TEACHING & LEARNING

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.

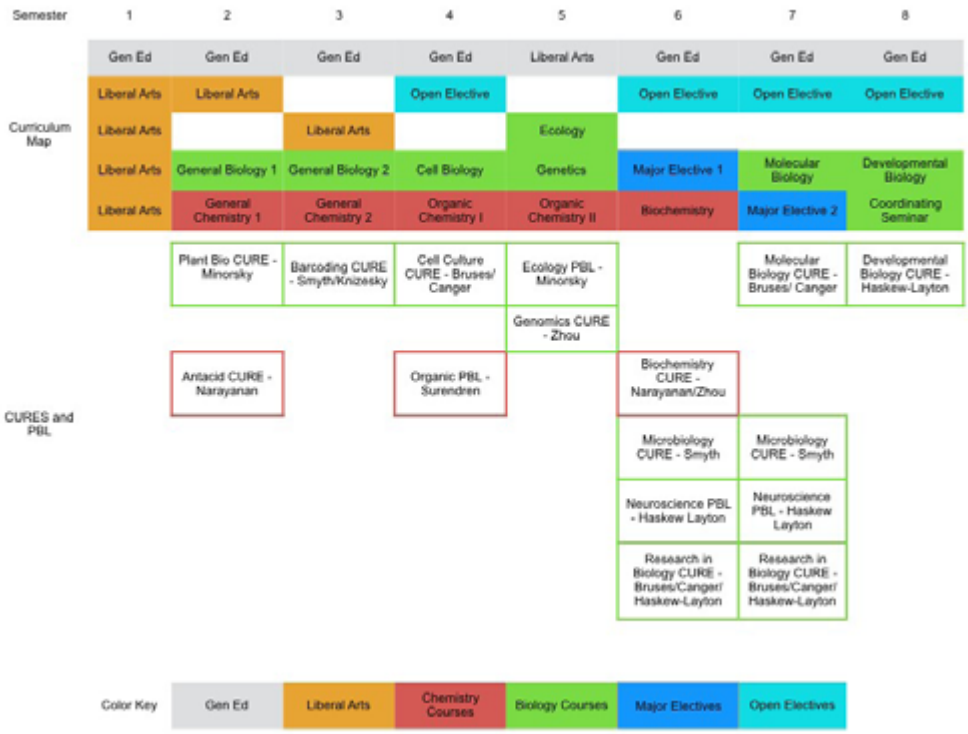
At the Advanced Level

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

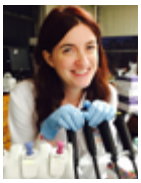
R. Drew Sieg is an assistant professor of biology who recently transferred to Truman State University from Young Harris College. He is a SENCER Leadership Fellow whose traditional research interests examine chemically mediated ecological interactions among plants, fungi, algae, and herbivores. He is 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.



Davida S. Smyth is an associate professor of natural sciences at Eugene Lang College of Liberal Arts at the New School in New York. She has previously served as Associate Professor and Chair of Natural Sciences at Mercy College. A SENCER Leadership Fellow, her research focuses on the genomics of Staphylococcus aureus, and the prevalence of antibiotic resistance in clinical and environmental strains of Staphylococci. She is also interested in pedagogical research in the area of student reading skills in STEM disciplines, classroom undergraduate research experiences and Peer-Led Team Learning in biology.

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