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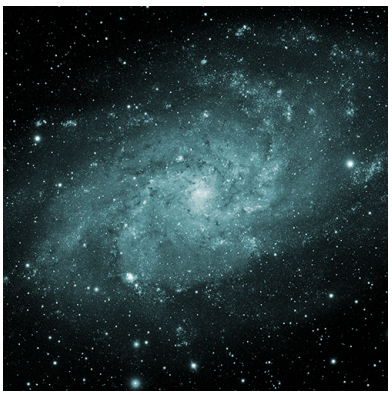
IMPACT

THE JOURNAL OF THE CENTER FOR INTERDISCIPLINARY TEACHING & LEARNING






VOLUME 10, NUMBER 2, SUMMER 2021

BU College of General Studies

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Impact: The Journal of the Center for Interdisciplinary Teaching & Learning is a peer-reviewed, biannual online journal that publishes scholarly and creative non-fiction essays about the theory, practice, and assessment of interdisciplinary education. Impact is produced by the Center for Interdisciplinary Teaching & Learning at Boston University College of General Studies. Impact accepts submissions throughout the year and publishes issues in February and July. Please submit your essays for consideration at https://citl.submittable.com/submit.

 If readers want to search by journal subject they might use these words: education, graduate, undergraduate, interdisciplinary, disciplines, curriculum, higher education.

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EDITORIAL STATEMENT

Dear Readers,

Welcome to the Summer 2021 special issue of *Impact: The Journal of the Center for Interdisciplinary Teaching & Learning*. The theme of this issue is interdisciplinary approaches to, or including, the sciences. STEM disciplines like chemistry, biology, physics, computer science, and math are often taught as separate and distinct from the humanities. The concept of STEAM (STEM + Arts) has attempted to make STEM subjects more interdisciplinary, allowing students to interact with the material from different perspectives. The essays in this issue explore unique ways to design and implement interdisciplinary curricula that combine sciences and humanities/arts.

In their essay *Cosmic Visions: Bridging Science and Art*, authors Chuck Henebry and Millard Baublitz describe an interdisciplinary course that combines scientific concepts of astronomy with examination of works of art. Students are exposed to the creative aspect of the scientific process, as well as the analytical side of artistic expression.

The combination of science and art is the theme of another essay, *Melding Art and Science to More Fully Explore Issues of Public Health*, by Abby Miller, Alexis C. Pheng, and David R. Wessner. The authors present an interdisciplinary assignment from the perspective of both the instructor and two undergraduate students who took the course. The value of this approach to a STEM course is discussed.

In their essay *Tip of the Iceberg: Collaboration and Scientific Writing*, Lisa DeTora and Sabrina Sobel describe how their Seminars in Chemistry course introduces students not only to specific writing formats (the tip of the iceberg) but also to the iceberg below; the collaborative process and spirit that informs all scientific writing. Students gain exposure to the disciplinary and cultural practices beneath the surface of scientific writing while exploring the current chemical literature on a specific topic, culminating with the presentation of a seminar and production of a review paper guided by their mentors.

This is followed by *The Journey to Community-Engaged Transdisciplinary Research*, in which Ruth Kassel, Krysta Dennis, Robin Flatland, and Scott Foster discuss how students conduct collaborative work across disciplines to produce publications. Their approach captures the spirit of collaboration across fields, including the sciences. Students are exposed to the entire process involved in completing a collaborative project, including the challenges inherent in the experience, ultimately producing a final product for which they have a strong sense of ownership.

The final paper, *Limit to Lifespan Will Limit Human Knowledge*, explores the tension between specialization and interdisciplinary work and how this will affect advancement within the scientific fields. John Richard Schrock explores this idea from a historical perspective and connects these ideas to the limit of the human lifespan, suggesting a balance between interdisciplinary approaches and specialization.

We end this special issue with an interview with Richard W. Bulliet, Professor of History Emeritus at Columbia University. In this wide-ranging discussion, he explains the path that led him to bring natural history and the sciences into his Middle East history research and teaching curriculum, as well as his thoughts on how the historical record could provide a useful perspective for students engaged in our current climate crisis with examples from the past.

We hope you are inspired by the innovative ideas and methods shared within this issue, and we encourage you to reach out to us with your thoughts. We wish you continued good health as we slowly return to the “new normal.”

All the best,

Sandra, Robin, and Sal

Sandra Buerger, Senior Lecturer, Division of Natural Sciences and Mathematics, College of General Studies at Boston University
Robin Hulbert, Lecturer, Division of Natural Sciences and Mathematics, College of General Studies at Boston University
Sal Genovese, Lecturer, Division of Natural Sciences and Mathematics, College of General Studies at Boston University
Guest Editors

ABOUT THIS ISSUE'S AUTHORS AND EDITORS

Millard Baublitz is an Associate Professor in the Division of Natural Sciences and Mathematics in the College of General Studies at Boston University. He was a scientist at NASA Goddard Space Flight Center early in his career. He also worked with a research group that measured the rotation of the Galaxy using 21-cm wavelength radio telescopic observations. Most of Baublitz's research publications have been in solid state physics or the foundations of quantum mechanics. He was awarded the 2003 Peyton Richter Award for excellence in interdisciplinary teaching.

Sandra Buerger is a Senior Lecturer in the Division of Natural Sciences and Mathematics in the College of General Studies at Boston University. She holds a Ph.D. from Northeastern University in the field of Biology. Her research has focused on bacterial communities, probiotics, and the search for antimicrobial compounds. She was the 2019 and 2021 recipient of the Ismail Sensel Award for outstanding professional contributions.

Richard W. Bulliet is Professor of History Emeritus at Columbia University. Beyond his primary job of teaching about the Middle East, he also lectured on the history of technology, the history of domestic animals, and environmental history. His books dealing with the ways in which a historian deals with the natural world in include: *The Camel and the Wheel* (1975), *Hunters, Herders, and Hamburgers* (2005), *Cotton, Climate, and Camels in Early Islamic Iran* (2009), and *The Wheel: Inventions and Reinventions* (2016). His global history textbook, *The Earth and Its Peoples* (7ed, 2017) features "Environment and Technology" as a major theme.

Krysta Dennis is producer of Creative Arts at Siena College and works as a theatre-maker, producer, and director in the US and internationally. Krysta holds a dual Ph.D. from the University of Kent in the UK and the Sorbonne in Paris, and trained as a performer at L'Ecole Jacques Lecoq. She is the author of three plays, *Votes for Women*, *The Burden of the Ballot*, and *Dutch.* She has also published with Contemporary Theatre Review, Interdisciplinary Network, Routledge, and the Pirandello Society of America. Krysta is the chair of dramaturgy for Region 1 of the Kennedy Center American College Theatre Festival.

Lisa DeTora earned an A.B. from Bard College and was awarded the William J. Lockwood Prize for intellectual contributions to the college. She earned an M.A .and Ph.D. in English as well as a graduate certificate in Women's Studies from the University of Rochester and an M.S. in Bioethics from the Alden March Bioethics Institute of Albany Medical College. Her doctoral thesis examined the representation of domestic violence in medicine, social sciences and popular culture. Lisa's career has spanned industry and academic roles and her scholarship bridges technical communication, rhetorics of health and medicine, medical humanities, and bioethics. Recent research projects include edited volumes on embodiment and graphic narratives and graphic narrative research. She is also the editor of *Regulatory Writing: An Overview,* now in its second edition.

Robin Flatland is a professor of computer science (CS) at Siena College. She earned her M.S. and Ph.D. in CS at Rensselaer Polytechnic Institute in Troy, NY. Her research interests include computer science education and computational geometry, and she has published over 50 conference and journal articles in these areas. She serves as a coordinator of Siena's CS dual-enrollment program and has worked on multiple National Science Foundation grants to improve secondary computer science education through teacher development.

Scott Nelson Foster is an Associate Professor of Studio Art and serves as Chair of the Creative Arts Department at Siena College. He received a B.A. in Drawing, Painting, & Printmaking from Northwest Nazarene University and an M.F.A. in Painting & Drawing from Utah State University. His paintings have been exhibited in solo and juried exhibitions nationally and is represented by the Carrie Haddad Gallery of Hudson, NY.

Sal Genovese is a Lecturer in the Division of Natural Sciences and Mathematics in the College of General Studies at Boston University, where he teaches courses in Introductory Biology and Global Human Ecology, and was a 2021 recipient of the Peyton Richter Award for Outstanding Interdisciplinary Teaching. He earned a Ph.D. in Biology from Northeastern University and pursues research interests at the intersection of marine ecology and oceanography.

Charles W. Henebry received his doctorate in English literature from New York University in 2003. Originally a student of the late Middle Ages and Renaissance, he has for the past 10 years focused his scholarship on the four-color world of

ABOUT THIS ISSUE'S AUTHORS AND EDITORS

superheroes, from the genesis of Superman's costume change to the impact of the 1960s antiwar movement on Iron Man. He is the author of seven articles in Greenwood Publishing Group's 2014 *Comics Through Time* encyclopedia and long-form essays in *The Ages of Iron Man, The Ages of the Justice League, The Ages of the Flash,* and the *Ages of the Black Panther*.

Robin Hulbert is a Lecturer in the Division of Natural Sciences and Mathematics in the College of General Studies at Boston University. She earned a Ph.D. in Microbiology and Immunology from Dartmouth College. Her research focuses on public health microbiology and environmental microbiology.

Ruth Kassel is Associate Director of Academic Community Engagement at Siena College. She holds a Ph.D. in Spanish Sociolinguistics from the University at Albany and has engaged in community-based teaching and research nationally and internationally. She has developed multiple programs that bring together faculty, students, and community organizations in collaborative research. Her research areas include high impact practices, community development, and students as colleagues.

Abby Miller graduated from Davidson College, where she earned a B.S. in Chemistry. Since graduating, she has served as an online educator and will begin medical school in the fall.

Alexis C. Pheng is a graduate of Davidson College where she received a B.A. in Hispanic Studies with a minor in Health and Human Values. She also studied public health in Chile through Harvard University during the summer of 2019. Currently, she is a medical scribe for a pulmonary disease/sleep medicine specialist and soon will be working alongside a dermatologist. Alexis is an aspiring physician who loves to travel the world and hopes to provide health care to medically underserved communities.

John Richard Schrock is a Roe R. Cross Distinguished Professor and Professor Emeritus of Biology at Emporia State University where he trained secondary biology teachers for 30 years. He had previously taught secondary biology at Campbell County Schools (Kentucky), Indiana State University Laboratory School, and Hong Kong International School. Schrock completed his doctorate in entomology at the University of Kansas and has authored or co-authored books on State Wildlife Regulations, a Chinese-English Dictionary of Molecular Biology, and multiple editions of instruction manuals and test item files for college biology and zoology textbooks. He is currently Editor of the *Kansas School Naturalist* and English Editor of *Entomotaxonomia*, an insect systematics journal based in China. Besides teaching three years in Hong Kong, Schrock has so far spoken at 27 different universities in China, including keynote speaker on publication ethics at a graduate research forum at Tsinghua University (2018) and both conferences of the Future of Scholarly Publishing at Zhejiang University in Hangzhou (2019, 2020).

Sabrina Sobel earned a B.A. Chemistry degree from Pomona College (1987) and was awarded the Rowan Memorial Award for being "the student who shows the best promise of making the most contributions to Chemistry." She earned her Ph.D. in Inorganic Chemistry from University of California, Berkeley (1993). Dr. Sobel has spent her career (1992 – present) at Hofstra University as the sole inorganic chemist in the department. She has mentored both undergraduates and high school students in research, and served as the Chair of the department of Chemistry at Hofstra for nine years. Her research is an eclectic mix of the study of chemistry education research, oscillating chemical reactions and aluminum corrosion. Dr. Sobel has served on three rounds of development of ACS standard undergraduate inorganic chemistry exams, and is now part of the Long Island STEM2 initiative.

David R. Wessner is a Professor in the Departments of Biology and Public Health at Davidson College, where he teaches introductory biology and courses on microbiology and HIV/AIDS. His research focuses mainly on microbial pathogenesis. He is a co-author of *Microbiology*, a textbook for undergraduate biology majors, and *The Cartoon Guide to Biology*. He also co-curated *Re/Presenting HIV/AIDS*, an exhibition that featured artistic works related to HIV. Prior to joining the faculty at Davidson, David conducted research at the Uniformed Services University of the Health Sciences and National Zoo in Washington, DC. He earned his Ph.D. in Microbiology and Molecular Genetics from Harvard University and his B.A. in Biology from Franklin and Marshall College.

ANNOUNCEMENTS

Latest Announcements

Creating an Antiracist Classroom through Interdisciplinary Teaching, Learning, and Curriculum

Impact: The Journal of the Center for Interdisciplinary Teaching & Learning based at Boston University currently solicits pieces for a special issue on creating antiracist teaching, learning, and/or curriculum, slated to appear in the summer of 2022.

We welcome submissions on topics related to creating an antiracist classroom through interdisciplinary teaching, learning, and/or curriculum. For example, what are the core elements of antiracist teaching, learning, and/or curricula? What can an interdisciplinary perspective bring to antiracist teaching and/or learning? What does a successful interdisciplinary antiracist assignment in your class or discipline look like? What are the different ways to assess students' learning experiences in antiracist assignments or learning activities? How can we build effective partnerships with antiracist organizations and create networks of faculty interested in antiracist curricula?

We seek pieces that offer insight from specific teaching experiences as well as articles detailing research conducted on antiracist curriculum. Book reviews related to antiracist teaching and learning are also welcome.

Word limit: 3,000 words. MLA Citations, please. Submissions should be received by September 15, 2021 to Lynn O'Brien Hallstein at lhallst@bu.edu.

Impact publishes both scholarly and non-scholarly essays of varying lengths, as well as work in other modes and media. General information about Impact can be found on http://sites.bu.edu/impact/.

Please refer to CITL's website for additional announcements: http://www.bu.edu/cgs/citl/.

Impact Essay Competition

Every December, the editors of *Impact: The Journal of the Center for Interdisciplinary Teaching & Learning* invite submissions of scholarly and creative non-fiction essays between 1,000 and 5,000 words on any aspect of interdisciplinary teaching or research. The author of the winning essay will receive a $250 award and publication in Impact.

Essays should be readable to a general, educated audience, and they should follow the documentation style most prevalent in the author's disciplinary field. Essays for this contest should be submitted by the first Monday in December to http://CITL.submittable.com/submit. See our general submission guidelines in Submittable.

CITL reserves the right to not publish a winner in any given year. Faculty and staff from the College of General Studies are not eligible to submit to this contest.

ESSAYS

Cosmic Visions: Bridging Science and Art

Chuck Henebry & Millard Baublitz, Boston University, College of General Studies

Since the dawn of recorded history, stargazing has shaped—and been shaped by—our understanding of the universe and the place of humans within it. Though we tend to conceptualize art and science as separate spheres, the observation of the heavens has always been interwoven with culture, and artists and astronomers continue to draw inspiration from one another even today. The authors of this paper, over the past few years, have developed and team-taught an interdisciplinary course titled *Cosmic Visions: The Science of Astronomy and the Arts*. Our course traces the shared, often symbiotic, history of these two ways of knowing, combining scientific instruction with examination of art in a range of genres and traditions, including visual art, music, and theater. Each week students engage in discussions, listen to lectures, and consider readings related to both the science of astronomy and the role of celestial objects in literature and the arts. A midterm and a final exam test students' mastery of the science, while short essays on works of art and literature challenge them to think about how our changing understanding of heavenly bodies intersects with changing beliefs about humanity. The course culminates in an art project in which students express their own vision of the cosmos and our place within it.

What happens when students employ humanistic modes of analysis in company with scientific ones? How does artistic expression change students' apprehension of scientific concepts? This short essay offers preliminary answers to these deep pedagogical questions.

I. Student Population

We developed *Cosmic Visions* in response to changes in Boston University's general education requirements. Whereas the preceding system allowed individual colleges to set their own general education distribution requirements for their students, the 2018 BU Hub for the first time applied a single framework for undergraduate general education across the university. As faculty at BU's College of General Studies, we saw an opportunity for creating a science course that would appeal to students at the university's College of Fine Arts (CFA). Working in consultation with CFA division heads, we crafted a course of study that would check off a Writing Intensive Hub requirement as well as Scientific Inquiry I.

In our first year of operation, the course was dominated by students from CFA's theater program, many of whom transferred in during the first weeks of the semester, as word-of-mouth circulated within that tight-knit group. They were a lively group to teach, full of questions and ideas, but also full of anxiety about basic mathematical concepts like ratios—not to mention concern about mastering scientific content in preparation for exams. At the end of the semester, they premiered some truly amazing artworks, ranging from movement pieces to costume designs.

The student population shifted markedly in our second year of operation, with a significant contingent of STEM students from the College of Arts and Sciences (CAS) signing up. While unsurprising in retrospect, it had not occurred to us that our arts-friendly science course might also appeal to STEM students looking for a science-friendly writing-intensive course. Direct comparison of the two groups is hindered, however, by a fundamental difference in class structure: in an effort to allow all students to attend in-person during the 2020 pandemic, we moved Professor Baublitz's astronomy lectures online and divided classroom time into discussion sections covering the astronomy homework, the experimental fieldwork, and the assigned art and literature. In this discussion-heavy class structure, the new population proved not only more willing to engage with simple mathematical relationships, but also more eager to think about the interrelationship of astronomy with religion and the arts. But both groups benefitted, we believe, from our historical approach to teaching the science of astronomy.

II. The History of an Ancient Science

Science can be described as a system of knowledge or way of knowing that relies on (1) observations of phenomena and (2) the formulation of theories or models to explain the observations and perhaps predict future observations. Thus, it is fitting that the first weeks of the course emphasize observations of the sun, moon, planets, and stars made by ancients, and

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similar “naked eye” observations that can be replicated today except as precluded by light pollution. Our ancient ancestors observed the sun, moon, and stars far more intently than most people today because their lives depended on those observations. The ancients had to observe the sun and moon to know when to plant or harvest crops, to keep track of seasons and create calendars, and for navigation at sea. Ancient inscriptions describing astronomical phenomena remain today, fascinating archaeologists and astronomers alike. Some ancient cultures constructed megalithic stone structures, like Stonehenge in England and Chichén Itzá in Mexico, to observe the solstices, equinoxes, and other astronomical events.

To illustrate the apparent motions of the sun and moon, we turned the darkened classroom into a low-budget planetarium using only a flashlight and signs marking the four cardinal directions: North, South, East, and West. We demonstrated the diurnal apparent motion of the sun and the variation of the sun’s altitude as a function of season and the observer’s latitude on Earth.

In an effort to expose students to the rudiments of the scientific method, we created a series of astronomical fieldwork assignments. Introduced late in course development, these were considerably expanded and systematized in our second year. A typical experiment involved asking students to observe and measure the autumnal equinox, one of two days when the sun rises precisely in the East and sets precisely in the West. For this assignment, students photographed the setting sun on September 22, 2020, weather permitting, diagrammed their observations on a map, and then explained any apparent deviation of sunset from due West.

Figure 1 shows a student’s experimental results for the time and location of sunset on the autumnal equinox, as observed from a bridge over the Massachusetts Turnpike close to Kenmore Square in Boston. The student estimated the final position of the sun by extrapolating from observations of its position prior to sunset. Her results show a slight experimental error, 4.5° south of true west.

Figure 1

The earliest civilizations also took special note of the moon and five “wandering stars” or planets in the sky, which seemed to roam over the course of months from one constellation of stars to another. We sought to bring this to life for our students by scheduling the class for an evening time slot, allowing us to take our students outside on clear evenings to observe any planets visible in the sky and to distinguish them from the “fixed stars” of the constellations. The results were particularly spectacular in fall 2020, when we observed on several consecutive Monday evenings the approaching conjunction of Jupiter and Saturn, as well as Mars in retrogression, shining brightly red in the east.

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Although observation is an essential component of the scientific endeavor, without the construction of models or theories even systematic observation of natural phenomena can yield only an inchoate, incomplete form of science. In an effort to spotlight the messy process of scientific progress, we organize course material historically, allowing us to explore both incremental changes in scientific understanding and revolutionary shifts. In total, we examine three distinct epistemes in the development of astronomy, the oldest of the sciences: the earth-centered systems of ancient Mediterranean and Central American peoples, the sun-centered system developed in sixteenth- and seventeenth-centuries, and the radically uncentered, infinitely expanding universe of twentieth and twenty-first century cosmology.

The apparently irregular motions of the planets, especially the retrograde motions of the planets when they would seem to stop and then reverse direction, were especially perplexing to the early observers. Aristotle adopted an Earth-centered model of the cosmos in which each planet was associated with four or more nested geocentric spheres that rotated about different axes at different rates; in this way, he could provide a crude representation of the planets' irregular motions. (Aristotle). About four centuries later, Ptolemy improved accuracy by proposing a more complex model, adding epicycles and shifting the stationary Earth slightly away from the cosmos' center (Ptolemy).

In the year 1500, few people believed that Earth moved, and the Ptolemaic model of planetary motion was generally, if not universally, accepted. By 1700, few educated people doubted that the Earth orbits yearly about the sun. Students in our course make telescopic observations of the moons of Jupiter, learn of the astronomical observations of Galileo and others, study the planetary models of Copernicus and Kepler, and grapple with the paradigm shift, as a sun-centered solar system became the commonsense way to understand the cosmos by the close of the seventeenth century.

The invention of the telescope provided not only detailed images of the planets and their newly discovered moons, but this invention also allowed Galileo and others to resolve the faint band of light known as the Milky Way into a vast number of individual stars. The Sun is only a somewhat larger than average star in the Milky Way, which is a rotating disk-shaped aggregate of more than a hundred billion stars. More recently, the construction of large reflecting telescopes, which use mirrors instead of lenses, has allowed astronomers to confirm that some nebulae, which previously appeared as just hazy patches of light, are actually what Immanuel Kant had hypothesized as "island universes," or in other words, galaxies of stars comparable in size to the Milky Way. Figure 2 is an image of the galaxy UGC 12158, which is about 380 million light-years away and resembles the Milky Way in appearance.

Figure 2 [ESA/Hubble & NASA]

Twentieth-century measurements show that all galaxies in the universe are moving away from the Local Group of galaxies where the Milky Way is located. This expansion suggests that at an earlier time the universe must have been much smaller and denser. This is one line of reasoning that led to formulation of the Big Bang Theory, which today is the generally accepted scientific theory of the origin of the universe: all matter, energy, and even space-time itself had its origin in a singularity about 13.7 billion years ago. Earlier generations believed the Earth, or the Sun, or perhaps the center of the Milky Way was the center of the universe. By contrast, according to current ideas, the big bang "had no center, it had no past, it simply was the sudden beginning of everything in an expanding geometry" (Impey). Truly, humankind's

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conception of the cosmos has changed remarkably, since our ancient ancestors gazed at the sky!

Why is this historical approach to astronomy a useful one, pedagogically speaking?

On the one hand, by taking a qualitative approach to astronomy, we help non-STEM students appreciate what makes a science a science: the scientific method. In their fieldwork experiments students get a sense of the challenges that scientists face in conducting even routine observations—and hence the difficulty of making even incremental improvements to scientific understanding. At the same time, the historical sweep of the course demonstrates how science proceeds sometimes at a crawl and sometimes in great leaps. This perspective is valuable for STEM and non-STEM students alike, as it is rarely given extended attention outside specialized courses in the history of science. In short, the millennia-old struggle of astronomers to understand the cosmos typifies the broader human pursuit of scientific understanding, a process Francis Bacon compared to the episode in the *Odyssey* when Menelaus wrestled with the shape-changing sea-god Proteus, clinging fast until the god was forced to show his true nature (Bacon).

III. The Cosmos and the Arts

Our historical orientation also provides scaffolding for works of art and literature. Each week in preparation for class, students write a brief response to one or more cultural artifacts roughly contemporaneous to the astronomers we are studying that week. The twentieth century proves an especially fertile era, with art ranging from sci-fi stories, radio plays, and movies to "space music" and "space art." But earlier in the semester, we focus on cosmologies represented in Egyptian religious artifacts, Roman epic, and Renaissance love poems. These various works of art provide windows on the mindset of earlier eras, whether the stoic fatalism of Virgil, the anticolonial satire of Georges Méliès, or the otherworldly optimism of John Serrie. In so doing they invite students to draw connections between an era's cultural and religious beliefs and the scientific understanding then prevailing. One student gave particularly eloquent expression to the connection between science and religion in an essay-length analysis of Kubrick's *2001: A Space Odyssey* entitled "Monolithism: The Religion of the Cosmos":

> As science has progressed, … the field has slowly explained away many of nature's supernatural interpretations and sacred objects: we no longer view the planets as literal gods in the sky, but as the nearly spherical collections of gas, dust, rock, and ice that they are. We now look to the stars in search of data, not deities. However, this gradual transition has not stopped humans from exploring their origin and place in the universe through space art, music, and film. Although some may think that the modern, scientific view of cosmology downplays spiritual importance from the heavens, Stanley Kubrick's film *2001: A Space Odyssey* uses monoliths in place of more typical religious deities to show that humans still look to the cosmos for a source of inspiration and creation in an otherwise cold, unforgiving universe. (Gjonbalaj)

In this opening to his essay, Nik Gjonbalaj offers an insightful explanation for Kubrick's strange coupling of cold empiricism with cosmic wonder, showing how that film participates in an age-old tendency for humans to look to the stars in search of answers.

Several students testify in course evaluations to the value of coupling astronomy with historical analysis of the arts. One notes, "The arts portion of the course was really interesting. I can see how the cosmos has affected human perspective and how it continues to influence to this day. When outside the classroom, I can see influences the cosmos has on artwork I see every day." Another student comments: "This course effectively ties the arts with the science of astronomy." Still another enthuses, "This is exactly the type of class BU should encourage.… I love astronomy, but never would have been able to fit an astronomy class in with all the classes I need to take to graduate." More than a few students indicated that weekly assignments and feedback helped improve their writing skills.

But our course adds a further dimension to its interdisciplinarity, asking students to plan and execute an end-of-semester art project that, like the historical artworks we examine, in some way gives expression to the cosmos and/or our chang-

ESSAYS – CONTINUED

ing conceptions of humanity's place within it. Over the past two years, projects have ranged from performance pieces, to visual art, to costume or set design, to works of fiction and even comic books. Some students choose to draw on ancient myths and artifacts that we study, while others have created future-facing works of science fiction.

Unsurprisingly, this element of the course proved particularly popular in 2019, with its large contingent of students from the College of Fine Arts: "I found the artistic element of the class to be vital in my overall success…. I really appreciated this class because it provided me an opportunity to learn science but still stimulate my very artistic brain" (emphasis in original). Another gave a notably similar assessment of the course's neurological appeal: "I learned a lot, and the engagement with humanities allowed me to stay engaged and use both parts of my brain in class." Such comments suggest that CFA students conceptualize science and the arts in oppositional terms—and that they think of the wider university as a space generally hostile to creative expression.

These students' excitement stands in marked contrast to the trepidation of students who do not consider themselves artists: "I have never dreaded an assignment as much as I dreaded the Final Art Project all semester," one wrote in an evaluation from the 2020 class, before going on to report "But then it turned out to be one of my favorite assignments ever." Here we encounter the same oppositional thinking, only from the other side of the fence, as if analysis and creativity were so distinct as to constitute different types of people.

Turning from this testimony to students' artistic output, we find evidence that analysis and creativity actually do work hand-in-hand. In 2019, Mya Ison and Isabel Van Natta crafted and performed a movement piece, *The Creation of Eden,* connecting the famous centerpiece on the ceiling of the Sistine Chapel to the gravitational attraction of astronomical bodies and the erotic connection between two humans (Figure 3).

Figure 3: Link to video

In the same year, Maia Soltis designed eight costumes for a ballet centered on myths from around the world of the "Seven Sisters": known variously as "the Pleiades, the MaiMia, Matariki, and Subaru," their stories are remarkably consistent: a cluster of maidens fleeing a brutish male pursuer. In all these versions, comments Soltis, "they are never caught. Often, the pursuer joins them in the sky, but is forced to forever chase the sisters and never catch up. I find this example of female empowerment extremely compelling, especially because of its universal nature." In her artist's statement, Soltis makes clear how both scientific knowledge and cultural analysis fed her artistic vision (Figure 4):

> I wanted to explore the sisters' female strength as well as draw upon the many cultures that inspired the piece. I wanted the sisters' costumes to be simple and light so as to emulate the nebulae that surround the stars and con-

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> trast them with the male dancer. The goal was to create dresses that cling to the women in such a way that they look like a part of their bodies while the male dancer's costume is heavier and obviously manmade. (Soltis)

More recently, in our second year, Lauren Girouard, a CFA music student, riffed on Holst's 1916 suite *The Planets* in creating *A Percussive Journey through Outer Space*. Her finished work shows the impact of a century's worth of musical innovation and scientific discovery:

> While *The Planets* depicts planetary mythology through a symphonic work, this percussive journey narrows the expression of musical ideas to the realm of percussion. In this way, the soundtrack follows the trend of contemporary music, which often takes more of a minimalistic approach in terms of instrumentation and harmonies. (Girouard)

As a work of music, Girouard's work stands out for the priority it gives to vision over sound, taking video footage from space missions as its starting point and plotting percussive "beats" to match those visuals: "Instrumentation and textures were guided by the visual stimuli of the video, and sounds were deliberately made to evoke astronomical characteristics of celestial bodies." In this sense, Girouard conceptualizes her artistry as responding to observation, something like the practice of scientists.

A final instance shows the capacity of STEM students to engage creatively with the course material. Nicholas Melvin, a math and computer science major from the College of Arts and Sciences, created a 13-page comic-book retelling a Cherokee myth in a science-fiction setting. The frog that ate the sun is one of a host of myths dreamed up to explain the rare and terrifying experience of a total solar eclipse. But where the Chinese imagine the sun being swallowed by a great dragon, the Cherokee cast a mere frog as the villain, giving a humorous cast to the fearful event. According to tradition, the frog can be driven away by making noise: drumming, shouting, a festive hullaballoo. Appropriately, then, Melvin's comic has both epic scope and comedic delivery. Executed in a mixture of styles, from a professional "Photoshop" look to the deliberately childish look of Microsoft Paint, it shows mastery of the rhythms of comic-book narrative.

Figure 4 (See link for enlarged version)

ESSAYS – CONTINUED

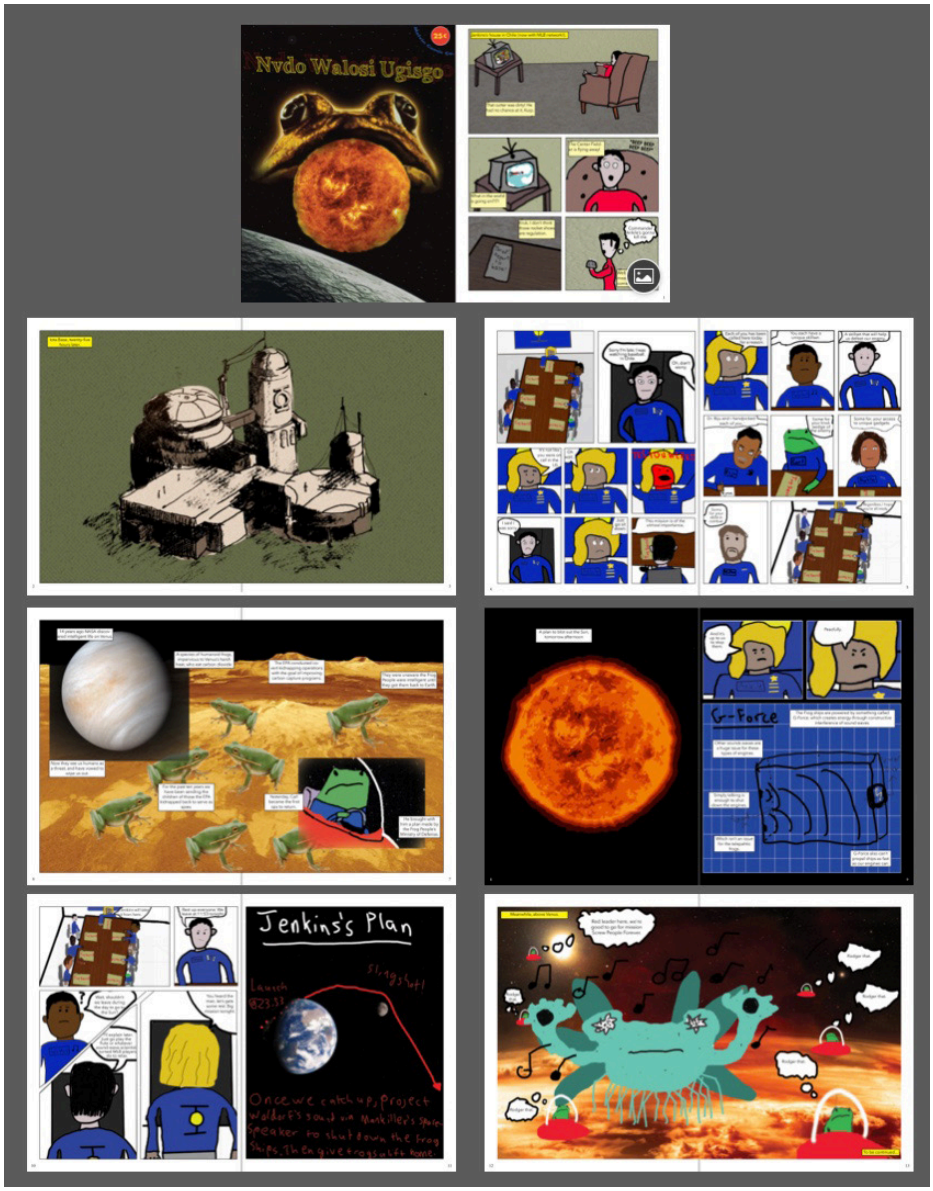

Figure 5 (See link for full version)

IV. Concluding Thoughts

Cosmic Visions presents a natural science, astronomy, in qualitative terms with a focus on its history and with the goal of teaching students an appreciation of the scientific method. Many students begin the course with a sense of a clear divide between the sciences and the arts, between left and right brain, between analysis and creativity. Our course instantiates that divide in its subtitle, “the science of astronomy and the arts” and in its team-taught structure, with one professor from Natural Sciences and the other from Rhetoric. At the same time, however, we challenge that divide, showing how the practice of science is often creative, and how creative expression in the arts often draws on analysis for insight.

ESSAYS – CONTINUED

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ESSAYS – CONTINUED

Melding Art and Science to More Fully Explore Issues of Public Health

Abby Miller, Alexis C. Pheng, and David R. Wessner, Davidson College

The Value In Combining Art and Science

Over 60 years ago, C. P. Snow lamented the separation of the sciences and the humanities. As he argued in his influential book, *The Two Cultures and the Scientific Revolution*, scientists and artists talk past each other, assuming their disciplines to be separate and distinct (Snow, 1959) Despite his call to action, the sciences and the humanities too often remain separate on college campuses. Students may identify themselves as right-brained or left-brained; artists or scientists. Courses may present content in a siloed fashion. Even the layout of campuses may perpetuate this division, with classrooms, buildings, and libraries devoted to one discipline or the other existing in physically disparate spaces.

Yet, there is a true worth in melding art and science in the classroom. We and others have described the pedagogical value of interdisciplinary courses that allow students to use art to explore scientific topics (McDonald and Wessner, 2003; Fox and Wessner, 2015; Thurley, 2016; Segarra et al., 2018). In this essay, we further investigate how art can be incorporated into STEM classes by describing a particular interdisciplinary assignment, presenting work done by students to complete this assignment, and discussing the usefulness of this approach. The assignment was administered in an upper level undergraduate seminar course in which HIV/AIDS is used as a case study to explore issues of public health. While all three collaborated on writing this essay, the perspectives of the course instructor (Wessner) and two undergraduate students (Miller and Pheng), who completed and then reflect on their experiences with the assignment, are presented.

The Assignment

To promote student engagement with art, the curator of our institution's art gallery approached instructors of three different courses and explored ways in which we could incorporate art in our classes. Although each instructor ultimately approached this challenge differently, all of us pursued the same general framework. Students in each class would visit the gallery and receive an introduction to the collection. Then, small groups of students would select a piece of art from the collection and explore how it related to the course content. Finally, some of the pieces selected by the students would be displayed in a small exhibition designed to show the larger College community how art could be incorporated into various classes.

For the instructor (Wessner), the goals of this assignment were several-fold. First, it would provide the students with an opportunity to explore the College's art collection and learn more about this valuable resource. Second, it would allow members of the class to approach course material in an interdisciplinary fashion. Third, it would allow the students to explore independently a topic that was not covered previously during the semester. The students worked in pairs, with each pair selecting a piece of art that they thought resonated with the course content. I encouraged them to think broadly. As I noted in my instructions to the class, a painting from the 1800s that depicts the mistreatment of women certainly isn't about HIV/AIDS. Instead, it could be used as an entrée to a discussion about HIV/AIDS and gender-based violence. After selecting their work of art, students were asked to write a 300-word curator's statement that provided a brief description of the piece and the rationale for selecting it. Additionally, they were asked to write a longer, more academic essay that thoroughly explored the HIV/AIDS-related issue addressed by the art.

The Student Piece: How Art Parallels Current Public Health Issue

[DW] For this project, two students (Miller and Pheng) selected the art piece "The Unfortunate Man" produced by American photographer, Duane Michals (for an example of the photo, see this website: https://collection.cmoa.org/objects/ff87351e-9151-40c5-892e-d9bb071cce8d). The photo, shot in 1976, presents a grayscale photograph of a naked man arching himself in agony, while the accompanying text reads:

ESSAYS – CONTINUED

The unfortunate man could not touch the one he loved.
It had been declared illegal by the law.
Slowly his fingers became toes and his hands gradually became feet.
He began to wear shoes on his hands to disguise his pain.
It never occurred to him to break the law.

In their analysis of this piece, they explored the stigma still experienced by members of the LGBTQ+ community and how that stigma affects access to healthcare.

[AB, AP] As seen in the photograph, shoes cover the man's extended hands, presenting a visual metaphor of his inability to "touch the one he loved." The man is unable to pursue his partner of choice.
To us, this photograph presents a visual representation of the barriers imposed upon the LGBTQ+ community in the pursuit of basic human rights, such as health and happiness.

When viewing this work of art, we were reminded of previous class discussions about the stigma faced by members of the LGBTQ+ community and how this stigma can lead to poorer health outcomes among people living with HIV. To complete this assignment, we decided to explore the intersection of LGBTQ+ stigma, healthcare access, and HIV/AIDS more fully.

The constraints placed on the unfortunate man by societal standards reflect the considerable number of LGBTQ+ Americans who are restricted in their access to full benefits of the health-care system. Certain legal, economic and social factors continue to stand between LGBTQ+ Americans and treatment, and this phenomenon has detrimental secondary impacts on the spread of HIV/AIDS beyond just the LGBTQ+ community in America.

Due to the absence of federal legislation prohibiting healthcare inequity based on sexual orientation and gender identity, people of the LGBTQ+ community are often limited in recourse when they face legal obstacles. During the Trump administration, the US Department of Health and Human Services (HHS) renounced regulations that prohibit unfair practices against the LGBTQ+ community. In June of 2020, HHS released legislation that redefined "sex discrimination" as it pertains to exclusively male versus female, therefore reversing the Obama-era rule that protections can be based on not only birth-assigned sex, but gender identity as well (Simmons-Duffin, 2020).

Additionally, HHS enacted new regulations that essentially give health providers the ability to refuse providing certain key services to LGBTQ+ and other individuals based on their own religious or social preconceptions, such that healthcare workers are "free from coercion" on account of their "religious beliefs or moral convictions" (Moreau, par. 2, 2019). This virtually allows any individual or entity involved in a patient's care, from the hospital's board of directors to the receptionist that schedules appointments and procedures, to put their personal beliefs ahead of a patient's health. State-level health research has shown that as a result of this practice-based discrimination, LGBTQ+ individuals, particularly lesbian and bisexual women and transgender people, are more likely to forego treatment for chronic conditions because of discomfort in healthcare spaces (Thoreson, 2018). This regulation averts health care organizations and providers from guaranteeing equal access of care. In practice, it allows healthcare providers not only to deny access to abortion and sterilization procedures, but also to deny treatment, therapy, and preventative care for patients seeking HIV/AIDS resources.

Despite alarming rates of infection within the nation, the provision of HIV services for the LGBTQ+ community is inadequate, as their specific needs are not prioritized by the government. In one study, researchers reported that only 78% of primary care providers would be comfortable treating LGBTQ+ patients, leaving the other 22% to perpetuate their own prejudice due to personal beliefs and cultural incompetency (Nowaskie and Sowinski, 2019). Brian Byamukama, founder of RUMI (Rural Movement Initiative) highlights the insecurity many LGBTQ+ people face in the health care system when he states that:

ESSAYS – CONTINUED

> "Many LGBT people are too shy to go to health centres to get services as they face a lot of discrimination when they get there. There is an idea that you can contaminate people somehow… Once I went to get tested for HIV and I realised the doctor did not want to touch me. They separated me from the rest of the people in the clinic. That really brought my heart down" ("Homophobia and HIV," par. 31, 2019).

Practices like this are prevalent and they decrease the accessibility and likelihood of HIV testing, which is both a means of obtaining personal treatment and a preventative measure against further spread of HIV/AIDS. When people stop receiving HIV tests and do not treat chronic conditions such as HIV, the net infection rate in the United States could steadily increase. Although healthcare providers may protect their freedom of conscience, discrimination based on religious beliefs ultimately contributes to the 14% of HIV positive people in the United States who do not know they are infected and are able to spread infection.

Another exacerbating factor of HIV viremia in the LGBTQ+ community is homelessness, which is often caused by familial rejection, inability to get a job based on sexual orientation or gender identification, and secondary mental health conditions caused by social stigma, such as depression and anxiety. Though there are no nationally representative datasets of the adult population experiencing homelessness in the US that include covariates of sexual orientation and gender identity, many analyses show that anywhere between 20-40% of the homeless youth population in the United States identifies as part of the LGBTQ+ community (Durso and Gates, 2012). LGBTQ+ youth are 120% more likely than those who identify as heterosexual or cisgender to face homelessness (Chapin Hall, 2017).

One article highlights a tight link between homelessness, HIV infection and low rates of viral suppression based on data released by the San Francisco Department of Public Health in 2017 (Land, 2018). It defines homelessness as "a main driver of new [HIV] transmission" (Land, par.11, 2018) and observes trends in homeless persons having higher viral loads on average when compared to people with housing, and also the likelihood of viral suppression relating to the degree of housing stability. Another study supports these findings, concluding homelessness as a predictor for incomplete HIV viral load suppression (Thakarar, 2016). The study focused on HIV-seropositive individuals enrolled in a health care program for homeless persons. Linkage to care is essential for HIV-seropositive persons to have access to cART and other supportive services. Combination antiretroviral therapy, or cART, refers to the combinations of drugs that decrease HIV viral loads to keep infections under control. Thakarar's study (2016) emphasizes that housing plays a critical role in the bridge to healthcare and ultimately, HIV viral suppression. It demonstrated that a higher proportion of homeless individuals on cART had incomplete viral suppression compared to housed individuals on cART. Such results are consistent with prior research, which find that poor compliance with cART is associated with homelessness. The provision of stable housing can lower the costs of caring for homeless individuals, which in turn, decreases their financial burden and promotes continuum of HIV care. Moreover, high percentages of homeless individuals are infected due to increased exposure to injection drug use, lack of clean needles, and stifled access to HIV prevention methods, such as condoms, antiretroviral therapy, PEP, and PrEP. These co-factors contribute to the spread of HIV/AIDS in the homeless community - particularly in the homeless LGBTQ+ community - and are rooted in the perpetuation of anti-LGBTQ+ beliefs and exacerbate the national HIV/AIDS epidemic.

In addition to social and legal barriers to HIV/AIDS treatment, the economic disparities between LGBTQ+ individuals and the rest of the population have barred them, both directly and indirectly, from accessing treatment associated with HIV/AIDS. A 2013 survey (Brown) undertaken by the Pew Research Center stated that 21% of LGBTQ+ respondents had reported the unfair treatment from employers in their pay and promotions. This practice in the workplace feeds economic disparities on a national scale, and various wage gap analysis has demonstrated that gay and bisexual men in the U.S. earn 10 to 32% less in comparison to their similarly qualified heterosexual counterparts (Rivas, 2015). Although tobacco, poor diet and exposure to toxic agents are often cited as some of the top killers in the United States, low socioeconomic status overwhelmingly underlies all of these variables and is directly linked to morbidity and mortality. The national trend in stifled economic status leaves the LGBTQ+ population at a deficit in their access to health care and increases the likelihood of their HIV/AIDS going untreated. In 2010, antiretroviral therapeutics cost an average of $9360 per year (Carter, 2010). Now, the total yearly cost of ARV drugs have more than doubled since that time, proving to be a severe monetary

ESSAYS – CONTINUED

stressor for many adults in the LGBTQ+ community, a group that is reported to be more likely to experience food insecurity and participate in SNAP, formerly known as Food Stamps (Brown et al., 2016). Therefore, the LGBTQ+ community in the lowest socioeconomic bracket has both the lowest rate of HIV viral suppression and the highest chance of further transmission.

Stigma remains a significant barrier to treating the current infected population and preventing further spread. Aggressions toward LGBTQ+ people, on both the micro and macro scales, perpetuate secondary conditions under which HIV/AIDS thrives disproportionately. Legal and economic discrimination are perpetuated by underlying social stigma associated with sexual or gender "deviance," and until concrete measures are taken to address these institutions, HIV/AIDS will continue to thrive under the oppressive conditions opposed against LGBTQ+ people in the United States. The impact of stigma associated with identifying as an LGBTQ+ person has been proven to have negative implications for overall health and well-being. Discrimination perpetuated in the healthcare field undermines diagnosis, treatment, and successful health outcomes for LGBTQ+ people, and acts as a persistent barrier for these individuals in accessing basic health care needs. This trend can be seen world-wide, but the evaluation of the LGBTQ+ community and their access to HIV/AIDS treatment specifically in the United States offers a critical commentary on the concrete social and legislative barriers formed as a secondary result of prejudice.

Conclusion

In this seminar, we explored the intersection of scientific discoveries and public health outcomes, using HIV/AIDS as a case study. This final project furthered that exploration by incorporating art as an additional means of investigating HIV/AIDS. Naturally, many people compartmentalize art and science into their own mutually exclusive disciplines. However, we often find art used as a medium to advertise, raise awareness, or spark conversations about science and public health. This is especially true for HIV/AIDS. From the very beginning of the epidemic, artists like Keith Haring and the collective Gran Fury used their work as a form of activism and public health intervention, eventually leading to the emergence of a culture in response to the epidemic through collective arts.

Today, we also find scientists using art as a tool of translation, allowing their audience to interpret their findings in a more comprehensible and relatable manner. The *Blood: Attract and Repel* 2017 exhibition at the Science Gallery Melbourne, curated by scientists and artists alike, is a great example of an aggregation formed between art and science. Focusing on the notion of blood as a social taboo and form of self-identity, this exhibition highlights the underlying stigma associated with the biological fluid. A piece titled "Blood Objects," created by German designer Basse Stittgen, consists of plastic products molded out of HIV+ blood. Made under intense heat, the blood-ridden objects are completely sterilized and are thus, incapable of infection. Despite their noninfectious status, some people are still uncomfortable holding the objects. Comprised of both the collection of objects and the reaction towards it, this art piece can be interpreted as a reflection of the underlying stigma against HIV+ people in spite of having treatments available rendering low transmission rates of the disease. Our final assignment for the seminar was curated in a similar fashion in an effort to explore how the HIV/AIDS epidemic specifically affected the LGBTQ+ community in the United States.

Throughout our class, we explored the history of HIV diagnosis and treatment in the United States and learned how the epidemic has disproportionately affected minorities and individuals with stigmatized identities. As the course instructor, I thought this final assignment provided students with a unique opportunity to explore the interdisciplinary nature of not only public health, but also a liberal arts education. They were able to investigate the art collection of our institution, think broadly about the meaning of artistic works, and dive deeper into a specific public health topic. The exercise, in my opinion, allowed them to develop a more nuanced and more compassionate view of the course material.

As students, we found this project to be a profound supplement to the course, as it allowed us to not only examine the inequities in disease proliferation within the LGBTQ+ population, but also examine the sensitivity and training that we need in the medical field going forward. High quality health care should not only take into consideration the patient's disease state, but act as an interdisciplinary practice through factoring in personal backgrounds and identities. Both of us (Miller

ESSAYS – CONTINUED

and Pheng) are aspiring physicians, and this project has been an invaluable investigation into the pervasive, underlying causes of disease in the United States. Over the past 10 years, medical schools have begun incorporating greater public health focuses on disease, and they have encouraged medical students to explore the impact of stigma in the healthcare field in the curricula. This change will hopefully create a physician base that is committed to treating patients regardless of their identities and provide a more equitable healthcare system for our diverse, 21st century population. By intentionally incorporating art into STEM courses, as we have done in this course, we may be able to achieve more fully this goal.

As the instructor, I appreciated the thoughtfulness and depth of understanding exhibited by all of the students who completed this assignment. Although each pair explored a different aspect of HIV/AIDS, they all expertly integrated knowledge from the course, outside information, and their interpretation of the art. The assignment allowed students to explore the central theme of the course in a new way. Hopefully, it also fostered in them a deeper appreciation of art and a sense of how the arts and STEM can be united.

Acknowledgements

We'd like to thank Lia Newman, Director and Curator of the Van Every/Smith Galleries at Davidson College, for encouraging our class to explore the art collections of the College and for graciously talking with us about how to interpret pieces of art. We'd also like to thank the other members of HHV 395 for completing their own versions of this assignment.

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ESSAYS – CONTINUED

Tip of the Iceberg: Collaboration and Scientific Writing

Lisa DeTora and Sabrina Sobel, Hofstra University

Many scholars study different types of writing in the sciences, like published manuscripts, presentations, letters, or reports. Science journalism, blogs, and science textbooks are sometimes also studied. Halliday and Martin's influential book *Writing Science: Literacy and Discursive Power* (2015), for example, presents the authors' analysis of popular science and high-school textbooks. Alan Gross, a famous rhetorician of science who discussed peer-reviewed literature in his book *Starring the Text* (2006), also discussed popular science writing (2018) which, to him, creates a more "sublime" version of the literature. For some people, especially experts in nonscientific disciplines, any text that conveys science can appear to be part of just one large community of thinkers and authors. This is not really the case, but it can be difficult for "outsiders," including undergraduate science students, to understand how these communities are organized. One way of identifying the relationships between texts and the communities of people who write them is by examining collaborative practices.

We draw on Hemingway's "iceberg theory" of writing (Johnston, 1984) to consider the disciplinary and cultural practices beneath the surface of scientific writing. Central to this discussion is the role of collaboration. We will describe how we use our knowledge of information beneath the surface of scientific texts in the teaching of scientific writing for science majors. One complication in this type of teaching is that standard undergraduate laboratory experiments are often intended to impart specific manual, conceptual, and writing skills, not to discover new information. Hence, teachers of scientific writing must find ways to make visible the myriad sources of information that must be conveyed to a reader by students working in artificial situations.

The Scientific Iceberg

In "Hemingway and Freud: The Tip of the Iceberg," Kenneth G. Johnston (1984) describes the origins of the "iceberg theory" of writing in the "fortunate loss" (68) of draft manuscripts that represented years of Hemingway's creative work. As he reconstructed texts, Hemingway developed a theory of "omission" (68) that relies on the writer's deep knowledge to deliver the minimal text needed to achieve an intended effect. As Johnston notes, the "oft-quoted iceberg passage in *Death in the Afternoon"* (69) explains how the power of writing, like the "dignity of an iceberg" (69) derives from fact that most of it remains submerged. Johnston also connects the "implicit and explicit" (69) modalities of communication in Hemingway with Sigmund Freud's construction of the conscious and the subconscious, creating an intersection of a scientific context and the iceberg theory. We believe that recognizing the interplay of implicit and explicit communication, as Johnston describes, is an essential component not only of psychiatry but all scientific writing. Scientists assume that their readers understand the depths of investigation beneath the written word.

The iceberg under scientific writing can be used to inform undergraduate writing pedagogies. Critical to understanding the iceberg beneath any scientific text is an implied voyage of discovery that led to a scientific question. It's always tempting, especially to nonscientists, to think of a study in Platonic terms, as an isolated act of lone genius enacted by its author. However, a crucial characteristic of the scientific iceberg is a series of collaborations that both implicitly and explicitly inform the design and conduct of each study and the writing of their papers. Each new collaboration is like a new community of scholarship. Linguist John Swales (1990) used the term "discourse communities" (9), to describe any group of people who exchange ideas and texts with one another and who create rules that determine the nature and form of different writing genres. In the sciences, shared habits, like the structured research format of introduction, materials and methods, results, and discussion may make it difficult for nonscientists or students to understand which groups work together. Helpfully, Bawarshi and Reiff (2010) have described genres in terms of communities and conversations, which may be easier for students to understand than more philosophical terms. Students need to learn how to identify scientific work that builds toward a common goal and work that intends to address new questions or disrupt current understanding.

We believe that the opacity of writing practices within the sciences makes it difficult to identify, and therefore differenti-

ESSAYS – CONTINUED

ate, the different communities of research and exchange. Understanding the demands of a discourse community (or not understanding them) also can be an important advantage (or barrier) to success in the sciences. In fact, inequalities in undergraduate science education can be linked directly to an understanding of writing demands, which may be unyielding and inflexible. Ironically, social scientists Yerrick and Gilbert (2011) found that programs developed with an aim to transition underrepresented students into STEM majors often used scientific language in a way that marginalized the students further. These programs inadvertently failed to help these students learn how to think and write more scientifically, which resulted in students leaving the sciences. hese authors identify the stakes of failing to characterize and make visible the deep knowledge beneath the surface of scientific writing in student attrition. We would like our students to find ways to discern the boundaries between discourse communities and to produce acceptable texts, while also learning how to manage structured genres.

Undergraduate Writing Pedagogy

As co-teachers of a course called *Seminars in Chemistry*, we explore the iceberg of scientific writing by explicitly describing how our knowledge and experience might apply to students. *Seminars in Chemistry* is intended for advanced majors in chemistry, including dual majors in chemistry and physics. The course description seems relatively straightforward:

Exploration of current chemical literature on a specific topic with presentation of a seminar and production of a review paper. Oral and written scientific communication following JACS format is emphasized.

Of note, proficiency in American Chemical Society style, the organization that publishes JACS (*Journal of the American Chemical Society*), is required to maintain program accreditation.

It may seem that learning the American Chemical Society format might not have very much to do with collaboration, professionalization, or original thought. However, one of the primary features of Seminars in Chemistry is that students select topics and read published literature to develop professional-quality review materials. One way we teach these skills is by modeling professional collaborative behavior. Thus, *Seminars in Chemistry* supplements the usual apprenticeship mode of collaborative authoring, which concentrates on task management. We describe this process in the following dialogue:

LD: I've been working with you for a few years now and I've noticed how you try to get students to formulate review papers. With your research students, how do you approach writing for publication?

SS: The work done by research students in my lab usually involves experiments paired with theoretical calculations. They have already gotten mini lessons in this sort of work when writing in their lab reports. As you know, a classic lab report has an introduction, background/purpose section, a materials and methods section, a results section and a discussion section.

LD: Yes, definitely. I've worked with your department to help students achieve success in these papers in classroom settings. And I have worked in more professional environments with people who already have advanced degrees, but how do you impart these skills to undergraduates?

SS: I always start with the concrete content. For instance, I can have them write up methods and results, which is an easier task for them than an introduction or discussion. I spend time editing and shaping their initial drafts in dialogue with them because they often lack the skills to be concise enough for published work. An experienced scientific reader will understand how to decipher the accepted highly condensed language needed in scientific publishing, but it is very difficult to learn how to write that way. We also have to work on tables, graphs and figures to move from the lab report standard to more publishable quality. Creating these items is a real art and students must gain technical and analytical skills to be successful in transitioning to making more professional outputs. They also have to be quite organized when dealing with data.

LD: Not surprisingly, you and your colleagues seem to me to complain most about the introduction and discussion sections in student lab reports. I hear the word "incoherent" rather a lot. How do you overcome this sort of tendency when preparing work for publication?

ESSAYS – CONTINUED

SS: Students must be able to write a solid lab report before they can progress to a publication. For original research papers, I have the students identify relevant published literature, then we compare what I found and write up mini summaries of each paper. Students often might struggle to identify relevant key words for effective searching. I have a deeper knowledge of the field – the greater underside of the iceberg, and I can better see the figurative forest and how our tree fits into it. Although I have one notable exception: a high school student found the most important key words for her research after months of us chasing our tails. She felt so proud, and I was so impressed. From that point, I take the lead in drafting the introduction. For discussions, we parse and fuss over the results that we have, and I shape and write based on these conversations. If I have a stronger student, then I will ask that student to write a discussion section that I can edit.

Mentoring students creates a sort of iceberg, with some information presented explicitly but a great deal only implied. The final paper, for instance, reveals none of this process (Sobel et al., 2020). In this account, a mentor maintains focus on the end product, a submittable paper incorporating writing in different tones, styles, and voices as well as visual information like tables and figures within a prescribed word count. The students operate only on the surface of the work, relying on their mentor for deeper knowledge and guidance.

Seminars in Chemistry furthers such mentorship by instructing students regarding the nature of scientific collaboration, situating different scientific discourses relative to one another, and preparing students to become effective collaborators. A further area of interest for us as instructors is how we can make use of our knowledge and experience to impart knowledge about writing in the sciences. One of these areas is the means by which we can use wisdom gleaned from rhetoric and writing studies to help students develop facility in drafting text. Another is the ways that cultural information about the sciences is implied rather than stated in scientific papers. We can liken these texts to Hemingway's iceberg theory of writing.

Scientific Writing, Collaboration, and Outlines

In *Seminars in Chemistry*, we often discuss how interdisciplinary collaboration is embedded behind the scenes of the final written accounts in all scientific contexts. In the fall of 2020, for instance, we used global warming as a general framework to encourage students to situate their work relative to existing knowledge and the projects of other students. As one of us has expertise in rhetoric and biomedical writing, we drew on her past experience and ongoing research to help students understand how their in-class projects might be related to future endeavors and their coursework in other subjects. Our choice of global warming as a broader theme permitted the use of any scientific specialty as a focus, allowing students to choose from many different types of projects while still using some related examples.

Seminars in Chemistry, by encouraging students to review published literature and concentrate on their own projects, also allows students to refine their own writing practice so that they can become more effective collaborators in the future. Effective collaboration requires an ability to think about coauthors as well as the end audience. Coauthoring, then, often requires an ability to contribute part of a text in such a way as to invite further comment or added information. To this end, we forward a mentoring practice introduced to our chemist by a family member:

SS: Laura, I'm feeling really overwhelmed with writing my Ph.D. thesis. It seems like more than I can handle.

Laura: I'm a linguist, as you know, and I always start with an outline. Then I slowly fill that in with more and more details and examples. It's easy to outline sections, and the outline format is easier to organize than paragraphs at first. If you tried that, you could think about what you need in each section of your thesis separately. I gradually fill in the outline until I am writing practically full sentences. This should apply in your field, too. Just give it a try.

SS: That's a great idea! I'll try it. This process should help me to break up the paper into digestible chunks. I could even write little chunks separately for each part of a structured paper. Then I could integrate those chunks into a coherent

whole more systematically.

Laura: Good luck! Let me know how it goes.

One of the benefits of the "outline method" is that initial text is easy to write and organize. It is also easy to lay out a series of sections so that different authors can choose one area to build up without losing sight of the whole project. To this end, in fall 2020 we encouraged our students to build interconnected mind maps and a shared background slide kit about global warming to help organize a set of key references and concepts. By using the slide set as an outline of sorts, students could use shared concepts and references to develop the introductions of their own papers while developing a discourse community of their own. Unsurprisingly, the outline method worked very well in *Seminars in Chemistry*:

(years later)
SS: I've been using your outlining method for so many years in my own work. Recently, though, my colleague convinced me to use it as a teaching tool in our *Seminars in Chemistry* class. I simply review the process for outlining, using a specific introduction section, usually from whatever my last paper was. It's fun because students see the names of their peers, and they also see how a literature search can lead to a published introduction. We do a literature search in our class, and after the students spend some time selecting the most interesting articles, I can model how to organize the most relevant topics and then to fill in each section with bullet points.

Laura: It's great to hear that you have used my ideas. I knew my idea was good, but it had more uses than I would have expected.

Seminars in Chemistry introduces students not only to specific writing formats, but also to the collaborative spirit that informs all scientific writing. As we have shown above, however, these practices gain more meaning when we situate them not only relative to scientific discourses, like journal articles and regulatory documentation, but also to writing studies, technical communication, and rhetorical studies of science. These studies provide the needed context that informs students why they should build outlines, read the scientific literature, or consider contexts outside an immediate product like an experiment, report, or paper.

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ESSAYS – CONTINUED

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The Journey to Community-Engaged Transdisciplinary Research

Ruth Kassel, Krysta Dennis, Robin Flatland, Scott Foster, Siena College

Introduction

The Siena Project Incubator (SPIn) is an interdisciplinary community engaged research program that represents a collaboration between the Center for Academic Community Engagement and the Center for Undergraduate Research and Creative Activities at Siena College. Based on the literature of authentic faculty-student partnership (Healey Flint and Harrington), transdisciplinary research (McClam and Flores-Scott), and community engaged research (Stoecker), this program brings together faculty from diverse disciplines, students at different stages of study, and community organizations who serve as research sites and educational partners. Over the years, our undergraduates have built strong research and leadership skills engaging in diverse forms of publication and dissemination like plays, quantitative homelessness studies, new business ventures, and innovative opioid programming.

This article outlines how community engaged undergraduate research creates an environment, a space, where transdisciplinary research emerges organically through democratic partnership, minimized power differentials, and alternative pedagogical spaces. Our focus on space is rooted in the authentic educational experience of Freire and is adapted from the concepts of counterspace (Cook-Sather and Agu) and brave space (Arao and Clemens). We provide concrete examples and stories of how we created these spaces in The Living Museum Project, a multi-year initiative that has brought together computer science, theatre, history, and visual arts to engage in virtual and augmented reality with local historic sites. While this project works with different historic sites, in this article we discuss one iteration where we worked with a historic house museum significant to the Underground Railroad and a black theatre troupe. Students, faculty, and partners in this project engaged in highly collaborative work combining virtual reality programming, historic dramaturgy, playwriting, visual arts, and graphic arts. In the end, a virtual reality tour with original artwork and a play with virtual reality elements ensured that students took on highly collaborative leadership roles and the research went from interdisciplinary to transdisciplinary. For this article, we consider transdisciplinarity to be trans-sector, problem-oriented research involving a wider range of stakeholders in society (Klein).

We aim to demonstrate that, before considering the steps to success on a project like this, the transdisciplinary research team must have a shared epistemology and way of thinking about the research, as well as shared goals and approach. Collaborative undergraduate transdisciplinary research in the community must stem from the creation of spaces through community engagement where power differentials can be neutralized, and attention can be paid to best practices in transdisciplinary research (Klein) and student-centered learning. These spaces enable the authentic relationships that take the work from multidisciplinary to interdisciplinary to transdisciplinary. We demonstrate how developing these spaces leads to increased student motivation and ownership, greater appreciation of interdisciplinarity for faculty and students, and high quality publications in academic and public venues.

Siena College is a Franciscan liberal arts undergraduate institution of approximately 3000 students in Upstate New York. The Living Museum Project, which grew out of the Siena Project Incubator, aims to work with local historic sites to create experiences that will engage new audiences in reimagining history and to connect the unique history of the sites to modern day issues and the surrounding local community. This may have implications for how our campuses can engage our students more broadly in an interdisciplinary fashion by giving them opportunities to work across disciplines to do research and create artifacts that are motivated and guided by the needs of the site. How this can be integrated into campus structures traditionally designed around formal disciplinary structures merits further investigation.

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Table 1. The Living Museum team

Year 1		Year 2	
Title	Discipline/Expertise	Title	Discipline/Expertise
3 Students	Theatre, dramaturgy	2 Students	Theatre, dramaturgy
1 Student	Visual Arts	1 Student	Visual Arts
2 Students	Computer Science	2 Students	Computer Science
2 Students	History		
2 Faculty	Creative Arts	2 Faculty	Creative Arts
1 Faculty	Computer Science	1 Faculty	Computer Science
1 Faculty	History		
1 Associate Director	Academic Community Engagement Center	1 Associate Director	Academic Community Engagement Center
2 Museum Directors	Local historians	2 Museum Directors	Local historians
		Black Theatre Troupe of Upstate NY	Theatre, acting

The Living Museum team consists of students (all undergraduates), faculty, and community partners from a variety of disciplines, as shown in Table 1. From year 1 to year 2, the core faculty from computer science and creative arts remained the same. Most of the students were rising seniors when they worked on the project, so only two theater students continued on from year 1 to year 2. In the first year, we had two history students and a faculty member working with us to supplement the knowledge of the community partners. Their research laid the historical groundwork and was infused throughout the project in year 1 and year 2.

Building a Student-Centered Learning Space

"Give them a team challenge, help them grow as a team right away." This is the directive we were given from our community engagement coordinator before the start of our second year on the project, and it seemed reasonable. To begin building the relationships and trust needed for transdisciplinary work, we needed a cohort-building activity, one that would get the team into a transdisciplinary mode of thinking and prepare them for the type of learning needed for the project ahead. Klein states that, "intellectual integration is leveraged socially through mutual learning and joint activities that foster common conceptions of a project or program and common assessments" and this certainly held true in this project (S119).

We sent the students on a mission to the Albany Rural Cemetery, a sprawling historic cemetery located within walking distance from the Siena campus. They were to imagine that the cemetery was our community partner, and devise a project for virtual or augmented reality that might appeal to the cemetery and be feasible for our team. At the end of the day, the students would present their ideas to the faculty. Taking the students out of the context of the specific community partner that we were working with allowed them to think about transdisciplinary creation rather than focus narrowly on the project at hand, thus leaving room for creative thought and potential student-led shifts in focus. It also developed friendship and camaraderie among the students that set the stage for integrated learning and collaborative research.

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Left to right: Dr Robin Flatland, Luis Villa (in virtual reality headset), and Quillan Cummings. The year 2 computer science team. Photograph by Sergio Sericolo.

Undergraduate transdisciplinary research begins with transdisciplinary learning, and this commitment to learning must be shared by the faculty, students and community partners. While the introductory activity was certainly helpful for the undergraduate researchers, it was also a turning point for us. We quickly realized that the act of collaborating on developing and implementing a problem-based experience also brought us together as a faculty community and allowed us to begin thinking about them as a group of students we would all work with, rather than feeling that we could only work directly with the students in our own disciplinary group. We discussed the capabilities and characteristics of each student and learned how many connections they already shared. In addition, the energy the students brought to this task energized us, and we continued to work together to develop problem-based learning tasks throughout the summer.

In this learning space, we were careful to engage students as partners in research and learning. Healey, Flint, and Harrington state “only where students are given a significant amount of autonomy, independence, and choice can this be considered partnership” (3). While we have many disciplinary skills to teach them, we were partners in learning in this transdisciplinary space. This forced us to focus on leadership and interpersonal skills over research content, which in turn enabled us to recognize opportunities for teachable moments. For example, when three of the student researchers and two actors in period costume traveled to the partner site with a 360 camera, we knew all had been rehearsed and carefully planned. Everything went off without a hitch except for the fact that the camera had been on when it was meant to be off, and off when it was meant to be on. When the students came to deliver the bad news to the faculty, we did not resolve the issue for them, but worked together to establish a solution. We could have certainly cut that part of the virtual reality experience, or called the community organization ourselves to explain the situation, however, allowing the space and time for setbacks and minor failures to become teachable moments is paramount to teaching students about leadership. The students contacted the actors, rescheduled the shoot, and grew in confidence. While the students ultimately delivered a good quality product, the process of learning how to take responsibility and engage in productive conflict are consistently mentioned by students as an important element of the program.

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Higher education in the United States is based on a 19th century Germanic model, a fallacy of neutrality and specialization, and our students have come to expect both hyper-focused disciplinary teaching and faculty as givers of knowledge. In order to break this antiquated "habit," it is important to teach disciplinary approaches, while also creating spaces for transdisciplinary learning and collaboration, ones that are student-centered, problem-based, and relationship driven. This commitment to co-creation of knowledge minimizes power differentials and sets the stage for students to engage fully in the academic transdisciplinary space.

Defining the Academic Transdisciplinary Space

In the first year of the Living Museum Project, the team worked within a multidisciplinary framework, each in our own field creating work that engaged with the community partner. The visual-art students created artwork and graphic visualizations; the computer-science students created a virtual reality application allowing users to virtually explore the site as it was in the 1850s; the history students created an annotated list of the museum's original document collection; and the theatre students wrote an original full-length play about the historic inhabitants of the site. We visited the community partner and communicated with the partner as a team, but worked in our own disciplines. The students were engaged with one another in a limited manner, and presented their individual work at the Researching New York conference.

We began to pivot from an interdisciplinary to a transdisciplinary mindset near the end of our first year working together. Our visual-art student had reached an impasse in their current work, and offered to create digital wallpaper, based on historical data, that could be incorporated into the virtual reality environment. What started as a spur-of-the-moment decision to fill time when their own project stalled quickly transformed into something new, as the student discerned a need to know more about virtual reality development software in order to more effectively work on the design. Our computer-science and visual-art students began collaborating across their disciplines, sharing knowledge and synthesizing the result into the virtual reality environment.

Virtual reality presents a unique opportunity for educators and artists. A computer simulation of reality through a software interface, virtual reality allows for the integration of material from multiple content areas into a unified and experiential framework. It can be understood as a postmodern *Gesamtkunstwerk*. Packer observes that "Wagner used the mechanisms of the theater, as we would the computer today, to transport the viewer's mind, emotion, and senses to an otherworldly place where the perception of reality is reconfigured by the artistic construction" (160). The phrase, *artistic construction* is critical. It is effectively designed user interfaces, graphic visualizations, and narrative/experiential elements that allow virtual reality to simulate reality. All of these elements collectively are beyond the scope of any one student, professor, or creative professional to achieve. Just as the production team for a video-game or CGI movie would bring together programmers, artists, writers, actors, and others, our Living Museum team has brought together the skills and knowledge from four different fields to achieve a unified vision. While we initially conceived of our project as multidisciplinary, it was soon evident that we were working with "[problems] that cannot be divided," (McClam and Flores-Scott 232).

Before the start of the second year, we decided to embrace that change. We realized that a more integrated model worked better, featuring weekly meetings and a great deal of communication as a team. We utilized team-building activities that were focused on exposing the group to other virtual reality experiences. For example, we traveled together to the Massachusetts Museum of Contemporary Art to see Laurie Anderson's *Chalkroom* and *To the Moon* installations. The computer-science students organized another team activity in which the group spent an afternoon "playing" with a variety of virtual reality content and watched a 360 video production of Hamlet.

Our goal was to create an integrated virtual reality experience. At team meetings, we established a theme and structure for the virtual reality experience. Students and faculty talked about what they could bring to the project; e.g., the theater students had written a period play and had access to a 360 degree camera and actors, the art student was interested in sketches of period clothing and could digitize and enhance original historical documents, and the computer-science students shared their research on the capabilities and limitations of the virtual reality development tools. The team meetings created a common space of mentoring and educating around the shared goal.

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Within this group-oriented structure, a further transformation took effect. Students soon left the confines of their disciplines as they realized that new skills and modes of thinking would be required to make this project a success. Our students continued to rely on the skills honed through the computer science, visual art, and theatre curriculum, but they were able to learn from each other, modify their methodologies to suit the project goals, and accommodate the necessity of acquiring new skills. In other words, we arrived at a "fusion of disciplinary knowledges (sic)" (McClam and Flores-Scott 232) that gave rise to something new.

Developing Urgency in the Community Space

"We must do a fundraiser for the partner toward the end of the project." Our community engagement coordinator was firm on this part of the process, even in year 1, as it would bring together the community engagement elements and create a culminating effect. While some comments like, "maybe next year when we are more comfortable" or "let's have them present to each other first" were mentioned, we all quickly understood how important this fundraiser would be to the research, the student learning, and to the nonprofit partner. In a sense, all of our work is for an audience, whether it be in an academic journal or public-facing event. Computer science, visual arts, and theatre are all disciplines in which there is a fundamental understanding that the work will sooner or later reach its audience. For visual-art and theatre students, there is an expectation that work will be showcased to the public, even if it is presented as a work in progress. In year 1, for the computer-science students, anticipating the public demonstration of the virtual reality application exposed the challenges of developing and deploying reliable, user-friendly software. Since the typical classroom programming assignment does not get executed by anyone other than the student and the teacher, it was their first experience writing software that others would use. This pushed them to add features users would enjoy and to make the virtual reality user interface intuitive.

Black Theatre Troupe of Upstate New York preparing to perform at the year 2 fundraiser. Photograph by Michael Lounello.

A project like this, with so many moving parts, benefits from external urgency, and aids student researchers in overcoming the common hurdles of the research process. Rich, diverse community outlets for the work allow the research and creative activity to do more and be more. A connection to the community makes the work more meaningful to its

creators than a simple paper or campus presentation, as well as adding incentive to create work that will be of sufficient quality to share with a broader public beyond the academy. Work can be both academically rigorous and meaningful in our communities: the two are not mutually exclusive. As McClam and Flores-Scott suggest, "transdisciplinarity cannot function or exist within the abstracted, decontextualized knowledge spaces produced within the disciplines. Doing transdisciplinarity . . . requires the application and bridging of our disciplinary practices within the messy complexity of the 'real' world" (9). Often traditional models neglect to include the community space, or it is incorporated as something of an afterthought. Within our model, this "real world messiness" is intrinsic to the process. The students must learn to balance the community-focused elements with academic accomplishments. Alongside their work with the community partner, the year 1 student cohort presented their work at the Researching New York Conference; the visual-art student submitted work to the Historic Albany Foundation for their annual fundraiser, "Built: Albany's Architecture Through Artists' Eyes" at the New York State Museum; the theatre students in year 2 submitted their original play to the Kennedy Center American College Theatre Festival, saw it move up to compete at the national level from the regional level, and are seeking publication. All students who take part in the project showcase their work in the form of research posters at Siena's academic celebration, thereby engaging in traditional academic activities alongside community engagement.

The day of the fundraiser for our community partner in year 1, the rain had cleared up just in time for our outdoor event, though the heat and humidity had not. In this community/real world environment, we witnessed our students directing the Black Theatre Troupe actors, who would be doing a dramatic reading of the play they had just researched and written, the computer-science students giving virtual reality tours to eager attendees, and the historically correct portraits and landscapes--which would later be used in further fundraising efforts--were displayed on easels. It was a gratifying and encouraging experience to witness the hard work and professionalism of the students as they engaged with the audience. This event at the end of year 1 prompted an even more integrated model for year 2. Both events focused on the soft skills, the "in-between" skills, that highlight the importance of transdisciplinary research on everyone involved.

Conclusion

In this article, we demonstrated how a community engaged undergraduate research project, The Living Museum Project, creates spaces for student-centered learning and transdisciplinary academic work, with a sense of urgency created in the community space through the development of outward facing products. We provided examples of how we cultivated these spaces through shared activities and giving students autonomy and room to fail. We described how the common goal of developing a virtual reality experience connected the work across the disciplines and created a level playing field where the disciplines were dependent on each other for the success of the project. Finally, we showed that the integration of a community partner fundraiser motivated the work and supported the project's longer-term academic goals. Having completed our two-year collaboration with the Underground Railroad site, the Living Museum Project team is now applying what we have learned to working with a new local historic house museum and leveraging our past successes in seeking external funding.

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ESSAYS – CONTINUED

Limit to Lifespan Will Limit Human Knowledge

John Richard Schrock, Emporia State University

There is a long-term tension between the need for science to continue to specialize, and the calls for more interdisciplinary education.

In the late 1700s, study of medical science could be merely a matter of apprenticing under a master and passing an oral examination. There was no college coursework in the preparation of the famous doctor, William Beaumont (1785–1853). He saved the life of French fur-trapper Alexis St. Martin who accidentally shot himself in the stomach. Beaumont proceeded to study the functions of St. Martin's stomach by dangling food on a string through the fistula left by the wound (Kelly and Burrage). His pioneer work was often featured in biology textbooks.

By the time doctor Samuel Mudd (1833–1883) repaired the broken leg of John Wilkes Booth, the assassin of President Lincoln, Mudd had spent only two years in college medical study (Mudd). It has been one of my joys in biology teaching to inform my biology sophomores that they were nearly finished with the education needed to be a medical doctor...over 150 years ago.

Today, of course, a medical education extends far beyond a college bachelor's degree. Depending on whether a specialty is pursued, a medical doctor today may not complete training until he or she is nearly 30 years old.

Learning Takes Time

This need to learn ever more will not stop. Learning is not instantaneous; you cannot simply take a pill and immediately understand. "Meaning" is dependent upon experience, and experience takes time. A baby suspended in a sensory deprivation chamber from birth can learn nothing. Despite the assertions of Carl Sagan in his classic program "Cosmos" that the library at ancient Alexandria held a vast amount of "knowledge," that is not knowledge but mere "information" (Sagan *et al*.). When a librarian hands you a book, they are handing you information, not knowledge. Whether you will understand what is in that book will depend on whether it is related to your experiences, directly or indirectly. And that is the job of a teacher and others involved in our learning. Life experiences and associated learning are the Rosetta Stone that allows us to understand, to convert the information learned by those before us and by our contemporaries into our knowledge. Simply: no experience, no meaning. And for every new discovery we add to the edge of our growing paradigms, it also gives rise to even more new questions. The universe has a complexity that extends far beyond our current understanding and there is no current evidence that we will eventually "know everything."

New concepts also result in more new terminology. In the 1800s, the disease "consumption" referred to a sinking in of the chest; it was one generalized entity. After the new germ theory of Pasteur and Koch, and additional discoveries since then, the word "consumption" has disappeared and been replaced by over two dozen different well-defined ailments that are now recognized, from various lung cancers to viral and bacterial pneumonias to emphysema and black lung disease (Davis). Another example is infection of the liver or "hepatitis." And, when a second cause of infection was discovered, it was separated into Hepatitis A and Hepatitis Non-A. This process of discovery advanced into Hepatitis A and B, and Hepatitis Non-AB, and continues to expand much further down the alphabet today (Kahn*)*. Scientific terminology expands as scientific research further reveals the complexity of the real world. Our science dictionaries will continue to expand.

But we have come to see the various persons who knew everything that was known about their broad field of study die in the 1700s and 1800s. The last polymath in entomology, the study of insects, was probably Johan Christian Fabricius (1745–1808) (Tuxen). Insects are divided into many orders, and probably the last polymath for just the order Hymenoptera—the last person to know everything that was currently known about ants, bees, wasps, etc.—was John Lubbock (1834–1913) (Lubbock). And in the study of just bees (mellitology), that would be Charles Michener of the University of Kansas, who died in 2015. "There is no single individual today, and perhaps never shall be again, who has had as much

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firsthand experience with every lineage of bees in the field and who commands such an all-encompassing knowledge of our world's bees" (Engel 5). Thus Michener is likely the last person who knew all there was to know at his time about bees. Now there is simply too much for any one person to learn in one lifetime about bees.

Thus, it is an absolute certainty that in the future, in order to learn more about a specific science field, the future student must narrow their focus. It will take a longer time for them to learn the expanding body of what is known and to arrive at the forefront of their specialized knowledge to conduct new research to expand their paradigm. Therefore the medical doctors of tomorrow will take longer and longer to learn their specialty. And there will be ever more narrower specialties. Just having stockpiles of information available in a print or digital library does not solve the problem of knowing enough to ask the correct question or to understand the ever more complex answers we get.

That brings us to an interesting dilemma. Despite various proclamations by various biologists that human life can be extended in the future by maintaining telomere length or otherwise manipulating factors that cause senescence (decline with aging) over time, it remains fairly certain that there is a set lifespan limit that is roughly between 115 and 120 years maximum. This is the "Hayflick limit" named for Leonard Hayflick who has carefully documented the many factors of aging (Hayflick). Unless you are a cancer or germ cell line, the number of your various body cell's divisions is limited, and that in turn limits our lifespan. While we live under the impression that humans are living longer, in fact a few humans in ancient times lived to our maximum old age. With improvements in nutrition and human living standards, a larger percentage of us are living closer to that upper limit today. But that upper limit has not changed.

This fact of a set maximum lifespan, combined with a necessary minimal time to learn, leads to an ultimate limit to human progress. Considering that from the earliest time in childhood we detect the intellectual desires of a child, and then customize their learning into ever-narrowing fields of specialization, some future day will come when it will take a full lifetime of learning to finally master the knowledge of a specialized field to the point that would allow the specialist to propose one new experiment before reaching their Hayflick limit. This limit on lifetime therefore would in turn set a limit beyond which further scientific advancement will not be possible.

Can Group Cooperation Overcome Individual Specialization?

Now we consider the proposal to promote interdisciplinary education. While the 2020 COVID-19 pandemic has slowed overall efforts in both education and general science research, a concept I refer to as *Years of Potential Intellectual Life Lost* (Schrock), it has greatly expanded research related to the narrow field of the coronavirus disease agent and its origin. On January 22, 2020, a journal in virology published a paper by five authors investigating similar codon usage proposing that the coronavirus had passed from its bat origin through a *snake* before infecting humans. On April 14, 2020, another author in a journal in molecular biology published research asserting that the lack of a specific dinucleotide indicated that *dogs* were the intermediate host between bats and humans. This "finding" in particular sent fear through many dog owners. Both journals supposedly use peer review. But the broader biological and medical community was very skeptical from the beginning. While I do not know who the peer reviewers were, there was concern that both the authors and the reviewers were all molecular biologists with little understanding of snakes or dogs, an understanding of organismic biology that molecular biologists generally do not have. Finally a deeper analysis of "Susceptibility of ferrets, cats, dogs, and other domesticated animals to SARS-coronavirus 2" (Shi et. al.) was published in the journal *Science* on May 29, 2020 and it was co-authored by 21 researchers, some with expertise in molecular biology and some with organismic specialization, all working together. This research is better accepted, while those prior two papers are mostly disregarded.

Here we have an example where interdisciplinary research goes beyond the expertise of any one specialist and relies on each researcher understanding the mission in generality and contributing their unique expertise as a partial contribution to the whole effort. Today, we no longer educate one biologist to be expert in the molecular biology of viruses, the complexities of immune systems, and the host biology of a wide assortment of mammalian hosts. But it appears that both the authors and peer reviewers of the articles in the first two journals were so narrowly specialized that they failed to understand their limitations. But the third *Science* article, and similar studies since, have succeeded in combining the expertise of different specialists to perform a cross-disciplinary investigation.

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This then poses the question: Can cooperation among different specialists overcome the limitations imposed by the Hayflick limit? There is no question that as scientific fields of study become narrower in the future, the solution to problems of complexity requiring a range of different expertise will require the cooperation of a variety of experts. Here the difficulty will be the ability of specialists in one branch of study to communicate in sufficient depth with specialists in another branch of study, both converging upon a shared problem, just as the molecular and zoological biologists had to understand each other in the above example. But that need for "co-understanding" does not solve the problem insofar as it takes time away from the specialization.

Breadth Prevents Depth

This problem grows greater because research is not done in a vacuum. It takes funding and political and institutional support. Folks in government therefore have to understand enough to make judgements on research funding and policy. In the case of the speculative snake and dog-intermediate host papers, a consequence to the China government was to require pre-approval of any further studies on origin of the coronavirus (Gan et al.). And unnecessary fear by dog owners was certainly a valid reason for insisting on better review. But then government officials have to be knowledgeable enough to understand their science advisors and the potential and limitations of proposed science research. And that complexity will expand. The science understanding of governmental, medical, corporate and other partners will have to grow to remain adequate to understand the expanding complexity of science. This cross-communication requirement does not solve the problem of reaching a limit to our knowledge due to the Hayflick limit. Already university administrators are relying on "bibliometrics" that merely counts citations and journal ratings in order to make decisions far beyond their ability to otherwise understand and judge the research (Biagioli and Lippman, Gingras).

That is not to deny that a broader education of an individual will bring important understanding from one area of study into solving a problem in another specialized field. My doctoral training in entomology, specifically in systematics and ecology, is critical to my functioning as an English editor to a journal on insect taxonomy. But part of my position at my university was the training of secondary biology teachers. And teaching is very much based on understanding semantics. Communication is the paradigm of education, and semantics is the central study of associating the meaning of language with experience (Hayakawa). The earlier examples used in this essay explaining experience as the basis for knowledge, and common experience as the basis for communication between teacher and student, draws directly on my accidental but fortunate participation in a college semantics class. I doubt if any science professors worldwide have any semantics course required in their background. Therefore, my ability to advance this very thesis is a result of interdisciplinary education. The extra study of semantics provided the examples above and has been essential to teaching future biology teachers over the years. Yet while that breadth of education allowed me to parse this problem in a unique perspective, I have forfeited the depth to move to the cutting edge of research in entomology. Breadth prevents depth.

We do not have an endless lifetime. The more we trim education in one growing field of specialization in order to provide more interdisciplinary education, the less time there will be to advance in the narrowing fields of specialization. One answer to this would be to carefully separate those students whose mission is to assist general society in fuller general literacy from those designated to advance a specializing field of science, realizing that any time spent with interdisciplinary learning with this second lineage will merely delay humanity eventually reaching the maximum knowledge limitation imposed by the Hayflick limit.

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Interview with Richard W. Bulliet, Professor of History Emeritus, Columbia University

Conducted by Sal Genovese, Boston University, June 3, 2021

Interviewer's Note: Beyond his primary job of teaching about the Middle East, Richard "Dick" Bulliet also lectured and authored several books on the history of technology, the history of domestic animals, and environmental history.

I had come to know "Uncle Dick" over the past two decades, primarily at family holiday gatherings. In what always seemed like fleeting moments, we'd get a chance to discuss overlapping interests in our academic and research pursuits. As a marine biologist with teaching interests in human ecology and the environmental sciences, I always enjoyed my conversations with Dick and appreciated how he could draw upon events in the natural world to make connections with the historical record. And I was delighted and honored to be a guest lecturer in his World Environmental History course a decade or so ago.

Serving as a guest editor for this special issue of *Impact* provided an excuse to reach out to Dick, fill in some gaps in my knowledge about his teaching and research, and ask some direct questions about how he thought the historical record could help inform students about our current climate crisis. We spoke over Zoom for more than two hours, and what's presented below is obviously a very small subset of our entire conversation. Any deficiencies or overindulgences in the text below are solely my responsibility.

Before I focus our discussion on integrating the natural sciences into a history curriculum, I wanted to start by asking about the quantity and breadth of courses you taught at Columbia University. I have a good understanding from reliable family sources that both were significant, but have never spoken with you directly about this topic.

In my 39 years at Columbia, I don't believe I ever taught the mandated 3-2 course load. I always taught, at the minimum, 3-3 or 4-4. I believe I was as high as 8-8 at some point. I simply taught more than other faculty, and that gave me the opportunity to cover the Middle East, which was my assignment when I was hired, and also teach in the core curriculum, which was something that the university very much wanted senior professors to do. I taught in the core curriculum for 15 semesters.

I thought that the way to get a Columbia education was to teach the core, so I taught all of the four core courses: major works of Western thought, major works of Western literature, major works of Western art, and major works of Western music. Then I worked with Professor Theodore de Bary in creating a non-Western core component, and he and I collaborated in teaching it for several years. My feeling was that whenever I had anything that really interested me, I could create a new course, so long as I fulfilled my basic coverage for the university by being, for most of my time at Columbia, the History Department's only Middle East historian.

How receptive was your department to the interdisciplinary courses you offered?

I never heard a chairperson say, "I wish you would teach this more than that." They were always just very pleased that I was teaching in the core, and then I could teach whatever I wanted in addition. So when I started teaching History of Technology that was fine. When I taught Domestic Animals and Human History, they were cool with that. Then, very late in my career, I filled in for a faculty member who had gone on medical leave, to teach a course on World Environmental history. That was certainly not my bailiwick in any formal sense, but I had thought a lot about issues in World Environmental history over the years.

Can you describe the process by which you came to integrate the natural sciences into your history classes?

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I did not start out with the intention of bringing natural science into my classroom. It really arose in two different ways. My initial research for my doctorate was on the great medieval city of Nishapur in Iran. I bicycled every day out to the ruins of the city, which is now just farmland. Looking at a landscape of undulating mounds and depressions concealing ruined buildings 20 feet below the surface, I wondered about the whole process by which a city dissolves into ruins.

That made me aware of the very distinctive irrigation system of underground channels they have in Iran called "qanat irrigation." I was interested in how the water was supplied. This was, after all, a city in a desert that had very little actual rainfall. But there were some mountains north of the city, and the water table there would be tapped by a long underground tunnel, or *qanat*. Every village depended on a *qanat* delivering a small stream for household use and for irrigating crops. This raised all sorts of questions about how the tunnels were dug, how the water was distributed for irrigation, and what happened over the course of time as the flowing water slowly eroded the underground soil.

So that got me interested in how the city was maintained, and I also recall a day when I was bicycling through the ruins and my way was blocked by a small flock of sheep. There was a young man driving the sheep, and it was apparent that one of them might not make it into the city to be sold. In order to get the weak or ill sheep to walk, the shepherd was beating it with a stick. It would take a few more steps and then collapse again. I saw that the shepherd was weeping, and I thought, "He doesn't own the sheep. Someone is paying him to drive these sheep to market." His season's pay was probably something close to the value of that one sheep. So if the sheep died before reaching town, he might have lost a season of work. It struck me then how crucial the relationship was between livestock, the people who care for the livestock, and the needs of a large city that has to be supplied. I've calculated, for example, how many thousand camel loads of goods must have been brought in per week or per month to sustain a city of 100,000 people in the middle of the desert.

These things stuck in my mind, even though my primary research was based on analyzing a collection of 2000-3000 tiny biographical notices about people who lived in Nishapur at one time. I was doing a sociological analysis of a long list of names and brief career descriptions, but my experience on the ground was adding something else. When I returned home, gradually, over the course of years, I thought more about the irrigation system. And I thought about the livestock.

I remember vividly a day back in my family home one summer after I'd finished my PhD when I suddenly thought, "What is the word for 'wheel' in Arabic?" I was surprised that after seven years of classical Arabic, I didn't know the word for something a commonplace as a wheel. Then I realized that I wasn't sure I'd ever seen the word for "wheel" in any medieval text I had read. Several possibilities came to mind. Maybe I just had a bad memory for Arabic words. But maybe there hadn't been any wheels in the medieval period from which the texts were drawn.

And the more I thought about it and collected other sorts of evidence, I realized that there had indeed been an absence of wheeled transport. That led to me writing *The Camel and the Wheel,* a book with two components: one was the technological history of carts and wagons, putting forward the thought that wheeled transport had at some point disappeared from the Middle East. That ended up being a thesis that resonated with a lot of readers. The other component proposed that the reason this disappearance of the wheel took place when it did was that cheaper transport by pack camel became available, partly for technological and partly for political reasons, at a certain point in time. Camels were decidedly cheaper than wheels, a conclusion that led me to the whole question of how the herding of animals can affect every aspect of an economy. All of this was culminating back at the time I left Harvard in 1973. My book manuscript contained ideas I discussed in a freshman seminar on camels, but otherwise my teaching did not incorporate very much of what I was discovering about animals.

Was there much interest in that seminar?

I could take 10 students in the class, but something like 30 or 40 wanted to register. I thought, "Surprise. Camels are popular!" It helped me to have two hours once a week to talk to students about things I was thinking about, about camels in different parts of the world, about different types of evidence, and so forth. Then when I went out to Berkeley I taught a course on the history of animals: mostly camels, cows, and donkeys, plus a little bit on horses. I taught that for a couple

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of years and then I let it drop until I'd been at Columbia for a decade or so, when I thought, "That stuff on animals really sticks in my mind. I need to do more."

I created a course called "Domestic Animals in Human History," and that proved to be a real mind changer for me. Now, instead of simply talking about the things that I already knew something about, transport and camels and deserts and so on, I had an entire course where I could go from the earliest experience of *Homo sapiens* with animals to the present day. I taught the course for five or six years, and ultimately wrote *Hunters, Herders and Hamburgers*, a book that ended up taking a look, at both the theoretical level and the day-to-day level, at the entire history of the human species and its relationship with animals.

I'm quite interested in your book *Cotton, Climate, and Camels*, especially given society's current focus on climate-related issues. Did it develop in a similar manner as the two books we've discussed so far?

This book focuses on the history of Iran and the broader Middle East. I started my career, as I mentioned, working on the city of Nishapur. Many questions I tried to answer I couldn't initially, but I got a pretty good grasp of how this city of 100,000-200,000 people operated in the year 1000. A city that size must have been one of the largest cities in the world not situated on navigable water. A city without water transport must bring in overland all sorts of things that are consumed by the population: food, charcoal, cotton and other raw materials for manufacturing and building, and so on.

So I knew a lot about that city, and I had a suspicion that there was something about place names that was peculiar. I remember a student who wrote a doctoral dissertation about Lebanon in the 1600s. He was able to show on maps that every village in a particular region of today's Lebanon was already there, and known by the same name, 400 years earlier. The tenacity of place names in these very old parts of the world is often quite extraordinary.

When I first went to Nishapur to do field work, I had a list of all the village names I'd found mentioned in history books. Once on the scene, I expected to find the same villages under the same names. But they were all gone. I thought, "Why is it that in one part of the Middle East, villages continue for centuries, and in another part they disappear?" I tied the disappearance to the *qanat* system I described earlier. These underground water channels must wear out, and therefore need to be rebuilt. But who does that? Who pays for it? There's no mention of some king ordering 1000 underground tunnels to be built.

Instead, they appeared very clearly to have been built by people who, one way or another, had acquired a right to the water that allowed villagers to grow the crops that are irrigated through the *qanats*. Those people hired canal-building specialists who knew how to deliver flowing water to otherwise desert land. Before the first water came out, however, the tunnel digging is just an infrastructural investment. And that investment could only be justified by building a village, relocating workers, and selling the crops they grew. How did this rural investment system come into being? Who reaped the rewards?

It took me many years to work it out in my head, but it struck me that the most common pattern of village names in Iran consisted of a person's name, followed by the word "Abad". It wasn't exactly clear what "abad" meant, but I figured if the personal name was that of the man who owned the rights to the water and paid for digging the irrigation tunnel, the following word "Abad" probably meant "with a *qanat*."

I found a fairly strong correlation between these things by going through gazeteers, and then I found one medieval Persian text that gave a list of all the villages that were then producing taxes in a certain district in central Iran. Suddenly it became clear what had happened. The person who financed the tunnel put his name on the village that was built to make use of the new stream of water. So, if your name was Mohammed, and you had enough money, you could pay people to dig the tunnel and thus become the owner of the village the tunnel made possible. And you call it Mohammed-abad. What was important about the many new villages that Arab Muslims and Iranian converts to Islam built in the 8th and 9th century was that the water flowed all year long. Other villages, ones that relied on winter rain or seasonal streams from

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melting snow, had enough water for a spring crop of wheat or barley. But in deep summer, their water was insufficient for further field crops. Only the villages with year-round water from *qanats* were able to utilize Iran's torrid summer climate for growing cotton.

It became apparent that cotton was the great product that resulted from the early Islamic expansion of the *qanat* system. This changed the basic economy of Iran and made the country a great exporter of cotton. But then the cotton industry all but disappeared between 1000 and 1200. What happened? My theory is that a change to a colder, drier climate undermined the cotton industry. Famines and epidemics became more common and many villages shifted to growing food crops. Cotton returned to northern Iran a few centuries later when the weather regained its warmth.

I have not persuaded my colleagues in Iranian history that this is what happened. Some people think that I'm imagining a chilling of the climate beyond just everyday variance from year to year, just as today, people who are in climate denial will say, "Well, the weather always varies."

But I still think that there was a significant chilling on the climate that led to the fall of the cotton industry and, ultimately, to the arrival from the north of camel-breeding nomads whose animals did not take well to the colder weather. That is the thesis of my book. I was proud of the research methods I used, but I'm afraid the details about village naming do not make for a very readable text. Nevertheless, it was another way of bringing together agriculture, animal culture, and climate. So I ended up working on climate history, something which I had not anticipated doing.

What lines of evidence for climate cooling did you find? For instance, was there tree ring data available from that time and location?

To the best my knowledge, we still do not have any tree ring sequences from the parts of the Middle East that the cotton came from, so the tree ring data that are available are from Western Mongolia and Tibet and they show a narrowing of the tree rings in the in the 11th, 12th, and 13th centuries that I am interpreting as signaling a worsening of the climate. What contributes to the tree ring variance is temperature and moisture, with moisture presumably the more important. The problem is that I use tree rings as a proxy relating more to moisture, and there is an awkward comparison with my other proxy, weather reports in medieval Baghdad that address temperature more than dryness.

In the period I concentrate on, detailed chronicles for Baghdad, the closest place that I could find to the area I was most interested in, would comment on severe winters, and the frequency of those severe winters increased substantially. The severe winters would be described in terms of precipitation and freezing. It was interesting that, when they talked about freezing, the chroniclers were quite aware that different fluids freeze at different temperatures. When they would say that the water and the water wheels froze that year, they would also say rosewater froze or bulls' urine froze. Then you can look at the freezing points of these various substances and realize they were quite aware that different fluids freeze at different temperatures, and that was their way of telling you how far below freezing it was.

My third source consists of anecdotal evidence of one sort or another having to do with what happens when you have a climate that is actually changing. One of the things that seems to happen in Iran is that you have a very substantial migration out of the country. This is how you end up with sizable populations of immigrant Iranian ancestry in Turkey and northern India. Their ancestors were people who migrated from Iran because the economy was falling apart a century or so before the devastating invasions of the Mongols in the 13th century.

Were you able to incorporate this body of work into the Middle East History curriculum at Columbia?

Middle Eastern history is taught in compartmentalized fashion. The way American universities were set up in the 1950s, they divided history of the region into a classical Islamic period, which is from Mohammed to Genghis Khan, an Ottoman period, and a modern period. So one person would be hired with skills in medieval Arabic language and manuscript reading, with maybe a little archaeology and art history. Then another would have research skills in Turkish to cover the

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Ottoman period from 1300 to 1900, often with a teaching focus on Turkey and the Balkans instead of Iraq, Iran and Egypt.

The third person would teach something called “Modern Middle East History,” which hasn’t held up well conceptually. It is founded on the idea that at some point “modernity” happens, and you have to explain what that is and how it manifested itself in the Middle East. I think that was a political project from the very beginning. When United States scholars thought of people becoming modern, they meant that they were on a track to become like us in America. I feel it was hubris to talk about modernization in that respect.

So you would end up having three professors, at say the University of Chicago or Harvard, where each one would deal with one piece of the totality without really having anything that asked them to look the broad sequence of 14 centuries of Islam, much less pre-Islam.

When I was hired at Columbia, however, I was told, “There will never be anyone other than you teaching Middle East history, so you have to teach about, and direct doctoral research on, everything from Muhammad to the present.” So I was that rare creature who was hired and paid to be a generalist, and it gave me an opportunity to make linkages across these dividing points of the Mongol invasion and the beginning of modernity. I had opportunities to structure things any way I wanted, so that *Cotton, Climate and Camels* and my other books fit well into medieval courses focused on the central Middle East, but also have implications for other periods.

Still, there are a lot of historians who are very uncomfortable with technology and with anything that is quantified. When I started, the field was, as it continues to be, overwhelmingly dominated by scholars who focus on theology, Islamic law, Islamic mysticism, poetry, literature, and the great men of history. None of those topics interest me very much. I’m sure my students to some degree suffered in curricular terms from having too little of those topics and too much of my stuff, but I think that there should have been somebody who does what I do.

Are there other historians who take your approach or your perspective on interpreting historical events?

The closest professional ancestry for me and my way of approaching history is the French school of history called the “Annales school,” named after the journal *Annales d’Histoire Economique et Sociale* (Annals of Economic and Social History), which goes back to the early 20th century and produced great historians in France. The Annales school was devoted to expanding the universe of what constitutes historical data. So they brought in a lot of archaeology, a lot of material evidence, and a lot of quantification.

The first article I ever wrote that touched on any of this was an article on the disappearance of wheeled vehicles vis-á-vis camel transport. I remember writing the article and then asking a colleague where he thought I might get it published. He said, “Send it to *Annales*.” I graduated from Harvard with a B.A., M.A., and Ph.D. in history, and I had never heard of the journal mentioned. So little awareness was there at that time, at least in my orbit, of what was going on in continental historical studies.

I wrote the article and sent it in. After a period of weeks, I wrote and asked whether they ever received it. They said, “Oh yes, we’re having it translated into French and will publish it.” I was happy about that. Then a few years later, a paperback appeared in the United States titled *Social Historians in Contemporary France*. It was a selection of articles from *Annales*, and it contained my article. I was amused that they were trying to pass me off as a French historian, possibly because I have a French-looking name.

But for the history profession in America, the Annales school really came down to transferring from Europe to America the notion that class, race, and gender are *the* three most important things for historians to study. For me, however, it was the material history, the archaeological history, the quantitative history, and the infrastructural history. This is the Annales school that fascinated me, but it has never caught on very well in this country.

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Finally, can you speak about your experience teaching the World Environmental History class?

Well, as you know, I got a phone call from the chairperson of the history department who said that a newly hired professor had to take a leave for the semester, even though we were already in the third week. He had an American Environmental History course on his schedule, and the Chairperson asked if I could take over teaching it. I said I can't do American Environmental History, but I can do World Environmental History, because I know enough about specific episodes to fill such a course with substance.

I read a substantial portion of the readings on the professor's syllabus and found that they dealt with contested issues in the environmental history in the United States. These were very interesting books, but they were very much devoted to detailed accounts of how the conflicting economic and political interests of one sort of user or another swayed public policy, for better or worse.

My knowledge base dealt with much earlier history, for the most part, where that level of explicit political or ideological contest has usually been lost to history. Instead, you deal with a balance of interests that you cannot recover, or even know whether they were ever articulated as debates.

What I discovered was that virtually every student in the class had a primary interest in environmental studies, not in history. There was only one student enrolled in the course who was actually in the history department. So the first several weeks, where I was going through different episodes of environmental history — deforestation of Europe, relations between herders and farmers, and so forth — didn't arouse much enthusiasm.

At a certain point, I went around the class and got more input from the students as to what would interest them more. I remember asking the question: "Given that most of you are interested primarily in Environmental Studies at a time when we're deeply into the climate debate in this country, do you think it's already too late to save the planet?" Every one of the students in Environmental Studies thought it was, indeed, already too late.

I also realized that the earlier history of how we reached this stage was of very little interest. They wanted to know about contestation because of their desire to enter into public policy debates. Thus a book on who should benefit from the resources of the Columbia River valley intrigued them because it showed how the interests of state and local governments, Native American groups, salmon fisheries, and farmers using river water for irrigation got negotiated, either publicly or situationally.

So over the course of the semester, I gradually shifted from the topics that I had started with, to more contemporary topics that were more engaged with the students' interest in the here and now. The two classes that aroused the greatest student interest were ones where I arranged lectures by two practitioners, one a California farmer talking about how a modern farm negotiates state and federal environmental guidelines, and you, a marine biologist concerned with threats to fishing in New England and tropical coral reefs.

I did teach one course after that on land and water transport. That course enrolled 10 students, but only one from the history department. All the others were engineering majors. That experience drove home a lesson that I had been somewhat aware of for a long time, which is that Columbia University's history department had very little interest in the material world. Faculty and students concentrated primarily on issues of class, race, and gender, and on the politics surrounding them. We were admitting promising young people who wanted to study those things, and what I was increasingly interested in teaching dealt with the natural world, or the built world, or the world of technology.

Do you think this is a general trend among history departments in American universities?

At about this time, around 2013, I studied the program for the annual conference of The American Society for Environmental History in Toronto and took note of the affiliations of the speakers: zero from Columbia University, and a tiny

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handful from the Ivy League, except for Harvard, which furnished around a half dozen speakers. The great majority of presentations were from state universities, and often from their secondary campuses. It became clear to me that the environmental crisis has engaged historians at a practical level that is beneath the notice of the country's most elite historians.

How would you teach the World Environmental History course differently, if you were to do it again?

Teaching that class, I found out where the students' interest lay and what really engaged them. If I had known that before I jumped in, I would have designed the course differently. If I had engaged the students in the backgrounds, and then the pre-backgrounds, of their current existential concerns, I might have lured them into using earlier examples to see how those existential concerns are not entirely new.

There has to be some way of seeing futures that does not catastrophize at an Armageddon-like level. You do this by showing how parallel existential crises at the infrastructural level have worked through historically in previous episodes. These episodes would need to be brought together to show how they are addressing a common set of concerns that are concerns today and have been concerns in the past. There's too much of the present in the way it's examined now, and that leads to catastrophizing. There are other approaches that would be easier to convey to students if they had the deeper historical record that the teacher brings to bear.

Well, thank you for all your time, Dick, this was quite enjoyable.

You're welcome, it's been fun.

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