building that can occur by sharing one another's efforts through SENCER. In the case of this particular project, D. Sieg and D. Smyth met as new attendees to the 2014 SENCER Summer Institute (SSI) in Asheville and saw mutual alignment in their pedagogical interests. They built on these connections over the years, leading to collaborations for SSI workshops and Leadership Fellow opportunities. These initial connections led to recruiting more faculty into the fold, culminating in this article.
- **Program Assessment** – At Mercy, we have strategically placed PBL and CUREs at the forefront of achieving our programmatic goals. Tying PBL and CUREs to program outcomes can serve as a means of directing funding towards the efforts. Better yet, there can be direct funding and support when PBL and CUREs are tied to assessment, including expertise from assessment coordinators for generating tools and rubrics to help measure impact.
- **Provide the support** – If you are an administrator or dean, consider providing technical support for your faculty. Even small amounts of money can make all the difference when considering these types of projects. Fund opportunities for your faculty to attend workshops and training sessions. Better yet, consider lines that support the efforts directly. Hire technical staff, or train graduates of the program to support the efforts.
- **Support Scholarship of Teaching and Learning (SOTL) for promotion and tenure** – An effective way to both support and encourage faculty is to align promotion and tenure expectations with Boyer's model, which places value on SOTL (Boyer, 1990). Many teaching institutions lack adequate research facilities for faculty to engage in high-impact research analogous to what they conducted during their PhD and postdoctoral training. When the practice of implementing and assessing evidence-based and effective pedagogy in the classroom is valued and is tied to promotion and tenure, faculty will also benefit from engaging in these types of efforts.
- **Build community from within** – Often, the greatest support for new initiatives comes from one's peers. Upon our return from WPI, Mercy gathered as a learning community to continue the efforts to develop PBL. While this was not always fruitful (we often could not meet due to scheduling, and we differed in our approaches), it reinforced a common language and helped continue the momentum of our efforts beyond WPI. Recent efforts by YHC opened doors between departments by providing a forum for "Lightning Talks" where faculty can promote classroom initiatives to colleagues in a low-stakes setting.

- **Bring the support to you** – A more successful and inclusive approach was to bring the support to us. Our second collaborative community at Mercy involved Monica Devanas. She supported and bolstered our efforts to integrate CUREs into introductory courses by visiting the campus and using Skype to meet with us monthly. Her constant support and encouragement helped our CURE working group stay on track. We have also hosted Erin Dolan and CUREnet at Mercy in Spring 2018 and the Mid-Atlantic and New England PULSE network in October 2017. These efforts not only helped Mercy faculty develop curricula and innovate, but also helped support peers at neighboring institutions who are also dedicated to improving undergraduate education in STEM.
- **Leadership** – To garner faculty collaboration and administrative support of initiatives, having someone with a SENCERized vision who takes on a leadership role can be invaluable. Someone with the resources and experience with pathways to curricular reform can seek out others with a similar outlook to start a collaborative effort, encourage the nascent interest in others to grow, and be poised to confidently provide the needed rationale to administrators. Having the support of the SENCER community (or other similar communities) can provide campus leaders with the tools, support, and confidence they need to help make a difference at their institutions.

Despite our efforts, barriers and challenges remain. At many teaching-intensive institutions, the overreliance on contingent or adjunct faculty can be a barrier to implementing CUREs and PBL. At Mercy College the Department of Natural Sciences hires approximately 60 adjuncts each semester, to supplement 18 full-time faculty, teaching upwards of 200 sections. Often, these adjunct faculty are hired at the last minute and are insufficiently prepared or trained to implement high-impact practices (HIPs), and few if any have ever had any training in implementing or teaching PBL or CUREs. Having lectures and lab classes taught by different instructors (full-time or adjunct) can also cause difficulties, if students are not adequately prepared from lecture to be successful in the lab, and ensuring synergy of lab and lecture courses can be difficult. There are very few models available that address this issue. In Fall 2018, Mercy was awarded an Inclusive Excellence Grant from the Howard Hughes Medical Institute; among other things, the awardees aimed to develop an Adjunct Academy, the goal of which is to recruit, train, and retain adjunct faculty who will support teaching with PBL and CUREs at the college (HHMI, 2019). There are often small numbers of full-time faculty who make sustained efforts to incorporate HIPs, constraining efforts to expand and integrate these HIPs across the curriculum. By encouraging more full-timers to engage with SENCER and supporting them to attend the Summer Institutes and regional meetings, we can bring more full-time faculty to the table.

Lab support and lack of time can be another major barrier. Faculty at teaching-intensive institutions often teach four or more courses a semester (such as at Mercy and YHC), and part-time faculty generally have no access to active research programs or laboratory space. Technical support is often lacking and graduate assistants or technicians may not be available, meaning faculty must prepare materials for these courses themselves. Our pilots were supported by grants and faculty awards, as well as with funding from our deans and administration that helped purchase reagents and provide technical support to faculty. While pilots may be feasible, sustaining funding may be a challenge.

Infrastructure remains a significant barrier for many faculty, as we often lack dedicated research labs or areas for group work. When courses are taught across several campuses or buildings such as at Mercy, access to research space to support the CURE can be an issue. At Mercy, we've rearranged the teaching schedule to accommodate access to laboratories for preparation to make the teaching laboratories available for research when class is not in session. At YHC, we recently renovated a classroom into a shared research lab for chemistry and biology. While the space is functional, it is limiting to have only a single space for all undergraduate researchers. Since Mercy had no room for the poster sessions, we bought boards and easels and did our poster session in the corridors outside the labs. Currently we're trying to rearrange the available research space to make it more equitable and supportive of all faculty.

While a plethora of assessment tools are available for assessing the impact of CURE and PBL experiences on students (Shortlidge and Brownell, 2016), there are limited resources tailored to determine whether students make specific gains in SENCERized classes in the areas of civic engagement and scientific literacy. More tailored assessment tools could help faculty present a data-driven and evidence-based case for SENCERized approaches to the administration and faculty.

About the Authors

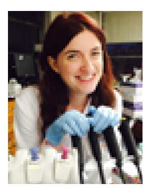
R. Drew Sieg is an assistant professor of biology who recently transferred to Truman State University from Young Harris College. He is a SENCER Leadership Fellow whose traditional research interests examine chemically mediated ecological interactions among plants, fungi, algae, and herbivores. He is also increasingly involved in educational research, particularly examining how authentic research experiences and other novel pedagogies affect student engagement in STEM.

Nancy Beverly is an associate professor in physics at Mercy College, in Dobbs Ferry, N.Y. Her pedagogical work focuses on the development of engaging and relevant curricular materials, activities, and approaches for the introductory physics for life science (IPLS) students. Her contributions to the national IPLS physics education community include organizing many national IPLS workshops and conference sessions, as well as being a part of multi-institutional collaborative NSF grants in this area. She is particularly interested in assessment and in guiding students to frame and investigate their own inquiries to make their own data-driven inferences.

Madhavan (Madi) Narayanan is an assistant professor of chemistry and a biophysical chemist at Mercy College. He is the Undergraduate Research Coordinator of the Natural Sciences Department and the Adjunct Academy Team leader for the Mercy Inclusive Excellence award from Howard Hughes Medical Institute. He uses both computation and experiments to understand structure and mechanisms in biological molecules. His current research interest is in developing and characterizing novel molecular probes which can serve as useful reporters of structure and dynamics in biomolecules and for applications in biological imaging.

Geetha Surendran is an associate professor of chemistry in the Department of Natural Sciences at Mercy College. She teaches general chemistry and organic chemistry. Her research focuses on sunscreens as well as on antioxidants from natural sources. Currently she is developing active ingredients to be used in sunscreen formulations for the UV as well as the blue light region. She is also involved in developing Course-Based Undergraduate Research Experiences (CURE) projects for General Chemistry students.

Joshua Sabatini is a new member of the faculty at Passaic County Community College and former instructor at Mercy College. His main work is leading students through all the finer points of general and organic chemistry. As a former organic chemist in the pharmaceutical industry he also seeks to pique students' interest in chemistry through work in the laboratory. Joshua led the students through the general chemistry CURE-based lab at Mercy in Fall 2017.



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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
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
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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.

About the Authors

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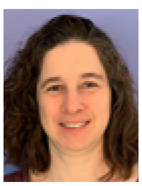

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Note

While Kerry Brenner is an employee of the National Academies of Sciences, Engineering, and Medicine; the views expressed herein do not necessarily represent the views of the National Academies of Sciences, Engineering, and Medicine or any of its constituent units.

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