SCIENCE EDUCATION
& CIVIC ENGAGEMENT
AN INTERNATIONAL JOURNAL

VOLUME ELEVEN
ISSUE TWO
Summer 2019

SCIENCE EDUCATION
& CIVIC ENGAGEMENT
AN INTERNATIONAL JOURNAL

Volume 11 Issue 2 · Summer 2019

ISSN: 2167-1230

National Center for Science and Civic Engagement
Department of Technology and Society
1432 Old Computer Science
Stony Brook University
Stony Brook, NY 11794-4400
www.ncsce.net

Partial support for this Journal was provided by the National Science Foundation's Course, Curriculum and Laboratory Improvement Program under grant DUE 0618431. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily represent the view of the National Science Foundation or the National Center for Science and Civic Engagement.

VOLUME ELEVEN
ISSUE TWO
Summer 2019

Contents

4 FROM THE EDITORS

5 FROM THE DIRECTOR OF NCSCE

6 BOOK REVIEW
American Wolf: A True Story of Survival and Obsession in the West—Nate Blakeslee
JoEllen Pederson, Et al.

7 BOOK REVIEW
She Has Her Mother's Laugh: The Powers, Perversions, and Potentials of Heredity—Carl Zimmer
Matt Fisher

8 BOOK REVIEW
Silent Travelers—Alan M. Kraut
Davida Smyth

9 BOOK REVIEW
The New Education: How to Revolutionize the University to Prepare Students for a World of Flux—Cathy N. Davidson
Eliza Reilly

10 BOOK REVIEW
Understanding How We Learn—Y. Weinstein and M. Sumeracki with illustrations by O. Caviglioli
Linden Higgins

11 PROJECT REPORT
Starting with SENCER: A First-year Experience Framed by the Science and Civic Issues of the Chesapeake Bay
Michelle Parry, Wade Znosko, Alix Dowling Fink, Mark Fink, Kenneth Fortino, Melissa Rhoten, Sarai Blincoe

22 PROJECT REPORT
Study of Healthcare-Associated Infections and Multi-drug Resistance in Brooklyn, An Integrative Approach
Liana Tsenova, Urmi Ghosh-Dastidar, Arnavaz Taraporevala, Aionga Pereira-Edwards, Pamela Brown

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*

The Journal is published twice per year in an online format. The official publisher of the journal is Stony Brook University home of the National Center for Science and Civic Engagement. Editorial offices for the Journal are located in Lancaster, PA.

WWW.SECEIJ.NET

From the Editors

For the Summer 2019 issue, we are pleased to provide a new journal feature—a collection of short books reviews to stimulate your reading. The books reviewed in this issue include a cultural history of infectious microorganisms, a chronicle of wolf ecology in Yellowstone National Park, a summary of the cognitive processes involved in learning, a revolutionary proposal for a new type of higher education in the 21st Century, and a nuanced examination of human heredity. These book reviews will become a regular feature in the summer issue of the journal, so we welcome contributions from eager readers for Summer 2020!

We are also excited to share two project reports that provide inspiring examples of science education and civic engagement.

A diverse team of faculty members and students from Longwood University describes the LIFE STEM Program, which provides low-income students with an intentional and supportive transition to the study of science in college. As described by lead author Michelle Parry, first-year students use the Chesapeake Bay as both a natural laboratory and a contested civic space. In addition to linking the Bay to students' coursework and research projects, LIFE STEM also focuses on cultivating students' sense of belonging in an academic community, developing their professional identity as scientists, and promoting their self-efficacy. Preliminary data suggest a positive impact of the project on the retention of STEM students and the development of their skills in research and communication.

The second project report describes an interdisciplinary collaboration at New York City College of Technology, with contributions from Liana Tsenova, Urmi Ghosh-Dastidar, Arnavaz Taraporevala, Aionga Sonya Pereira, and Pamela Brown. Students enrolled in a microbiology course and a statistics course worked together to examined the growing problem of healthcare-associated infections by antibiotic-resistant microorganisms. Using authentic data from 15 Brooklyn hospitals, students performed statistical tests to examine variation in antibiotic resistance among different bacterial species. Students then learned about methods to reduce hospital-based infections and developed informational flyers for public distribution. As an outcome of this project, students make meaningful connections between scientific knowledge and civic action.

We wish to thank all the book reviewers and manuscript authors for sharing their scholarly work with the readers of this journal.

Matt Fisher
Trace Jordan
Co-Editors-in-Chief

In Memoriam—David L. Ferguson

A beloved member of the SENCER community died suddenly in July. Dave Ferguson had been a leader and supporter of Science Education for New Civic Engagements and Responsibilities since it was first established by David Burns and Karen Oates at the Association of American Colleges and Universities in 2001. I recall Dave as a generous and engaged SENCER participant, particularly in aspects of the work that he was passionate about: mathematics education and supporting the academic success, especially in STEM, of underserved minority students.

Although I always appreciated Dave as a steady presence at SENCER Summer Institutes, one whose graciousness and enthusiasm made all interactions with him a pleasure, I only got to know him well as a colleague in 2015, when I succeeded David Burns as Executive Director of the National Center for Science and Civic Engagement (SENCER's organizational home). At that time the NCSCE and its staff moved to Stony Brook University under the auspices of the Department of Technology and Society. Dave was Chair of Tech and Society and Associate Provost for Diversity and Inclusion, among other roles, but it was clear that he saw the development and advancement of NCSCE at Stony Brook as an integral part, not only of the overall mission of the department, but part of his personal mission of ensuring that all students have access to the high-quality STEM learning they will need to address the "grand challenges" we are all facing. Although in administrative hierarchy he was our supervisor, Dave respected our autonomy as a program and our expertise as staff members, while offering us support, guidance, and wholehearted commitment.

I can honestly say that working with Dave these last few years has been an inspiration and a joy, not least because you knew you could trust him completely to do what was right, even though it might be hard. He was a lifelong student at heart and still lit up with excitement at new ideas, new projects, and especially, the creativity and achievements of his students. At the 2019 SENCER Summer Institute, where he posthumously received the Wm. E. Bennett award, so many colleagues and friends noted that when you were working with Dave "you had his complete attention, and felt like you were the only person who mattered." His ability to listen, understand, and fully engage with others partly explains why so many considered him their role model, mentor, and champion, and why he was widely respected on the campus he spent his entire career. The NCSCE gained immeasurably from our association with him, not only at Stony Brook, but in the national arena, as he opened up new avenues and audiences for NCSCE in engineering education and industry partnerships, all focused on "social good."

Dave was a stubbornly modest individual who rarely talked about himself, and many of us were unaware of his lifetime of accomplishments and many honors and awards until we read his obituary. It is not an exaggeration to say, as many did in reflecting on his life, that he was "irreplaceable." He left us too soon, but with a legacy of good works and achievements that we can only try to carry on.

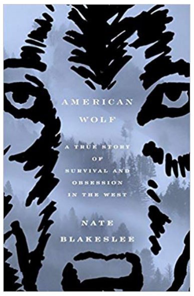
Eliza Reilly
Executive Editor

American Wolf:

A True Story of Survival and Obsession in the West

NATE BLAKESLEE

320 pp. 2017. Broadway Books.
9781101902806



In *American Wolf*, Nate Blakeslee presents the historic movement that led to what many have dubbed the greatest natural experiment of our time—the reintroduction of gray wolves (*Canis lupus*) to Yellowstone National Park. Blakeslee's account details two complex landscapes: the 18-million-acre Greater Yellowstone Ecosystem, one of Earth's largest intact temperate ecosystems,and the equally immense human cultural, political, and economic web into which the translocated animals were released. Unlike many accounts of this epic experiment, Blakeslee's focuses not on the Yellowstone wolves broadly but rather on the story of alpha female "O-Six." As he shares the natural history of O-Six and her kind, he weaves a parallel tale of the human communities that are at once removed from the wild wolves and yet absolutely tied to them. Chief among the human actors is Rick McIntyre, a now-retired National Park Service employee who for decades—and for countless visitors—was the interpretive voice for the animals. Though arguably pro-wolf narratives dominate, particularly through accounts of wolf watchers who spend their vacations—and, in some cases, their retirements—following wolves, other perspectives, including those of citizens who opposed reintroduction and some who legally hunt wolves, are represented thoughtfully and meaningfully. Drawing on years of field notes, countless interviews with stakeholders, national and regional media, and scientific data on this well-studied population, Blakeslee exposes the harsh realities of these linked landscapes, both the almost unbelievable tales of wolf interactions and the equally fraught and often harsh environmental politics in the human sphere.

Our instructional team assigned this text as part of a collaborative program that for fourteen years has immersed students from across the majors in contentious stewardship issues in the Greater Yellowstone Ecosystem. The course uses real issues of our public lands to teach students majoring both in science and in other disciplines. For our students, *American Wolf* grounded the thrills of seeing wild wolves in Yellowstone in a much larger context and longer narrative. It deepened students' engagement with both the Yellowstone landscape and that paired system of human politics, economics, history, and culture that created space for wolves within the boundaries of Yellowstone, but not always beyond. Blakeslee's exposition of these landscapes is transferrable to many teaching-and-learning contexts that seek to draw on unresolved public issues and make explicit the ways in which science and citizens can and cannot affect them.

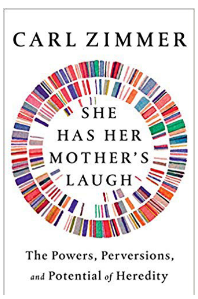
JoEllen Pederson, Jessi Znosko, Alton Coleman, Jennifer Cox, Alix Dowling Fink, Edward Kinman, Kevin Napier, and Phillip Poplin are all at Longwood University and are involved in the Greater Yellowstone Ecosystem educational experience offered by the institution.

She Has Her Mother's Laugh:

The Powers, Perversions, and Potentials of Heredity

CARL ZIMMER

672 pp. 2018. Dutton.
ISBN 9781101984598



The subtitle of Carl Zimmer's latest work makes explicit reference to powers, perversions, and potentials in relation to heredity. But he could easily have added complexity and subtlety as descriptors: Zimmer's goal is to provide an overview of "heredity," which in this case is not simply another word for "genetics." Certainly, the development of the concept of the gene and genetics as a mature science is an important part of the story Zimmer tells. But Zimmer weaves a far richer tapestry, looking not only at how characteristics get passed on from one generation of organisms to the next, but also how they can be passed on from one generation of cells to the next within the same organism. *She Has Her Mother's Laugh* takes the reader through Mendelian inheritance, genetic recombination and mosaicism, epigenetic inheritance in cells, and CRISPR technology, and even a fascinating exploration in one chapter of possible relationships between human biological evolution and how culture might be "inherited." The last pages make clear that the book was written to broaden how we think of heredity, and I was quite impressed at how Zimmer accomplishes this aim. He also does a masterful job of incorporating the process of science as well as societal contexts into the book. His description of efforts to find the genetic basis of intelligence and race powerfully demonstrates how science can be influenced by social contexts and factors.

Zimmer's book is a wonderful resource for faculty members teaching in a variety of disciplines, including (but not limited to) the life sciences. One aspect of the book that I found particularly useful is the way that Zimmer documents the enormous number of sources he has drawn on. Rather than footnotes or numbered endnotes, the Notes section at the end of the book is organized by page, with a brief phrase allowing the reader to connect an idea to the source Zimmer used. With the notes section running more than 20 pages paired with a bibliography more than 40 pages in length, interested instructors will find themselves with a wealth of resources that they can track down.

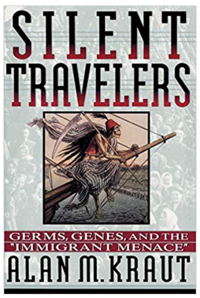
We live in a time when genetic determinism still seems thoroughly entrenched in modern society. News stories regularly touch on issues such as criminal justice, health, medicine, and the alteration of the genomes of a variety of organisms, where heredity is an important consideration. In *She Has Her Mother's Laugh*, Carl Zimmer has provided us with a superb overview of the many facets of heredity, what we understand now, and what questions scientists still wrestle with today.

Matt Fisher is a chemistry professor at Saint Vincent College and co-editor-in-chief of Science Education and Civic Engagement: An International Journal.

Silent Travelers

ALAN M. KRAUT

384 pp. 1994. Johns Hopkins University Press.
ISBN 9780801850967



Alan M. Kraut's *Silent Travelers* describes the history of American immigration alongside medicine and science, emerging diseases, prejudice against outsiders, and nativism. With the Irish being blamed for cholera in New York in 1832, the Chinese in San Francisco deemed the source of bubonic plague in 1900, Jews the reservoirs of tuberculosis in the early 1900s, and Haitians being targeted as the source of HIV in the 1980s, outsiders and immigrants have long been linked to contagion and disease. Prejudices and the associated stigmatizing of groups greatly influenced public health and immigration policy and drove much of the change we see today in our schools, workplaces, hospitals, and clinics. Kraut's book presents accounts from all sides. The nativists rejected immigrants for fear of their genetic "inferiority," together with other flaws—vice, physical weakness, and crime—that were attributed to them. Public health activists sought to protect Americans through quarantine, internment, and forced inoculation. Others lobbied and pressured the establishment to improve the infrastructure and living and workplace conditions of immigrant communities. When all else failed, former immigrants, traveling nurses, religious orders, benevolent societies, and philanthropists did the work themselves; immigrant physicians such as Maurice Fishberg and Antonio Stella were able to navigate the cultural and local practices of their patients while maintaining their own up-to-date medical standards. *Silent Travelers* is filled with evidence and data taken from government and medical records, along with personal anecdotes and detailed facts and figures in tables, appendices, and notes.

SENCER faculty teaching about public health and cultural and economic sensitivity though a civic lens will find a collection of photographic images depicting immigrants' daily lives and artwork, as well as posters and infographics that spread misinformation about the immigrant threat. In addition, *Silent Travelers* includes poetry and accounts from the lips of poor souls struggling to adapt to life in America. The book is filled with fascinating accounts of cultural differences regarding medicine and fear, as well as the acceptance of aid from nurses and physicians amid the shock and trauma of finding oneself in an alien world, without fluency in the language or understanding of the culture. While *Silent Travelers* was published 25 years ago in 1994, the landscape for today's immigrants—documented and undocumented alike, both here and abroad—is still much like that described in the book. Even today, we still see news outlets, political entities, and social media platforms continuing to spread myths of the immigrant menace and their silent travelers. As Kraut says, "The double helix of health and fear that accompanies immigration continues to mutate, producing malignancies on the culture, neither fatal nor readily eradicated." (p. 272)

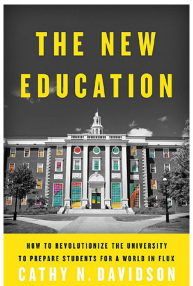
Davida Smyth is an associate professor of biology at the Eugene Lang College of the Liberal Arts at the New School and a SENCER Leadership Fellow.

The New Education:

How to Revolutionize the University to Prepare Students for a World of Flux

CATHY N. DAVIDSON

336 pp. 2017. Basic Books.
9780465079728



In *The New Education*, the scholar and educational innovator Cathy Davidson provides a comprehensive portrait of U.S. higher education's past, a stringent critique of its present, and a vision of a better future. Winner of the 2018 Ness Book Award, The New Education begins with Charles W. Eliot's 1869 manifesto, also called "*The New Education*," a radical prescription for the reform of higher education that launched his appointment and 40-year tenure as president of Harvard University. Eliot was convinced, as the second industrial revolution took shape, that an educational system designed for ministers, scholars, and sole-proprietors required a radical overhaul if it was to produce the managers, supervisors, bureaucrats, and policy makers needed for the emerging industries and professions that would dominate the US for the next century. Eliot's visionary and radical reform effort produced the university we know today, with divisions and departments, majors, minors and electives, credit hours, letter grades, distribution requirements, and admission standards. Most significantly, Eliot departed from European models in making the undergraduate college separate, and a pre-requisite for, graduate and professional programs. His approach, formulated in collaboration with industrial titans, efficiency experts, and eugenicists, also reinforced social and economic hierarchies, prioritized research over teaching, institutionalized exclusionary rankings and testing regimes, promoted disciplinary silos, and calcified an undergraduate curriculum that no longer serves the needs of the workforce and civil society in the age of the internet, big data, and artificial intelligence.

Davidson's proposed correctives to this situation will be familiar to educators acquainted with current research on learning and the "high-impact," problem-based approaches it advocates. However, her historically grounded analyses and case studies offer a tough-minded acknowledgement of the barriers to change, including shrinking financial support for students and institutions, the adjunctification of the faculty, outmoded and ineffective assessment strategies, and credential-centered, rather than student-centered, curricula. Fortunately, case studies also offer much-needed (and evidence-based) optimism regarding innovations and reforms that are taking place across a wide range of institutions. Davidson especially singles out community colleges, which educate more than half of all college students, for outperforming four-year colleges on the "social mobility index," for their integrative curricula, and for their rejection of the "tyranny of meritocracy," quoting LaGuardia Community College's president Gail Mellow's proud claim that "we take the top 100%."

For readers of this journal, her chapter dissecting reductionist, workforce-based arguments for STEM education may be of special interest. While she acknowledges the importance of, and national need for, more STEM graduates, she insists that the "hard" skills imputed to STEM may help graduates get their first job, but they are not enough for career advancement in what is now called "the fourth industrial revolution." Those "hard" skills, which could become irrelevant given the pace of technological change, must be integrated with transferable and enduring "soft" or "human" skills, such as communication, collaboration, critical thinking, historical analysis, and interpretation—all skills as important for civic agency and democracy as they are for employment. In fact, as AI and automation develop, "evidence suggests that over time the tortoise humanist may actually win the career race against the STEM hare" (p. 140)

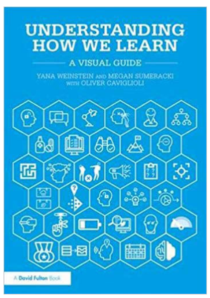
In an age where so much of the blame for higher education's shortcomings falls on the faculty, or even on today's students themselves (branded as "excellent sheep," or "the dumbest generation" in recent polemics), Davidson's prescriptions, and her unflagging confidence in the transformative potential of higher education to prepare us to survive and thrive in an uncertain future, is most energizing.

Eliza Reilly is the executive director of the National Center for Science and Civic Engagement and past co-editor-in-chief of Science Education and Civic Engagement: An International Journal.

Understanding How We Learn

Y. WEINSTEIN AND M. SUMERACKI WITH ILLUSTRATIONS BY O. CAVIGLIOLI

176 pp. 2018. Routledge Books.
ISBN 9781138561724



At only 165 pages, this well-organized book provides an accessible introduction to the cognitive processes underlying learning and presents clear, evidence-based strategies for improving learning. The strategies are explicitly tied both to the cognitive processes and to concrete recommendations for teachers and learners. The authors, Yana Weinstein and Megan Sumracki, are cognitive psychologists and faculty members engaged in research that links teaching strategies to learning. Their prior experience in communicating research results to practitioners is the foundation for this solid overview of the recent literature in learning and teaching that is clear yet not condescending.

The book models their recommendations in many ways. For example, they suggest interleaving to increase learning and transfer, and throughout the book they explicitly refer back to or forecast content covered elsewhere. Most strikingly, they model their recommendation for dual coding (visual and text or auditory) by collaborating with illustrator Oliver Caviglioli to visually represent main concepts. I particularly appreciate the visual summaries of each of the four sections (the science of learning, cognitive processes, strategies for effective learning, and tips for teachers, students, and parents) and of each chapter. I expect these digests will be very useful when discussing active learning design with students as well as with other faculty members. Despite the book's brevity, the authors include thorough reviews of relevant literature and clear indications of where we need further research in both cognitive psychology and curriculum design. Here again, Caviglioli's illustrations effectively convey the sometimes complex experiments and results summarized in the text.

There are only two points that I would like to see added. First, experimental results clearly indicate an advantage of handwritten notes and drawings, which would seem to tie in well with the cognitive approach these authors are using. Yet these studies are not mentioned even in the context of dual coding or the brief mention of multiple choice versus short-answer quizzes, a gap I find surprising. Second, perhaps reflecting the authors' research programs, the focus is entirely behavioral. I would have appreciated at least some connection to the issues of self-efficacy and epistemological development. My reasoning is that the "non-cognitive" components of self-efficacy combine with epistemological development to generate considerable variation among the students in our classrooms; including some brief introduction to both topics could help practitioners choose strategies appropriate for different students. These are, however, minor complaints in what is a thorough yet highly accessible introduction to the cognitive processes of learning and the educational implications of what we know (and do not know). I think that it will appeal to faculty in many disciplines at both the K-12 and college level.

Linden Higgins is a lecturer and research affiliate in the Department of Biology, University of Vermont, and founder of Education for Critical Learning LLC.

Starting with SENCER:

A First-year Experience Framed by the Science and Civic Issues of the Chesapeake Bay

MICHELLE PARRY
Longwood University

ALIX DOWLING FINK
Longwood University

MELISSA RHOTEN
Longwood University

WADE ZNOSKO
Longwood University

MARK FINK
Longwood University

SARAI BLINCOE
Longwood University

KENNETH FORTINO
Longwood University

Abstract

In 2017, Longwood University launched the LIFE STEM Program, a holistic program girded by best practices in STEM teaching: cohorts of students, summer bridge program, genuine community building, intentional faculty-student mentoring, focused academic support and professional development, early research experiences, engagement with challenging civic issues, and, importantly, financial support for students. The first-year experience is critical in establishing the academic expectations of the LIFE STEM Scholars, supporting their development as a community of learners, and engaging them in real work of scientists. That yearlong journey opens with a one-week summer bridge program on the Chesapeake Bay. While on the Bay, the Scholars begin to frame scientific questions tied to key civic issues and grapple with intersections of science, economics, and politics. In a two-semester Entering Research course sequence, Scholars expand on key questions, process field-derived samples, analyze data, and consider the meaning of their work in this complex and contested civic context.

Introduction

The LIFE STEM Program (Longwood Initiative for Future Excellence in STEM) was created to provide wrap-around support for academically talented science students with financial need. With funding from the National Science Foundation's Scholarships in STEM (S-STEM) program (Award #1564879), the LIFE STEM Program is supporting, through curricular, co-curricular, and financial elements, the four-year college experience of two cohorts of 12–14 students representing Longwood's four natural science majors (Biology, Chemistry, Integrated Environmental Sciences, and Physics).

In the 2017–2018 and 2018–2019 academic years, the first two multidisciplinary cohorts of LIFE STEM Scholars completed the first-year experience, which serves as the foundation on which the rest of the LIFE STEM Program builds. Recognizing the important challenges of the transition to college (PCAST, 2012), the program immediately connects the incoming Scholars with peer and faculty mentors and invests heavily in intentional community building. The fall course schedule of the Scholars includes cohort sections of the introductory chemistry course (CHEM 111), a first-year seminar focused on the transition to university work (ISCI 100), and a second seminar focused on research (ISCI 120; Table 1).

The context for the Scholars' first-year research activities—almost from the minute they arrive on campus—is the Chesapeake Bay, the largest of over 100 estuaries in the United States (US) and the third largest in the world. Throughout the written history of the US, the Bay has provided vital resources (e.g., blue crabs [*Callinectes sapidus*], oysters [*Crassostrea virginica*], and menhaden [*Brevoortia tyrannus*]) and has fueled robust local and regional economies. In fact, still today, the small town of Reedville ranks first in the contiguous US for fish landings (by weight of catch; NMFS, 2017). A focus of intensive conservation efforts since the 1970s, the Bay's key health indicators have improved, but overall it continues to earn a barely passing grade of D+ (CBF, 2018). With a watershed encompassing more than 64,000 square miles, the Bay is affected by land management practices extending from northern New York to southern Virginia. Furthermore, the watershed is home to more than 18 million people who have direct and indirect impacts on the Bay and the complex natural systems within it (CBF, 2018; CBP, 2019).

Clearly, this body of water presents almost endless potential for scientific research at all levels. Indeed, scholars in higher education and government service have invested careers in studying these natural systems. With its incredible jurisdictional complexity—six states and the District of Columbia and nearly 1,800 local jurisdictions (i.e., towns, cities, counties, and townships; CBP, 2017)—the Bay offers another level of scholarly engagement at the intersections of science and civic issues. For the LIFE STEM Scholars, the Bay is a study site in which they collect a variety of scientific data, but they also experience it as a home to the human communities that depend on it. Furthermore, many of our Scholars have a personal connection to the Bay, as it is an area where they and their families live. It is a contested space

TABLE 1. Overview of the LIFE STEM Program

Initial Immersion	Focus on the First Two Years: Cohort Building, Academic Success, Research Experiences				Support Through Graduation
Summer	Semester 1	Semester 2	Semester 3	Semester 4	Semesters 5-8
Chesapeake Bay-focused summer bridge (1 week) Honors Leadership Retreat (4 days)	LIFE STEM Seminar 1 (ISCI 100) (1 cr.) Fund. of Chemistry (CHEM 111) (4 cr.) Entering Research 1 (ISCI 120) (1 cr.)	Entering Research 2 (ISCI 121) (2 cr.)	LIFE STEM Seminar 2 (ISCI 220) (1 cr.)	Required enrichment activities	LIFE STEM Seminar 3 (ISCI 320) (1 cr.; Semester 5) Required enrichment activities
Intensive faculty mentoring and focused peer support throughout					

in many ways, and it has been for generations. Thus, the LIFE STEM Scholars do not start the college experience with prepared lab exercises at the bench, activities with known outcomes. Instead, they begin with an immersion in a complex civic issue, one where scientific study can offer new insights but for which science alone cannot offer solutions.

This focus on the Chesapeake Bay for the first-year experience grew from Longwood University's long-running engagement with the SENCER program (Science Education for New Civic Engagements and Responsibilities). The SENCER approach to teaching and learning (SENCER Ideals)

- robustly connects science and civic engagement "through" complex, contested, capacious, current, and unresolved public issues "to" basic science;
- invites students to put scientific knowledge and the scientific method to immediate use on matters of immediate interest to students;
- helps reveal the limits of science by identifying the elements of public issues where science does not offer a clear resolution;
- 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;
- conceives the intellectual project as practical and engaged from the start;
- locates the responsibilities (the burdens and the pleasures) of discovery as the work of the student;
- and, by focusing on contested issues, encourages student engagement with "multidisciplinary trouble" and with civic questions that require attention now. (SENCER, 2017)

The LIFE STEM Scholars' yearlong exploration of the challenging issues of the Chesapeake Bay was designed to intentionally operationalize the SENCER Ideals in each of the cornerstones of the first-year experience.

Cornerstones of the First-year Experience

Immersion Experience on the Chesapeake Bay

In the two weeks prior to the start of the fall semester, the LIFE STEM Scholars participated in a summer bridge program. The first week of that program was an immersion experience at the Chesapeake Bay for which Longwood University's 662-acre field station, Hull Springs Farm (HSF), situated on tributaries to the Potomac River and just a short distance from the Bay proper, served as the center of operations.

One important goal of the HSF week was to set the stage for a guided interdisciplinary research project in the Scholars' first year. That project intentionally incorporated the SENCER Ideals and, in so doing, expanded on Longwood's previous SENCER projects focused on non-science majors and the general education curriculum. Using the place-as-text approach to learning (Braid and Long, 2000), Scholars explored issues that link scientific and civic discourses, such as water quality (e.g., stormwater runoff, eutrophication, dead zones) and resource use (e.g., oysters, blue crab, menhaden). During their explorations on Tangier Island, Scholars engaged with members of the local community in order to begin to understand the complex intersections of civic and scientific issues (e.g., sea-level rise) and to connect them to the individuals

TABLE 2. Summer Bridge Activities That Engage Students in the Complex Issues of the Chesapeake Bay

Learning Activities	Key Outcomes for Scholars
• Full-day outing with a life-long waterman on a traditional Chesapeake Bay deadrise boat, including a tour of oyster processing and aquaculture facilities • Place-as-text exploration on Tangier Island • Presentation by Chesapeake Bay Program scientist • Collection of water and sediment samples and associated environmental data to be used in first-year course work • Culminating team presentation on the summer bridge experience and the state of the Chesapeake Bay	• Use foundational quantitative skills to address scientific issues • Explain how science can be used to understand problems • Explain how different scientific disciplines contribute to scientific knowledge • Examine the complexity of an environmental problem using multiple lenses • Use evidence to formulate questions and support answers • Collaborate with faculty and peers in an academic setting

who must live with them. As a culmination to the week, a scientist from the Chesapeake Bay Foundation presented data on the state of the Bay, supporting Scholars' development of their final projects and their team presentations, which focused on civic and science engagement (Table 2).

Honors Leadership Retreat

The second week of the summer bridge integrated the Scholars with the Cormier Honors College (CHC) students for the annual Honors Leadership Retreat, an on-campus "mini-bridge" program. The CHC has facilitated this retreat and its embedded peer mentoring for more than a decade and has had great success in building a cohesive community. During the Honors Leadership Retreat, Scholars participated in activities to promote leadership skills, community building, an academic mindset, and identification with a group of students for whom intellectual challenge and curiosity are shared values. Each LIFE STEM Scholar was paired with an experienced honors science major (for the first cohort of Scholars) or a current LIFE STEM Scholar (for the second cohort of Scholars), who served as a peer mentor. The retreat provided Scholars with opportunities for personal growth and connection to a larger cohort of academically talented students with whom they lived in the honors residence hall.

Coursework

In order to promote a strong cohort of Scholars, a sense of community, a scientific mindset, and the successful transition to college, the LIFE STEM curriculum has a deliberate focus on the first semester during which all Scholars are required to take three courses together (see Table 1). Two of those courses (CHEM 111 and ISCI 120) have explicit scientific connections to the bridge experience, including the analysis of water and sediment samples and associated environmental data, while the other course (ISCI 100) focuses on the transition to college. In addition to those common courses, Scholars also complete introductory courses in the major. During the second semester, Scholars focus primarily on their major course requirements but continue in ISCI 121, the second half of the two-semester course focused on promoting a scientific mindset and developing scientific skills. These courses are taught by members of the LIFE STEM Leadership Team, all of whom attended at least one HSF summer bridge. Thus, a strong sense of scientific community was initiated during the summer bridge and continued throughout the Scholars' first year.

Fundamentals of Chemistry I (CHEM 111)

Fundamentals of Chemistry I (CHEM 111) is a required course for science majors and a common stumbling block for first-year students. This course is taught using an inquiry-based model and utilized the POGIL (Process-Oriented Guided Inquiry Learning) pedagogy (Hein, 2012; De Gale & Boisselle, 2015) in both lecture and laboratory components. The collaborative POGIL environment is intended to help students learn, understand, and remember more while practicing skills essential for future success in the classroom, laboratory, and beyond. Connections to the summer bridge program were incorporated into the classroom component of the course as appropriate (e.g., polyatomic ions, molecular bonding, intermolecular forces, solubility, etc.). During the last five weeks of the laboratory portion of the course, the Scholars in the first cohort participated in "The Nitrate Analysis Project." The Scholars used a spectrophotometric method to determine nitrate concentrations in a series of simulated Chesapeake Bay water samples. The second cohort participated in a final laboratory project focused on harmful algal blooms. In this project, the Scholars grew cultures under differing conditions to determine the effect of nutrient levels on algal growth. Algal growth was determined using a fluorescence technique to measure the chlorophyll content.

LIFE STEM Seminar I (ISCI 100)

Scholars completed a one-credit freshman seminar course that blended an introduction to academics with the transition to college life. Scholars were expected to demonstrate critical thinking skills necessary for college success, learn the importance of a digital professional presence, begin the development of a four-year e-portfolio project, design a graduation plan, demonstrate an understanding of academic resources on campus, explore career opportunities through events on campus and guest speakers, and engage in activities with the college and local community.

Entering Research I (ISCI 120) and II (ISCI 121)

The first half of the Entering Research course sequence, adapted from Balster, Pfund, Rediske, and

Branchaw (2010), engages LIFE STEM Scholars in an authentic, albeit guided, research experience and supports their development of basic skills necessary for a successful research experience. The Chesapeake Bay serves as the research focus. It is a context broad enough to support a wide range of learning activities: field, bench, and modeling work by students in all four majors; literature searches and critical reading of relevant scientific articles; explorations of connections between science and society; and consideration of research ethics. Drawing on data collected during the summer bridge, Scholars developed research questions and hypotheses in multidisciplinary student teams. This experience culminated with project presentations that outlined all aspects of the project, from definition of the problem, formulation of the hypothesis, design of the experiment, collection and analysis of the

TABLE 3. The Entering Research Sequence: Student Outcomes for Key Skills, Weekly Course Topics That Support Development in Those Areas, and Student Research Products

Entering Research I (ISCI 120)	Entering Research II (ISCI 121)
Skill Objectives: students will be able to…	
• Differentiate between science and pseudoscience • Establish reasonable research expectations and mentor/mentee expectations • Find appropriate literature and apply concepts to a scientific question • Design and execute an experiment that tests a hypothesis • Critically evaluate data • Interpret models of scientific processes • Communicate scientific information in written and oral formats	• Find appropriate literature and apply concepts to a scientific question • Critically present a scientific paper to peers, focusing not only on content and results but the merits of the study • Design and execute an experiment that tests a hypothesis • Critically evaluate data • Interpret models of scientific processes • Communicate scientific information in written and oral formats • Continue to examine different research opportunities on Longwood's campus
Weekly Topics	
• The nature of science: science or pseudoscience? • Introduction to biological inquiry: the scientific method • Communicating science: information literacy • How to read scientific articles • Research experience expectations • Finding a research mentor • Mentor/mentee expectations • Background information and hypothesis/research question • Discussion with experienced undergraduate researchers • Case study: "Frustrated" • Collection of data • Analysis of data • Making charts, graphs, and figures • What's to discuss?: how to write the discussion of a paper • Communicating science with posters and presentations	• Scientific article review: practical reading strategies • Finding articles • Discussion of science in society • Introduction to research proposal • Proposal introduction: crash course • Article presentations (multiple) • Proposal-specific aims: crash course • Research case studies (multiple) • Peer reviews (multiple) • Proposal significance: crash course • Creating a research contract • CV vs. résumé • Research opportunities • Research: faculty members' perspectives • Developing proposal presentations • Discussion revisited: science in society
Student Research Projects (ISCI 120) and Proposals (ISCI 121)	
• Calculating levels of chlorophyll in the Chesapeake Bay • Determination of dissolved oxygen levels within the Chesapeake Bay • Concentration of microplastics in the Chesapeake Bay • Analyzing organic material found in sediment throughout the Chesapeake Bay	• Human impacts on the eastern oyster (*Crassostrea virginica*) in the Chesapeake Bay • The detrimental effects of the snakehead fish (*Channa argus*) in the Chesapeake Bay • Microplastic pollution in the Chesapeake Bay • Impacts of external forces on the area of Tangier Island: the effects of urbanization on the health of the Chesapeake Bay ecosystem • The effects of agricultural chemical runoff on water quality and benthic species • Invasive species in the Chesapeake Bay • Rays in the Bay: climate change and Rhinoptera bonasus behavior in the Chesapeake Bay

data, and drawing of the conclusions (Table 3). Several experiences within this course added to the breadth of content that continues to define the Scholars' e-portfolios.

Entering Research II reinforces and expands upon the knowledge and skills practiced in Entering Research I. Scholars continue to hone their skills in reading and comprehending primary literature by making a formal oral presentation of the background and findings of a scientific paper in their field of choice, thus allowing flexibility of interest in this multidisciplinary group. In addition, continuing the focus on the Chesapeake Bay, Scholars design formal proposals for research—from posing a question through final presentation—in a multidisciplinary team. This process challenges Scholars to practice experimental questioning and implementation, expand their thinking to consider the larger scope of a research proposal, and establish a strong argument to convince an audience of the significance of a project (Table 3).

Mentoring

Each LIFE STEM Scholar was paired with a faculty mentor prior to the Scholar's arrival on campus. This mentoring relationship, which is intended to grow and mature over four years, is a core component of the LIFE STEM experience. Mentoring is intensive in the first two years with weekly and biweekly meetings; regular but less frequent meetings continue during the third and fourth years as the Scholars develop more independence. Fourteen faculty members from the two science departments mentored at least one Scholar, with most mentoring two Scholars, one from each cohort. To prepare for this individualized work with Scholars, mentors participated in a workshop provided by Dr. Janet Branchaw of the University of Wisconsin's Institute for Biology Education. In addition to faculty mentors, Scholars also benefited from student peer mentors either from the CHC (cohort 1) or a current LIFE STEM Scholar (cohort 2). Although the structure was informal, peer mentors were often able to better understand and assist with the struggles associated with college life.

Student Voices: Reflections on the First-year Experience

Four LIFE STEM Scholars provided reflections on their experiences in the program: Samuel Morgan and Charlotte Pfamatter, Class of 2021 Integrated Environmental Sciences majors; Kelsey Thornton, Class of 2021 Biology major; and Cecily Hayek, Class of 2022 Biology major. These Scholars' voluntary narratives (for which no specific directions were given) articulated insights on their learning in the affective domain. Drawing on a framework outlined by Trujillo and Tanner (2014), we tie their reflections to three key constructs related to the successful transition to the college environment and subsequent academic success: a sense of belonging in an academic community; identity as a professional and, more specifically, a scientist; and self-efficacy. Importantly, the development of their understanding of the connections between science and civic issues also was highlighted.

Sense of belonging

Students' sense of belonging affects academic motivation, academic achievement, and well-being (Trujillo & Tanner, 2014), and first-year college students who experience more peer support performed better academically and had lower levels of stress, depression, and anxiety (Pittman & Richmond, 2008). LIFE STEM Scholars highlighted their early, meaningful, and persistent connections.

> "The immediate connections and opportunities we were afforded upon arrival to Longwood have had a lasting impression on my time here, thus far. I was able to develop friendships before other college students, which made the transition less intimidating." (Kelsey)

> "I cannot think of too many better ways that I could have started off college than going on my freshman summer bridge program. Meeting so many bright students and adults who shared my interest for science was an unexpected delight. What has been even more remarkable has been how I have kept my friendships and connections for almost two years and they have only gotten stronger. I have teamed up with many of my LIFE STEM friends for presentations, posters, and conferences, and each time, I know that

I am able to rely on my cohort for sterling work and helpful insight."

> "While my duty is to my assigned mentee, I see both cohorts as one community where we are all trying to help each other get through college and make it out with a brighter future. Besides partnering with them on projects, I have enjoyed many one-on-one conversations on making it through college. I have gotten to bond over dinners and lunches, and I have benefitted from a few late-night study groups. I see this community best exemplified when many of us go back each semester to Hull Springs to beautify the area through gardening. We get to spend a weekend doing some service while also bonding. We get to self-lead and organize ourselves while giving back to the university that granted us this excellent program in the first place." (Samuel)

> "My LIFE STEM peer mentor has been so kind and supportive this year that I decided to apply to be a peer mentor for the next cohort. I know that these relationships that I have formed over this past year will continue to grow, and I am so thankful that I have been able to create such a great support system." (Cecily)

The development of sense of belonging is not limited to peer interactions: connections to faculty members also are important in promoting students' sense of belonging in the university context (Freeman, Anderman, and Jensen, 2007).

> "I believe that the faculty-student connections we made upon arrival, and continue to make to this day, are the best reward of this program. Being able to go to any science faculty member and ask them about anything, whether it be in regard to academics or just life, they already know you and they are there and willing to help." (Kelsey)

> "The LIFE STEM faculty have been able to make Chichester (our science building) feel like home. I have gone to so many faculty STEM mentors for guidance on school projects, and I will always be thankful for the many opportunities they have afforded me." (Samuel)

> "Other than academic success, this program has also given me many great mentors who have been integral in helping me plan out my future. My faculty mentor is always there to give me advice on anything I ask about and is even assisting me in contacting people in my desired field." (Cecily)

Identity as a scientist

A student's identification as a scientist is linked to persistence, and students who left the sciences often did not adopt that professional identity (Trujillo & Tanner, 2014). Science identity can be framed as a composite of multiple factors, including performance, recognition, and competence (Carlone & Johnson, 2007). Those dimensions are evident in the following statements by LIFE STEM Scholars:

> "I have become a strong leader and a confident biologist in the making. I am excited to move forward in this program, meet and connect with future cohorts, and continue growing as a student and as a Citizen Leader." (Kelsey)

> "One of my proudest titles at Longwood is being a LIFE STEM Scholar. . . . LIFE STEM has been pivotal for me not only as a student but as a young professional. . . . Also, LIFE STEM has brought me confidence as an aspiring scientist. Coming to college, I had limited experience in science and had only brief exposure to it in high school. I was not knowledgeable on scientific writing and presentations. The LIFE STEM courses have groomed me to become a professional in the STEM world through step-by-step writing and presenting exercises, while providing many opportunities for practice. This program has equipped me with the tools I need to be a competitive student in my major, which will help me thrive in a

STEM career and graduate school after Longwood." (Charlotte)

"I hope to continue to grow as a student and forge even more connections that will allow me to further my education as a biologist." (Cecily)

Self-efficacy

A student's self-efficacy is the belief or confidence that his/her/zir actions can affect outcomes and have desired effects (Bandura, 1997). It is an ingredient that can move students beyond the "raw materials" of knowledge and skills to academic success (Klassen & Klassen, 2018). LIFE STEM Scholars' reflections indicate that the program's scaffolded academic experiences and early research immersion supported students' confidence in moving forward positively to more advanced work.

> "This program helped me to grow in many aspects, both professionally and personally. In my first year, I learned how to do scientific research and had the opportunity to improve my public speaking skills. The second year was predominately learning how to be a scientist; that is, how to read articles, how to synthesize, and how to report to different audiences. These were all skills that were challenging at the time; however, I was grateful to have learned them in the LIFE STEM Program classes. Once the cohort started taking classes outside of the program, I was personally able to see how far ahead we were compared to other students in regard to simple skills such as writing and public speaking." (Kelsey)

> "As a mentor to the second cohort of LIFE STEM students, I have been able to grow in my leadership skills. In my first year, I was provided with lots of help, advice, and opportunities, but, as a mentor in my second year, I got to provide those things to my mentees." (Samuel)

> "LIFE STEM has helped me gain momentum in pursuing undergraduate research. This academic program is designed for students to learn about undergraduate research, with the hope of actually taking on a research opportunity. The courses have exposed me to examples of some of the faculty's work, while also being able to meet face to face with professors to learn what research entails. Because of LIFE STEM, I was able to take on research in my sophomore year and the summer before my junior year. LIFE STEM prepared me with professional communication skills, which landed me an opportunity to do research for the duration of my time at Longwood." (Charlotte)

> "Coursework as a Biology major can be challenging, and I was pleased when I found myself performing much better on assignments and assessments than other students that are not in the program. This success is because of the skills and knowledge that LIFE STEM Scholars are exposed to within the first semester. I have been able to improve my writing immensely and even broaden my skills in researching and reading scientific articles. I believe that this program has opened doors for me within the scientific field as well as my other courses." (Cecily)

Connections between Science and Civic Issues

The LIFE STEM Scholars begin their university careers immersed in a complex and contested civic issue that at first is framed as a scientific problem. Their "engagement with 'multidisciplinary trouble' and civic questions that require attention now" (SENCER, 2017) has prompted students to reevaluate their perceptions of their identities and their responsibilities as citizens and scholars.

> "As I spent time on the Chesapeake Bay, I realized that an environmental scientist's purpose cannot be to merely understand the relationship between a community of organisms and the landscape they inhabit, or to work to preserve beneficial ecosystems. Instead, an environmental scientist's job is to lend their knowledge and skills to a cooperative effort of maintaining and improving a society's relationship with the natural world. The Bay is much more than

a tidal estuary for crabs, oysters, pelicans, and shad. The Bay has historical, economic, and recreational significance, and serves as a home to millions of people. Sometimes natural preservation conflicts with keeping these other values. An environmental scientist's purpose must involve attempting to preserve all of society's values." (Samuel)

Conclusion

Although it is still in the early stages of the evaluation process, initial assessment by Virginia Commonwealth University's Metropolitan Educational Research Consortium (MERC) suggested that the LIFE STEM Program has been successful in achieving its objectives. From first to second semester, LIFE STEM Scholars were retained at a higher rate than their peers in the science majors (Table 4). Additionally, Scholars reported feeling academically supported through the program and expressed gratitude for the opportunity to connect with a cohort of science peers and faculty through the summer bridge, mentoring program, and LIFE STEM coursework (MERC unpublished data). Scholars from the first cohort also informally reported to the LIFE STEM Leadership Team that as they transitioned to upper-level courses, they perceived themselves to be better prepared for scientific writing and oral presentations than their peers. They attributed that to the Entering Research course sequence. Longwood University also recognized the successes of the program by providing institutional funding to enroll a third cohort of LIFE STEM Scholars, which extends the positive impacts of the program to continue beyond the timeline initiated in the NSF S-STEM award.

Though the program is off to a strong start, it is not immune to both program- and institutional-level challenges such as faculty workload and sustainability. To address that, some members of the LIFE STEM Leadership Team applied and were accepted to the 2019 ASCN (Accelerating Systemic Change Network) Systemic Change Institute. The team's major goals for the institute were to develop a realistic plan for engaging faculty from the science departments in discussions about lessons learned and opportunities for implementation beyond LIFE STEM, learn about proven strategies for engaging faculty in scaling up nascent efforts, identify strategies for engaging faculty and staff in recruiting efforts, and consider program elements that might support different funding opportunities, including the Howard Hughes Medical Institute's Inclusive Excellence program.

As the LIFE STEM Leadership Team and MERC continue to learn about the program's successes, identify areas for improvement and growth, and pursue opportunities for scaling beyond the small cohorts, the Scholars' first-year immersion at the intersection of science and civic issues continues to serve as a foundation for the Scholars' academic and co-curricular efforts. The SENCER Ideals are infused into the upper-level LIFE STEM coursework, and Scholars are pursuing leadership roles on campus that again position them at that intersection (e.g., Eco-Reps in the university's Office of Sustainability).

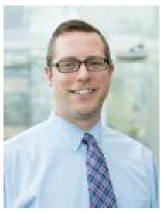
TABLE 4. Retention Rates* of Longwood University Undergraduates (UG) for the Two Classes in Which the LIFE STEM Cohorts Are Embedded

Term	All UG	All UG Retention (%)	All Science Majors	Science Retention (%)	LIFE STEM Scholars	LIFE STEM Retention (%)
Incoming Class of 2021 (Fall 2017)						
Fall 2017	1016	.	101	.	12	.
Spring 2018	899	88	86	85	11	92
Fall 2018	759	84	73	85	10	91
Spring 2019	740	97	66	90	9	90
Incoming Class of 2022 (Fall 2018)						
Fall 2018	993	.	97	.	16	.
Spring 2019	869	88	79	81	14	88

* *Retention is defined here as students who return to the university in the following term; these data were provided by the Longwood University Office of Assessment and Institutional Research. Cohort tracking includes only students who enter as first-time, full-time freshmen.*

Authors

Michelle Parry is associate professor of physics in the Department of Chemistry and Physics (C&P). She serves as the LIFE STEM Program coordinator and teaches the LIFE STEM Seminar I course that focuses on the successful transition to college. She also serves as the physics area coordinator and is responsible for program assessment and for leading curriculum change.



Wade Znosko is associate professor of biology in the Department of Biological and Environmental Sciences (BES). He leads the two-semester sequence of Entering Research for the LIFE STEM Program. His research on the effects of impaired waterways on the development of vertebrates helps to inform some of the data collection and analysis techniques during this sequence.

Alix Dowling Fink is dean of the Cormier Honors College for Citizen Scholars and professor of biology in BES. She has been involved with SENCER for more than 15 years and, with Michelle, developed a SENCER Model Course, The Power of Water. Collaborating with colleagues across the disciplines, she also developed a transdisciplinary student program in Yellowstone National Park focused on the stewardship of our public lands. Her commitment to the SENCER Ideals continues to shape her work with students in the classroom, in the field, and through her administrative efforts.

Mark Fink is the chair of BES and associate professor of biology. Since 2011, he has facilitated immersion learning experiences on the Chesapeake Bay, first with teacher candidates and in-service teachers and currently with students from all majors. In those programs and his life science course for future K–8 teachers, Mark has sought to engage students in learning science concepts by using relevant, timely, and challenging civic contexts.

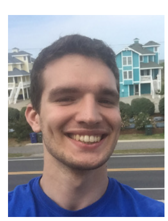
Kenneth Fortino is an associate professor of biology in BES, where he teaches courses in introductory biology, ecology and evolution, ecosystem ecology, and introductory environmental science. His current research is on the factors that affect organic matter processing in freshwater ecosystems.

Melissa Rhoten is a professor of chemistry in C&P. Her research interests include topics in chemical education, bioanalytical electrochemistry, and biosensors. Melissa has been involved in pedagogical activities focused on the implementation of inquiry-based learning in Longwood's chemistry curriculum. She currently serves as the director of Longwood's new Civitae Core Curriculum.

Sarai Blincoe is an associate professor in the Department of Psychology and is the discipline-based educational researcher for the LIFE STEM Program. She regularly teaches undergraduate courses in research methods and social psychology and publishes research on disrespect, trust, and the scholarship of teaching and learning. Sarai serves as assistant dean of curriculum and assessment in the Cook-Cole College of Arts and Sciences.

Student Contributors

Cecily Hayek is a biology major who graduated from Lake Braddock Secondary School in Fairfax, VA, in May 2018. In June 2019, she attended the Mid-Atlantic Marine Debris Summit that sought to find solutions for marine litter and subsequent problems such as microplastics. Cecily plans to pursue a career in veterinary medicine.



Samuel Morgan is an integrated environmental sciences major who started his studies at Longwood University in August 2017. Since then, he has been a LIFE STEM mentor as well as a student collaborator on faculty research focused on allelopathy.

Charlotte Pfamatter is an integrated environmental sciences major who graduated from Monacan High School in North Chesterfield, VA, in May 2017. In the summer of 2018, Charlotte participated in the School for Field Studies program in Turks and Caicos Islands that explored issues in marine conservation.

Kelsey Thornton is a biology major who graduated from Thomas Dale High School in Chester, VA, in May 2017. In the summer of 2019, she participated in the Longwood University study abroad experience examining conservation and economics in Ecuadorian Amazon. Kelsey's professional goal is to become a veterinarian.

References

Balster, N., Pfund, C., Rediske, R., & Branchaw, J. (2010). Entering research: A course that creates community and structure for beginning undergraduate researchers in the STEM disciplines. CBE Life Sciences Education, 9(2), 108–118. Retrieved from http://www.lifescied.org/content/9/2/108.long

Bandura, A. (1997). Self-efficacy: The exercise of control. New York: Freeman.

Braid, B., & Long, A. (2000). Place as text: Approaches to active learning. National Collegiate Honors Council. Retrieved from http://digitalcommons.unl.edu/nchcmono/3/

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of women of color: Science identity as an analytical lens. Journal of Research in Science Teaching, 44(8), 1187–1218.

Chesapeake Bay Foundation (CBF). (2018). State of the Bay report. Retrieved from https://www.cbf.org/document-library/cbf-reports/2018-state-of-the-bay-report.pdf

Chesapeake Bay Program (CBP). (2017). Facts and figures. Retrieved from https://www.chesapeakebay.net/discover/facts

Chesapeake Bay Program (CBP). (2019). Bay barometer. Retrieved from https://www.chesapeakebay.net/documents/2017-2018_Bay_Barometer.pdf

De Gale, S., & Boisselle, L. (2015). The effect of POGIL on academic performance and academic confidence. Science Education International, 26(1), 56–79.

Freeman, T. M., Anderman, L. H., & Jensen, J. M. (2007). Sense of belonging in college freshmen at the classroom and campus levels. Journal of Experimental Education, 75(3), 203–220.

Hein, S. M. (2012). Positive impacts using POGIL in organic chemistry. Journal of Chemical Education, 89(7), 860–864.

Klassen, R. M., & Klassen, J. R. L. (2018). Self-efficacy beliefs of medical students: A critical review. Perspectives on Medical Education, 7(2), 76–82.

National Marine Fisheries Service (NMFS). (2017). Commercial fisheries statistics. Retrieved from https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/other-specialized-programs/total-commercial-fishery-landings-at-major-u-s-ports-summarized-by-year-and-ranked-by-dollar-value/index

President's Council of Advisors on Science and Technology (PCAST). (2012). Engage to excel: Producing one million additional graduates with degrees in science, technology, engineering, and mathematics. Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

Pittman, L. D., & Richmond, A. (2008). University belonging, friendship quality, and psychological adjustment during the transition to college. Journal of Experimental Education, 76(4), 343–362.

Science Education for New Civic Engagements and Responsibilities (SENCER). (2017). SENCER Ideals. Retrieved from http://sencer.net/sencer-ideals/

Trujillo, G., & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. CBE Life Sciences Education, 13, 6–15. Retrieved from https://www.lifescied.org/doi/full/10.1187/cbe.13-12-0241

Study of Healthcare-Associated Infections and Multi-Drug Resistance in Brooklyn:

An Integrative Approach

LIANA TSENOVA
New York City College of Technology

URMI GHOSH-DASTIDAR
New York City College of Technology

ARNAVAZ TARAPOREVALA
New York City College of Technology

AIONGA PEREIRA-EDWARDS
New York University

PAMELA BROWN
New York City College of Technology

Abstract

One SENCER ideal is to connect science education and civic engagement by student learning through complex, unresolved public issues. Using this approach, we established a collaborative interdisciplinary project involving faculty and undergraduate students at NYC College of Technology. Over several semesters, students conducted literature search and discovered the complex factors contributing to the occurrence and transmission of healthcare-associated infections (HAIs). Using microbiology data from 15 hospitals in Brooklyn, NY, they applied statistical analyses, studied the antibiotic resistance, and developed a campaign to bring more awareness of this problem. The results of the project highlight the importance of immediate action in combating HAIs and support the need for a public health campaign. Undergraduate students were provided with the opportunity to conduct research, perform scientific and mathematical analyses, and present their results. They gained better understanding of the complex interactions among microbiology, epidemiology, and mathematics that is needed to develop preventative measures and combat HAIs.

Introduction

In April 2014, World Health Organization officials released a comprehensive report on antibiotic resistance, calling it a "major threat to public health" and seeking "improved collaboration around the world to track drug resistance, measure its health and economic impacts and design targeted solutions" (WHO, 2016). Using the SENCER ideals of connecting science education and civic engagement by teaching through complex, unresolved public issues, and inspired by the SENCER Summer Institute (SSI) in Chicago, we established a collaborative interdisciplinary project for undergraduate students at the NYC College of Technology, led by faculty from the Biological Sciences and Mathematics departments. By combining epidemiology and microbiology with mathematics, the project addressed the need for public education and awareness of two emerging health care problems: (a) healthcare-associated infections (HAIs), formerly known as nosocomial infections (NIs), and (b) antibiotic resistance. HAIs are infectious diseases, acquired during a hospital stay, with no evidence of being present at the time of admission to the hospital. HAIs affect 5–10% of hospitalized patients in the US per year. Approximately 1.7 million HAIs occur in U.S. hospitals each year, resulting in 99,000 deaths (CDC, 2015). Today the complications associated with HAIs may be responsible for an annual $5–10 billion financial burden on our healthcare system (Cowan, Smith, and Lusk, 2019). Education and public awareness campaigns have been among the most effective tools used in many industries, including healthcare. HAIs are easily transmitted due to the numerous microbes in the hospital environment, the interaction of healthcare workers with multiple patients, the compromised immunity of patients, improper use of antibiotics, and inadequate antiseptic procedures. More than 70% of these infections are caused by multi-drug resistant (MDR) pathogens, which contribute to increased morbidity and mortality (Black and Hawks, 2009). Antibiotic resistance is the capability of particular microorganisms to grow in the presence of a given antibiotic. The acquired resistance results from spontaneous mutations or from the transfer of resistance genes from other microbes (Drlica & Perlin, 2011). Each year in the US, at least 2 million people are infected with antibiotic resistant bacteria, and at least 23,000 people die as a result (CDC, 2018; Sifferlin, 2017). With the increased levels of antibiotic usage among humans, livestock, and crops, antibiotic resistant bacteria have increased dramatically in the past few decades (Foglia, Fraser, & Elward, 2007; Sedláková et al., 2014). If a bacterial cell carries several resistance genes, relating to more than just one antibiotic, it is termed MDR, for multiple drug-resistant. Today these organisms are known as superbugs (Sifferlin, 2017).

The rising rate of antimicrobial resistance demands research and development of entirely novel drugs and new therapeutic strategies, from small-molecule antibiotics to antimicrobial peptides, from enzymes to nucleic acid therapeutics, from metal-carbonyl complexes to phage therapy (Medina & Pieper, 2016; Brunetti et al, 2016; Betts, Nagel, Schatzschneider, Poole, & Ragione, 2017; Nayar et al., 2015; Phoenix, Harris, Dennison, & Ahmed, 2015.

The main goal of this research project was to study the complex factors that contribute to the occurrence and transmission of HAIs associated with antibiotic resistance in Brooklyn hospitals, to apply statistical analyses to the data, and to bring more awareness of this problem to our college community.

Student Involvement

Students enrolled in Microbiology (BIO3302) and Statistics (MAT1272) worked collaboratively on this project. Undergraduate researchers, with a greater time commitment, were also involved in the project, through the college's Emerging Scholars program (New York City College of Technology, Undergraduate Research, 2019) or the Honors Scholars Program (New York City College of Technology, Academics, 2019) the former providing stipends to students and the latter providing honors credit in a course. Both programs require student professional development related to research, such as abstract writing, preparing a poster, and making oral presentations, and each provides the opportunity for undergraduate students to conduct research with a faculty mentor and gain a practical understanding of the material learned in courses. Undergraduate researchers included students majoring in nursing and other health sciences (for whom both BIO3302 and MAT1272 are required), applied mathematics, and computer engineering technology.

The specific objectives of the project were (a) to define the most common bacterial pathogens responsible for the spread of HAIs; (b) to identify risk factors and common infection sites; (c) to analyze microbial resistance to commonly used antibiotics, using data on multi-drug resistant bacterial isolates from hospitals in Brooklyn; (d) to study variations of resistance rates among different hospitals, using statistical analysis; (e) to study association among resistant isolates, using regression analysis; (f) to define the antibiotics with the highest bacterial resistance; (g) to raise awareness of preventative measures for reducing HAIs; and (h) to introduce students to an interdisciplinary practical field.

Over six semesters, students performed comprehensive literature search on scientific articles by using the following key words: healthcare-associated infections, hospital acquired infections, HAI, nosocomial infections, antibiotic resistance, multi-drug resistance, epidemiology, Brooklyn hospitals. Additionally, they obtained already published data on multi-drug resistant clinical isolates from 15 coded (unidentified) hospitals in Brooklyn, (kindly provided by Dr. J. Quale, Division of Infectious Diseases, State University of New York Downstate Health Sciences University) (Bratu, Landman, Gupta, Trehan, Panwar, & Quale, 2006; Manikal, Landman, Saurina, Oydna, Lal, & Quale, 2002; Landman et al., 2002; Landman et al., 2007). Using the data, students performed statistical analysis, using chi-squared tests on antibiotic resistance and regression analysis.

Results

Most Common Bacterial Pathogens and Risk Factors

As a result of extensive literature search, students defined twelve bacterial pathogens associated with HAIs. The most common ones in Brooklyn were *Staphylococcus aureus*, including methicillin-resistant *Staphylococcus aureus* (MRSA), *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and *Clostridium difficile*. Next, the specific bacterial characteristics and the most prevalent sites of infections (urinary tract, lower respiratory tract, surgical incisions, and bloodstream) were described. Those at highest risk of contracting HAIs are patients with (a) a compromised immune system as a result of a transplant, HIV infection, malignant tumors, or possible prolonged treatment with antibiotics, cytostatics, or corticosteroids; (b) surgical procedures; (c) invasive procedures (e.g., urethral catheters, trachea ventilators, and/or intravenous therapy); (d) trauma and burn patients; (e) an underdeveloped immune system (e.g., newborns); and (f) diminished resistance (e.g. elderly); and (g) prolonged hospitalization, also a significant risk factor.

Statistical Analysis of Antibiotic Resistant Clinical Isolates

The next step of the project was to study the impact of multi-drug resistance on HAIs. One of the project participants established personal communication with Dr. J. Quale, who provided numerically coded data on clinical isolates collected from 15 Brooklyn hospitals. The percentage of resistance to the following most commonly used antibiotics was examined and compared: Amikacin (AK), Gentamicin (GEN), Ceftazidime (CAZ), Piperacillin-Tazobactam (Pip-Taz), Ciprofloxacin (Cip), and Imipenem (Imi).

Analyses of the antibiotic resistance indicated that most of the clinical isolates were highly resistant to Ciprofloxacin, reaching 100% resistance among *Acinetobacter baumannii*. These results demonstrate that Ciprofloxacin should be used minimally for the tested HAI pathogens. Newer therapies such as Tigecycline and the combination of Polymixine + Rifampin showed much better bacterial susceptibility.

Chi-squared tests (Table 1) revealed significant resistance variations of *Klebsiella* isolates to the antibiotics AK, CAZ, Cip, and Imi among the hospitals, that is, the variations of drug resistance of these isolates were too large to have occurred by chance alone. Significant resistance variations of *Pseudomonas* isolates to AK, Cip, and Imi were also observed. The underlying causes of these disparities are most likely the differences in the inpatient population. Elderly and sicker patients usually take in more antibiotics and thus harbor antibiotic resistant bacteria. Patients in trauma centers are also more likely to develop antibiotic resistance. Furthermore, overuse or repeated use of a specific antibiotic by a hospital would lead to a higher resistance rate for that particular antibiotic.

TABLE 1. Chi-Squared Tests on Resistance Variations Among Hospitals

Antibiotics/ Pathogens	Klebsiella	Pseudomonas	Acinetobacter
AK	$\Xi^2 = 68.8155$ p-value < 0.001 (Null hypothesis rejected)	$\Xi^2 = 25.5509$ p-value < 0.05 (Null hypothesis rejected)	$\Xi^2 = 16.4532$ (Null hypothesis not rejected)
CAZ	$\Xi^2 = 84.5723$ p-value < 0.001 (Null hypothesis rejected)	$\Xi^2 = 9.7463$ (Null hypothesis not rejected)	$\Xi^2 = 12.1614$ (Null hypothesis not rejected)
Cip	$\Xi^2 = 81.8907$ p-value < 0.001 (Null hypothesis rejected)	$\Xi^2 = 51.2586$ p-value < 0.001 (Null hypothesis rejected)	$\Xi^2 = 5.758$ (Null hypothesis not rejected)
Imi	$\Xi^2 = 91.8921$ p-value < 0.001 (Null hypothesis rejected)	$\Xi^2 = 37.2784$ p-value < 0.001 (Null hypothesis rejected)	$\Xi^2 = 41.1553$ p-value < 0.001 (Null hypothesis rejected)
Pip-Taz	$\Xi^2 = 80.4947$ p-value < 0.001 (Null hypothesis rejected)	Not Applicable	Not Applicable

Interestingly, different scenarios were observed for *Acinetobacter* isolates. Variations of *Acinetobacter* resistance to the antibiotics AK, CAZ and Cip among the hospitals were not statistically significant; however, significant variations to Imi were observed. Patients with *Acinetobacter* infections are usually very ill and heavily exposed to antibiotics. *Acinetobacter* bacteria are resistant to most antibiotics, and thus for these isolates, variations of resistance to most antibiotics do not show statistically significant differences among the participating hospitals.

Regression analysis showed high correlation between the antibiotic resistance of different pathogens. The correlation coefficient between *Klebsiella* and *Pseudomonas* was 0.929, *Klebsiella* and *Acinetobacter* - 0.825 and between *Pseudonomnas* and *Acinetobacter* - 0.859. The correlation between resistance of a specific organism to different antibiotics was also studied. Extremely strong positive correlation was found between Ceftazidime and Ciprofloxacin ($R^2 = .9961$) in *K. pneumoniae* (Table 2), suggesting that these bacteria may carry the resistant genes for both antibiotics. Most hospital facilities nowadays use common antibiotics to treat infections. Within inpatient population there is a greater chance of contracting and spreading infections due to compromised or weakened immunity and the variety of pathogenic organisms present in such settings. Therefore, resistance to antibiotics that are prevalently used is higher.

TABLE 2. Correlation of Resistance to Different Antibiotics in Isolates of K. pneumoniae

Klebsiella pneumoniae			
Caz and Pip-Taz	$R^2 = .9921$	Ak and Cip	$R^2 = .9208$
Caz and Cip	$R^2 = .9961$	Caz and Imi	$R^2 = .8904$
Piptaz and Cip	$R^2 = .9534$	Piptaz and Imi	$R^2 = .7593$
Piptaz and AZ	$R^2 = .8535$	Ak and Imi	$R^2 = .7531$
Ak and Caz	$R^2 = .8685$	Caz and Cip	$R^2 = .7264$
Cip and Imi	$R^2 = .8218$	Cip and Imi	$R^2 = .7184$

Preventative Measures

Another important objective of our study was to understand the need for proper preventative measures for reducing HAIs. In order to protect all individuals in the clinical setting—patients, healthcare workers, and public (visitors), CDC has laid down strict guidelines for handling patients and body specimens, termed Universal Precautions (CDC, 1998). All students, especially those majoring in health sciences, became acquainted with and learned these guidelines. The fight against the spread of MDR organisms begins with proper hand hygiene, correct use of personal protective equipment (PPE), and judicious use of pharmacologic treatment (Weinstein, 2001). Practicing proper frequent hand hygiene is essential to prevent the transmission of infections. It requires washing hands with soap and vigorous rubbing under running water for at least twenty seconds. Alcohol-base sanitizers are also used on unsoiled hands and require less time than hand washing. However, sanitizers are not effective in killing bacterial spores, whereas hand washing is effective on all microbes. PPE includes gowns, goggles, or facial shields to protect skin and mucus membranes. Targeted pharmaceutical treatment, as a result of an antibiogram, should be prescribed instead of blind use of broad-spectrum antibiotics. Repeated bacterial cultures are necessary to assess the effectiveness of treatment. Additional preventative measures to reduce HAIs are (a) decreasing the number of skin punctures on a patient, since they provide opportunities for colonizing microflora; (b) following aseptic techniques when performing invasive procedures such as placing urethral and intravenous catheters; (c) reducing the duration of intravenous lipid use, since lipids are immunosuppressive, are easily contaminated, and support growth of fungi and bacteria; and (d) limiting the number of days for percutaneous deep lines.

Technology is also playing a role in preventing and improving effective patient care through sharing health information. The Health Information Technology for Economic and Clinical Health Act allows hospitals and providers to share patients' health information (ONC, 2019). In New York City many healthcare providers are taking advantage of programs like the Regional Health Information Organization, a network that contains a complete picture of patient's health history.

Assessment and Outcomes

The information gained in this project highlights the importance of immediate action in combating HAIs and supports the need for a public health campaign. The project provided students with the opportunity to conduct mentored interdisciplinary research, work as a team, perform scientific and mathematic analyses, participate in discussions, and exchange opinions. Students were enabled to better understand the complex interaction between microbiology, epidemiology, and statistics and to gain knowledge of the need for preventative measures to combat HAIs. Adding the research component to the Microbiology course has helped students connect the information learned in class to the real world and to recognize the importance of HAIs and MDR as a threat to public health. Throughout the project, in a creative environment, students defined the most common bacterial species responsible for the spread of HAIs in Brooklyn and identified the risk factors and common infection sites. Using the data on multi-drug resistant isolates, they performed statistical analysis to study the correlation between two different antibiotic resistances and variability among Brooklyn hospitals. Their work was disseminated by publishing flyers (Figures 1 and 2) for distribution in local hospitals and clubs. Currently, the information from the project continues to be used by the participating faculty in MAT1272 for "hand washing habits" assignments, which also leads to a discussion on antibacterial soaps, sanitizers, and the occurrence of superbugs.

Furthermore, different phases of the project were presented at the end of each semester at the Semi-Annual Poster Sessions for Honors and Emerging Scholars at the New York City College of Technology. Several undergraduate students presented their research at regional and national conferences such as NYSMATYC (NYSMATYC, 2011), MAA Regional Meetings, Math Fest (Ghosh-dastidar, 2010), the 13th Annual CUNY Pipeline Honors Conference, and the Annual Biomedical Research Conference for Minority Students (ABRCMS). The project was also presented at the SENCER Washington Symposium and Capitol Hill Poster Session in Washington DC. The work was also reflected in MAA Focus magazine (Baron, 2011), and in the NY Daily News.

FIGURE 1. Flyer with Information about Nosocomial Infection (Courtesy of Gillian Persue)

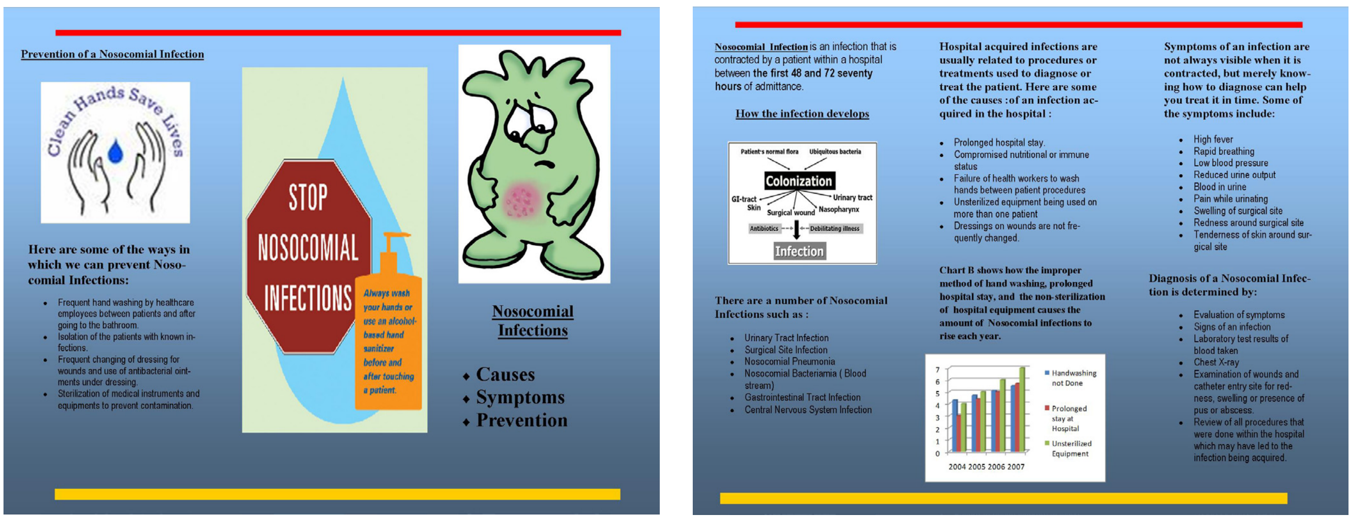


FIGURE 2. Flyer with Information about Nosocomial Infection (Courtesy of Michell Cadore)

In conclusion, we consider the research project very successful. Our main goal was achieved: to combine different subject areas, to address serious public health issues, such as HAIs and antibiotic resistance, and to bring more awareness in our community. The students were very enthusiastic and eager to learn and interacted very efficiently among themselves as a team. The success of the project is best conveyed by the students' reflections on their research work:

> "This was my first research project and it was challenging. I never thought I could do pathology research, but it opened a door to a new area. The experience was especially important for me, since health care workers can spread nosocomial infections. We're supposed to help patients, but we can harm them. I would encourage everyone to do a research project in college. It's definitely worth it."

> "The most significant part of this project for me was working as an interdisciplinary team. I am proud to say that the results of our research were later presented on a state level at Cornell University in Ithaca, New York."

Acknowledgement

This work was supported by a sub-award from SENCER, SSI 2009 to P.B. and the Emerging Scholars Program at New York City College of Technology. Many thanks to Dr. J. Quale, Division of Infectious Diseases, State University of New York

Downstate Health Sciences University for sharing his knowledge and his valuable suggestions. We acknowledge the excellent research performance of all student participants, led by Rona Gurin, Aionga Pereira (currently a co-author), Farjana Ferdousy, Efrah Hassan, Cintiana Execus, Jessica Obidimalor, Hui Meen Ong, Philip Ajisogun, and Jennifer Chan Wu.

Authors

Liana Tsenova is a professor of Biological Sciences at the New York City College of Technology. She earned her MD degree and specialty in microbiology and immunology from the Medical Academy in Sofia, Bulgaria. Dr. Tsenova received her postdoctoral training at the Rockefeller University in NYC. Her research is focused on the immune response and host-directed therapies in tuberculosis and other infectious diseases. She has co-authored more than 50 publications. At City Tech she has served as the PI/project director of the Bridges to the Baccalaureate Program, funded by NIH ($1.2million. She is a SENCER leadership fellow. She mentors undergraduate students in collaborative interdisciplinary projects, combining the study of microbiology and infectious diseases with chemistry and statistics, to address unresolved healthcare problems.

Urmi Ghosh-Dastidar is the coordinator of the Computer Science Program and a professor in the Mathematics Department at New York City College of Technology. She received a PhD in applied mathematics jointly from the New Jersey Institute of Technology and Rutgers University and a BS in applied mathematics from The Ohio State University. Her current interests include parameter estimation via optimization, infectious disease modeling, applications of graph theory in biology and chemistry, and developing and applying undergraduate bio-math modules in various SENCER related projects. She was elected a SENCER leadership fellow by the National Leadership Board of the National Center for Science and Civic Engagement.

Arnavaz Taraporevala is a professor of mathematics at New York City College of Technology. She received her doctorate in statistics from Michigan State University. She is a member of the Curriculum Committee of the Mathematics Department and is actively involved in curriculum development. Her courses include an intensive writing component and student portfolios. Professor Taraporevala has served as a mentor to several students in honors projects. Her research interests are in stable processes and in pedagogical issues in mathematics. She co-wrote (with Professors Benakli and Singh) the text *Visualizing Calculus by Way of Maple* (New York: McGraw Hill Publishers, 2012).

Aionga Sonya Pereira is a registered nurse. She graduated from Long Island University with a BSN and is currently working on her MSN. Her specialty areas and passion are emergency medicine and psychological health, and she has worked in both areas for the last six years. She is a reserve Air Force officer and is the current officer in charge (OIC) of mental health at the 459^{th} ASTS at Joint Base Andrews. Most recently she joined the Mount Sinai Healthcare System as an RN. Her love for research started as an undergraduate student at the New York City College of Technology, where she participated in the Emerging Scholars Program. Aionga continues to seek ways to merge civic engagement research and nursing.

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 her current position, Dr. Brown was dean of the School of Arts & Sciences for six years. Dr. Brown also served as 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, having earned her PhD from Polytechnic University and SM from the Massachusetts Institute of Technology. Her research interests include development and assessment of student success initiatives.

References

Baron, L. M. (2011). Microbiology project adds life to mathematics. *MAA Focus*, *31*(3), 19. Retrieved from http://digital.ipcprintservices.com/publication/?i=72837

Betts, J., Nagel, C., Schatzschneider, U., Poole, R., & Ragione, R. M. (2017). Antimicrobial activity of carbon monoxide-releasing molecule [Mn(CO)3(tpa-κ3N)]Br versus multidrug-resistant isolates of Avian Pathogenic Escherichia coli and its synergy with colistin. *Plos One*, *12*(10). doi:10.1371/journal.pone.0186359

Black, J. M., & Hawks, J. H. (2009). *Medical-surgical nursing: Clinical management for positive outcomes* (8th ed.). St. Louis: Saunders.

Bratu, S., Landman, D., Gupta, J., Trehan, M., Panwar, M., & Quale, J. (2006). A population-based study examining the emergence of community-associated methicillin-resistant Staphylococcus aureus USA300 in New York City. *Annals of Clinical Microbiology and Antimicrobials*, *5*(29).

Brunetti, J., Falciani, C., Roscia, G., Pollini, S., Bindi, S., Scali, S., . . . Pini, A. (2016). In vitro and in vivo efficacy, toxicity, bio-distribution and resistance selection of a novel antibacterial drug candidate. *Scientific Reports*, *6*(1). doi:10.1038/srep26077

Centers for Disease Prevention and Control (CDC). (1998, June 24). Perspectives in disease prevention and health promotion update: Universal precautions for prevention of transmission of human immunodeficiency virus, Hepatitis B virus, and other bloodborne pathogens in health-care settings. *MMWR Weekly*, *37*(24), 377–388. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/00000039.htm

Centers for Disease Prevention and Control (CDC). (2015). Healthcare-associated infections: Preventing healthcare-associated infections. Retrieved from https://www.cdc.gov/hai/prevent/prevention.html

Centers for Disease Control and Prevention (CDC). (2018). Antibiotic/antimicrobial resistance: About antimicrobial resistance; Antimicrobial resistance threatens everyone. Retrieved from https://www.cdc.gov/drugresistance/about.html

Cowan, M. K., Smith, H., & Lusk, J. (2019). *Microbiology fundamentals: A clinical approach*. New York, NY: McGraw-Hill Education.

Drlica, K., & Perlin, D. S. (2011). *Antibiotic resistance: Understanding and responding to an emerging crisis*. Upper Saddle River, NJ: FT Press.

Foglia, E. E., Fraser, V. J., & Elward, A. M. (2007). Effect of nosocomial infections due to antibiotic-resistant organisms on length of stay and mortality in the pediatric intensive care unit. *Infection Control & Hospital Epidemiology*, *28*(3), 299–306. doi:10.1086/512628

Ghosh-dastidar, U. (2010, August 5). *Math, our community, and civic engagement*. Paper presented at *MathFest 2010*, Pittsburgh, PA. Abstract retrieved from https://www.maa.org/sites/default/files/pdf/abstracts/mf2010-abstracts.pdf

Landman, D., Bratu, S., Kochar, S., Panwar, M., Trehan, M., Doymaz, M., & Quale, J. (2007). Evolution of antimicrobial resistance among Pseudomonas aeruginosa, Acinetobacter baumannii and Klebsiella pneumoniae in Brooklyn, NY. *Journal of Antimicrobial Chemotherapy*, *60*(1), 78–82. doi:10.1093/jac/dkm129

Landman, D., Quale J. M., Mayorga, D., Adedeji, A., Vangala, K., Ravishankar, J., . . . Brooks, S. (2002). Citywide clonal outbreak of multiresistant Acinetobacter baumannii and Pseudomonas aeruginosa in Brooklyn, NY: The preantibiotic era has returned. *Archives of Internal Medicine*, *162*(13), 1515–1520.

Manikal, V. M., Landman, D., Saurina, G., Oydna, E., Lal, H., & Quale, J. (2000). Endemic carbapenem-resistant acinetobacter species in Brooklyn, New York: Citywide prevalence, interinstitutional spread, and relation to antibiotic usage. *Clinical Infectious Diseases*, *31*(1), 101–106. doi:10.1086/313902

Medina, E., & Pieper, D. H. (2016). Tackling threats and future problems of multidrug-resistant bacteria. In M. Stadler & P. Dersch (Eds.), *How to Overcome the Antibiotic Crisis* (pp. 3–33). (Current Topics in Microbiology and Immunology, vol. 398.) N. p.: Springer International Publishing. doi:10.1007/82_2016_492

Nayar, A. S., Dougherty, T. J., Ferguson, K. E., Granger, B. A., Mcwilliams, L., Stacey, C., . . . Mcleod, S. M. (2015). Novel antibacterial targets and compounds revealed by a high-throughput cell wall reporter assay. *Journal of Bacteriology*, *197*(10), 1726–1734. doi:10.1128/jb.02552-14

New York City College of Technology, Academics. (2019). Honors Scholars Program. Retrieved from http://www.citytech.cuny.edu/academics/honors-scholarships.aspx

New York City College of Technology, Undergraduate Research. (2019). Emerging Scholars Program. Retrieved from http://www.citytech.cuny.edu/research/

New York State Mathematics Association of Two-Year Colleges (NYSMATYC). (2011). *An interdisciplinary study on nosocomial infection and our community*. Paper presented at the 43rd Annual Conference, NYSMATYC, Ithaca, New York. Retrieved from https://www.nysmatyc.org/conf2010/program_summary_2010-final.pdf

Office of the National Coordinator of Health Information Technology (ONC). (2019). Health IT legislation. Retrieved from https://www.healthit.gov/topic/laws-regulation-and-policy/health-it-legislation

Phoenix, D. A., Harris, F., Dennison, S. R., & Ahmed, W. (2015). *Novel antimicrobial agents and strategies*. Weinheim, Germany: Wiley-VCH.

Sedláková, M. H., Urbánek, K., Vojtová, V., Suchánková, H., Imwensi, P., & Kolář, M. (2014). Antibiotic consumption and its influence on the resistance in Enterobacteriaceae. *BMC Research Notes*,*7*(1). doi:10.1186/1756-0500-7-454

Sifferlin, A. (2017, December 25). The War on superbugs: How a forgotten 100-year-old therapy is saving lives. *Time*.

Weinstein, R. A. (2001). Controlling antimicrobial resistance in hospitals: Infection control and use of antibiotics *Emerging Infectious Diseases Journal*, *7*(2). Retrieved from https://wwwnc.cdc.gov/eid/article/7/2/70-0188_article

World Health Organization (WHO). (2016, August 17). Antimicrobial resistance: Global report on surveillance 2014. Retrieved from http://www.who.int/drugresistance/documents/surveillancereport/en