SCIENCE EDUCATION & CIVIC ENGAGEMENT

AN INTERNATIONAL JOURNAL

VOLUME FIFTEEN
ISSUE ONE
Winter 2023

SCIENCE EDUCATION & CIVIC ENGAGEMENT
AN INTERNATIONAL JOURNAL

Volume 15 Issue 1 · Winter 2023

ISSN: 2167-1230

National Center for Science and Civic Engagement
www.ncsce.net

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

VOLUME FIFTEEN
ISSUE ONE
Winter 2023

About the Journal

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

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

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

WWW.SECEIJ.NET

Contents

From the Editors

February 2023

FOR THE WINTER 2023 ISSUE OF THIS JOURNAL, we are excited to highlight a Teaching and Learning article on using climate justice and civic engagement to teach STEM. In addition, we are pleased to feature three project reports that include the development of a preparatory workshop for introductory mathematics courses; a campus-based research and service-learning project to use waste vegetable oil as a sustainable biodiesel fuel; and a creative approach to teaching botanical fieldwork under the constraints of the COVID-19 pandemic.

Climate justice, which exists at the intersection of climate change and social justice, is a pressing civic issue in the 21st century. In a collaborative project, **Sonya Remington Doucette,** (Bellevue College), **Heather U. Price** (North Seattle College), **Deb L. Morrison** (University of Washington), and **Irene Shaver** (Washington State Board of Community and Technical Colleges) have developed a repertoire of valuable resources for using climate justice and civic engagement as a framework for teaching STEM in a context that is relevant for today's "climate generation" of students. The authors first introduce the principles of climate justice, focusing on the importance of equity in deciding whose voices are heard and who is represented in discussions of climate policy. In particular, the global communities who are most affected by climate change need to have a seat at the table. Drawing on research literature and a variety of reports, the authors make a convincing case that focusing STEM courses on issues of equity, justice, and civic engagement improves the retention of women and students of color in STEM majors, since the courses now become more meaningful to students and their communities. The authors' presentation of using climate justice to teach STEM is an important contribution to current discussions within the STEM community about diversity, equity, inclusion, and belonging.

Mathematics is the cornerstone of STEM courses and majors, but many students enter college without the necessary skills to be successful in their foundational mathematics courses. These "gateway" courses can be an impediment that leads to attrition from pursuing a STEM major, especially for underserved students. A team of faculty members from New York City College of Technology, **Sandie Han, Diana Samaroo, Janet Liou-Mark,** and **Laurie Aguirre**, have developed an innovative support structure for students by offering free, non-credit preparatory workshops in mathematics, which are available to all students within their diverse undergraduate population. According to the authors, the key goal of the preparatory workshop is to improve student success in mathematics courses. Each workshop lasts for four or five days depending on student needs, and they are strategically scheduled right before the beginning of the fall and spring semesters. After assessing the impact of the preparatory workshops, the authors report that students who participated in these workshops during the summers of 2019, 2020, and 2021 earned a higher percentage of A, B, and C grades and a lower percentage of F grades in subsequent mathematics courses when compared to students who did not participate. These preparatory workshops provide a valuable model for supporting student success in gateway mathematics courses, which are critical for the pursuit of a STEM major.

Guang Jin and **Thomas Bierma**, both of the Department of Health Sciences at Illinois State University, describe a project that integrates service learning with undergraduate research by using waste vegetable oil as a sustainable biodiesel fuel. Students collected waste vegetable oil from campus designing facilities, which was able to provide 50% of the biodiesel needed for campus vehicles. As the research component of their project, students learned how to (1) sample and analyze waste vegetable oil from various campus dining centers, (2) produce biodiesel fuel from waste vegetable oil, and (3) build a solar-powered device for the recovery of methanol and glycerin from biodiesel waste. In their feedback on course evaluations, students reported high ratings for their ability to apply knowledge and skills to benefit others or serve the public good. This project provides an interesting example of using the college campus as a microcosm for civic engagement that is directly meaningful to students' lived experiences.

How were faculty members able to promote ecological field skills during the social-distancing restrictions of the COVID-19 pandemic? A creative solution to this challenge is described by a team of faculty colleagues from Truman State University (**R. Drew Sieg, Joanna K. Hubbard, Madison Williard,** and **Zachary A. Dwyer**) and Washington University in St. Louis (**Rachel M. Penczykowski**). Using the model of Course-Based Undergraduate Research (CURE), the faculty team designed authentic research activities based on an easily identifiable, plant species in the genus Plantago which could be observed by both in-person and remote students. New instructional videos were developed that introduced students to ecological research and plant species identification. After establishing an observational protocol, data collection about plant ecology within a local habitat was crowdsourced to all students in the course. All data were combined in a communal spreadsheet, which was then converted into a map displaying *Plantago* distributions within the city of Kirksville, MO (home of Truman State University). After training in statistical methods, students used the crowdsourced dataset to investigate their research questions. Survey responses indicate that students valued the real-world applicability of the project and the relationship of the course topics to everyday life. A comparison between student survey responses for the pre-COVID course and the COVID course demonstrated a statistically significant increase in the number of students who were willing to take other courses in ecology. The authors ascribe this increase to the development of the new lab module and the increased use of technological tools for the research investigation and hybrid instruction. This project illustrates how we can use the lessons learned from the exigencies of COVID-19 to inform the development of new course topics and pedagogical strategies.

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

Matt Fisher
Trace Jordan
Co-Editors-in-Chief

Teaching STEM Through Climate Justice and Civic Engagement

SONYA REMINGTON DOUCETTE
Bellevue College

HEATHER U. PRICE
North Seattle College

DEB L. MORRISON
University of Washington

IRENE SHAVER
Washington State Board of Community and Technical Colleges

Abstract

This article provides a rationale and resources for teaching climate justice and civic engagement across the STEM curriculum in K-12 and higher education. It presents a culturally responsive approach to STEM teaching and learning that centers social justice issues arising from climate impacts, and energy extraction and development activities, with a focus on participatory and equitable solutions and actions. This approach promotes STEM curricula that introduce social justice issues into the classroom as an entry point for investigating the issues using STEM. A social justice approach allows students to make meaning of abstract and disparate STEM knowledge and skills through real-world issues aligned with their interests, experiences, identities, and communities. In this article, we provide resources for teaching STEM through climate justice and civic engagement that are being collectively developed by groups in Washington (WA) State, led by Deb Morrison at the University of Washington (K-12); Sonya Remington Doucette and Heather Price at local community colleges (Bellevue College and North Seattle College); and Irene Shaver at the WA State Board of Community and Technical Colleges.

What is Climate Justice?

A good working definition of climate justice is rooted in the histories of the people who first defined it. In 1991, more than 1,100 people attended the First National People of Color Environmental Leadership Summit in Washington, D.C to address environmental inequities across the United States and define the issues they were concerned about. At this event, the 17 Principles of Environmental Justice were created (First National People of Color Environmental Leadership Summit, 1991). This event, which preceded the 1992 United Nations Framework Convention on Climate Change (UNFCCC), provided a basis for defining climate justice. A decade later, the 17 Principles of Environmental Justice were used as the basis for the 27 Bali Principles of Climate Justice (International Climate Justice Network, 2002). This brief history illustrates the significant role American grassroots organizations have played in shaping a global understanding of climate justice.

Bali Principle 7 states that environmental justice demands the right to participate as equal partners at every level of decision making. This principle can help us begin to think about what climate justice looks like. Additionally, Principle 7 helps us consider what climate justice learning might look like, in terms of what is learned, how it is assessed, and how curricula are planned and implemented.

The Mary Robinson Foundation, founded by former President of Ireland Mary Robinson a member of The Elders, an organization started by Nelson Mandela to foster issues of justice globally, has also contributed thinking to definitions of climate justice. In 2011 they developed basic principles of climate justice, specifically that climate justice is rooted in the opportunity to participate in decision-making processes. As such climate justice centers the voices of those most vulnerable to climate change impacts to ensure that they are heard, their knowledge and experiences are prioritized, and their thoughts are acted upon. These principles also note that a vital aspect of any coherent approach to climate justice is an openness to partnership in an arrangement that is equitable.

Emerging from this historical foundation, some central themes around defining climate justice are clear. First, climate justice sits at the intersection of climate change and social justice. This means that climate change and climate science are not value-neutral but instead are connected to social issues in the world. Second, the mobilization of resources for climate mitigation and adaptation is an equity issue when it comes to who gets what resources. Third, climate justice is about networks for collective action, not only individual behavior change. Grassroots organizations, and community organizations and efforts, are at the heart of climate justice because they offer a collective voice that is more powerful than any individual voice and this collective voice is grounded in the real life opportunities and struggles of people in communities most impacted by climate and environmental injustices. Finally, climate justice involves equitable participation in decision making, policy development, and implementation, including in the field of education.

Thus from a climate justice perspective within education, we can ask: Who is deciding what is being learned and how it is being learned? Who is at the table to make those decisions? Climate justice teaching and learning is about transformation and participation, and how we learn together in doing that. With a focus on disproportionate impacts of climate change on vulnerable and marginalized groups, and future generations, climate justice is often defined as what is missing based on how these frontline communities are more negatively impacted. However, Communities of Color and other heavily impacted groups have a wealth of knowledge, understandings, and resources that need to be brought into educational work. Those on the frontlines of climate change do not need to be saved, they do not need anybody's pity; they need to be adequately resourced, engaged in ethical and equitable partnerships, and be equitably involved in decision making processes.

In her book *Mind, Culture, and Activity* (2004), Barbara Rogoff, a leading learning scientist, defines learning as "…a process of transformation of participation itself" and notes that "… how people develop is a function of their transforming roles and understanding in the activities in which they participate." This is very much what the environmental justice and climate justice communities are asking for; changes in participation, improved access for youth into STEM careers, improved involvement in local decision making, and the authority to shift money and resources toward things that are central to community interests.

Why Teach "Through" Climate Justice?

Our students are the Climate Generation (Jaquette Ray, 2020). Most were born into a world in which the climate was already changing. To them, the connections between climate impacts and social inequity are clear. They are the most ethnically diverse of all time, and face some of the greatest challenges in human history: global climate and environmental change as it intersects with socioeconomic and racial inequity. Their Science, Technology, Engineering, and Math (STEM) education needs to be relevant to the scale and complexity of the problems they face. It needs to equip them with disciplinary practice and scientific knowledge in partnership with the systems thinking skills, critical consciousness, and civic engagement tools needed to leverage STEM to create societal change and improve their communities. Centering social justice issues, such as climate justice, in STEM classrooms broadens the participation of women and racial and ethnic groups that have been historically underrepresented in STEM fields. Over the past few decades, the STEM education community has awakened to the idea that the content and skills we teach in our courses must be humanized and taught in a context that is relevant to students' interests, experiences, identities, and communities. This brings meaning to seemingly abstract and disparate STEM knowledge and skills. Such work has been happening, in parallel and sometimes in collaboration, at both the K-12 level and in higher education.

The National Research Council, in its *A Framework for K-12 Science Education* (Framework; 2012), provided a strong entry point for bringing climate justice education into K-12 STEM teaching and learning. In particular, Chapter 11 deserves a read as it provides research and background on equity within STEM education. The *Framework* authors provide a grounded vision of equitable STEM education, such that "…all students are provided with equitable opportunities to learn science and become engaged in science and engineering practices…," with a recognition that "…connecting to students' interests and experiences is particularly important for broadening participation in science" (p. 28).

Teaching climate justice in STEM courses, and especially the *gateway* courses of mathematics and chemistry, offers learning spaces and authentic opportunities for meeting students *where they are* at by providing meaningful learning that connects to their interests, experiences, communities, and identities. We cannot teach STEM in a neutral, disconnected way, because it does not have meaning for students; students lives and science itself are connected to human socio-political activities and experiences. Science learning, and science itself, is a cultural activity. We want students to see STEM in their everyday experiences and it is our job as educators to help them make connections between their lives and seemingly abstract STEM content and skills.

Higher education has come to a similar realization, albeit in a more disconnected way. A SENCER evaluation showed that students who took SENCER courses, in which STEM was taught through complex unresolved social issues with a focus on civic involvement and democratic processes, learned more STEM content, were more interested in STEM, and more capable of relating it to real world problems (Weston et al 2006). They also found that gains in science literacy were particularly pronounced for women and other racial and ethnic groups underrepresented in STEM.

A transformation of STEM culture away from an economic workforce focus, toward socially-relevant civic issues, is needed to attract and retain these groups and make STEM relevant to 21st century challenges. A shifted focus on social and civic issues as part of an equitable STEM curriculum is illustrated by a quote by a high-performing Black male student who left an engineering major:

> "A big concern of a lot of Black students is we feel like we're being prepared to go into white corporate America, and it won't really help our community—we won't have the opportunity through our careers to give back to the community. Anything that we do for the community would be outside of our academic field, and that's a very serious concern." (Seymour & Hewitt, 1997, p. 337)

More than 20 years later Seymour & Hewitt (2019) reconfirmed similar values at play: 73% and 60% of women and racially and ethnically diverse students, respectively, who switched out of STEM majors had altruistic career intentions. Co-authors Remington Doucette and Price regularly receive similar feedback from their diverse community college students regarding their climate justice lessons. A Black woman in Price's class recently expressed thanks:

> "...for teaching me chemistry the way it should be taught with real life reference and practicality. I have been accepted to UW Chem E [University of Washington Chemical Engineering]. I can't wait to be a part of the problem solving community and hopefully come up with solutions to combat the climate crisis." (Personal Communication, February 2020)

These findings are echoed by a recent study about the Equity Ethic, a concept developed at Vanderbilt University (McGee & Bentley, 2017). The Equity Ethic focuses on "students' principled concern for social justice" (p. 6) and explains why a social justice-centered approach to STEM teaching may be more appealing to groups typically underrepresented in STEM fields, particularly Students of Color and women. Patterson Williams & Grey (2013) offer excellent examples of how the Equity Ethic may be operationalized in the classroom, with social justice as a meaningful phenomena for investigation using STEM knowledge and skills. Bringing social justice issues into the classroom brings real-world issues into the classroom that connect with students' identities and communities, which is one of eight core competencies for culturally responsive teaching (Muñiz, 2020). Furthermore, real-world issues focused specifically on social justice are part of educational equity in the STEM curriculum. Social Justice Education (SJE) is one of the three key areas of instructional equity (Hammond, 2015; Hammond, 2020).

A social justice approach to STEM teaching, rooted in climate justice, will resonate with most students. Two recent Pew Research Center polls found much higher concern about climate change in people ages 18 to 39, compared to their elders, even for youth with more conservative social and political leanings (PRC, 2020; PRC, 2022). This quote, by a White male student, who took Remington Doucette's chemistry course to transition from a career in big tech to a career in medicine, illustrates that students want and demand this type of STEM education:

> "I think if I remained in the big-tech-world and didn't take your class, I wouldn't have started thinking about these complicated health effects [related to climate impacts and fossil fuel burning] and general need for awareness. UW CS [University of Washington Computer Science] didn't reveal any of this to me which is a bit annoying to me now."(Personal Communication, February 2021)

At their community colleges, Remington Doucette and Price implemented student surveys beginning in 2021 with faculty from several other STEM disciplines as part of an NSF IUSE grant focused on teaching climate justice in STEM. The preliminary survey results showed that the top three issues of concern about the world today for students are climate change, racial inequality, and mental health. About 60 % of students felt these issues were not addressed in their STEM courses, but almost 80 % want them addressed. Climate justice lies at the intersection of these issues. (For an introduction to mental health and climate, and what we can do about it, see Remington Doucette, 2021.)

Climate Justice in Community College STEM Learning: The C-JUSTICE Project

Climate Justice in Undergraduate STEM: Incorporating Civic Engagement (C-JUSTICE) aims to improve STEM education by supporting community college faculty as they create course modules that teach disciplinary content through climate justice and civic engagement, with a solutions focus and action orientation. The project aims to improve student learning, broaden participation of women and racial and ethnic groups underrepresented in STEM fields, and prepare citizens and scientists to deal with 21st century challenges. It is supported by an NSF IUSE grant. Since the project's inception in 2021, course modules (C-JUSTICE modules) have covered a range of climate justice issues and have been implemented by 21 faculty across eight different STEM disciplines at Bellevue College (BC) and North Seattle College (NSC). (Table 1).

C-JUSTICE is based on a professional development curriculum for teaching climate justice and civic engagement across the curriculum developed at BC in 2017 and adopted by NSC in 2019. It is situated in two frameworks

TABLE 1. A sampling of C-JUSTICE modules implemented by community college STEM faculty at BC and NSC since September 2021.

Discipline	Examples of C-JUSTICE Module Climate Justice Issues
General Chemistry	1. PM 2.5 Pollution from Coal Combustion in Ulaanbaatar, Mongolia (published online: Remington Doucette, 2022) 2. Indigenous Ways of Knowing and Food Security 3. PNW Heat Waves, Salmon, and Indigenous Food Security
GOB Chemistry	4. Methane pollution and Snohomish Tribe pipeline case study 5. Methane from Gas Stoves and Pediatric 6. Climate Justice in Epigenetics
Oceanography	7. Cascading Effects and Disproportionate Harm Post-Hurricane
Meteorology	8. Air Pollution in Charlotte's (N.C.) Historic West End 9. Redlining and Urban Heat Islands in Spokane, WA
Computer Science	10. Creating a Decision Support System for Water Management 11. Designing a Mobile App to Reduce Emissions
Environmental Science	12. Ocean Acidification and the Washington Shellfish Industry
Biology	13. Ocean Acidification and Youth Activism 14. PM 2.5 and Health in Seattle's Marginalized Communities 15. Disproportionate Health Impacts from Heatwaves and Redlining
Mathematics	16. Climate life expectancies of women and girls
Physics	17. Carbon emissions and transportation justice
UGR Course	18. Historic Redlining, Heat Islands, and Air Pollution the USA

from STEM education practice and research: SENCER and the Equity Ethic. (Figure 1) SENCER provides a pedagogy for bringing complex unresolved societal issues into the classroom, whereas the Equity Ethic (McGee & Bentley, 2017) is more of a theory about why a social justice-centered approach to STEM teaching can be more appealing to groups typically underrepresented in STEM fields, particularly Students of Color and women. At its very heart, the Equity Ethic is about "students' principled concern for social justice." When students can see STEM as a means to promote social justice, help their communities (Elmi et al., 2022), and disrupt systems of oppression, then they are more likely to pursue a STEM major, stay in a STEM major, or end up in a STEM career. It is about transforming STEM culture away from a singular focus on workforce development and economics, toward a focus on socially relevant civic issues and democracy. C-JUSTICE modules aim to expose the social political context that students experience, raise consciousness about inequity in the world, and help students and faculty develop a "lens" for recognizing inequitable patterns and practices in society and develop the tools needed to interrupt them. A recent book by Eric Liu, *You're More Powerful Than You Think: A Citizen's Guide to Making Change Happen* (2017), provides frameworks and ideas for civic involvement being used by C-JUSTICE.

The three broad learning goals for C-JUSTICE modules are that they:

- make clear to students the intra- and inter-generational connections between climate change and racial, economic, gender, intergenerational, interspecies, and other injustices,
- foster the skills, knowledge, commitments, responsibilities, values, and efficacy (Figure 2; Wang & Jackson, 2005) as well as the actions needed to engage civically with a community beyond the classroom in a way that promotes collective systemic change, *and*
- highlight positive stories of change that make the world a more just and equitable place.

FIGURE 1. The framework used to situate the C-JUSTICE project

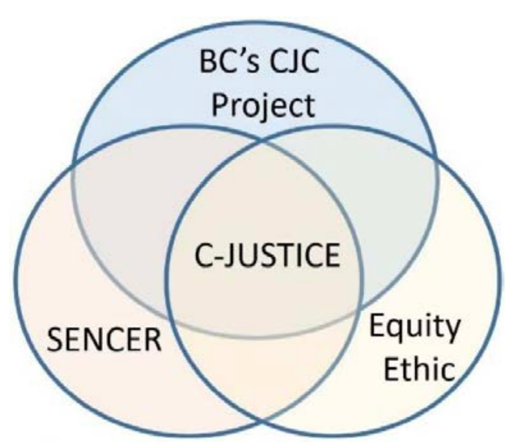


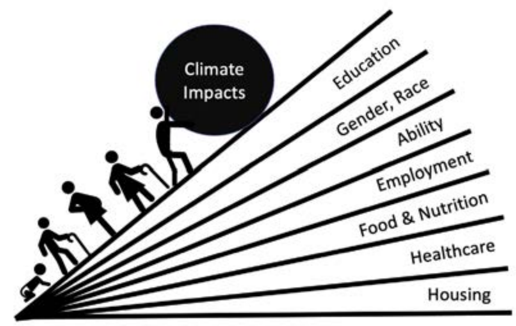
FIGURE 2. Seven dimensions of civic engagement

C-JUSTICE portrays intra-generational justice as a wedge (Figure 3), adapted from (Making Partners, 1988). The more vulnerable a person or group is, the more difficult it is going to be to deal with climate impacts. In the wedge, climate impacts are represented by the ball and vulnerabilities are the wedges. The more vulnerabilities, the steeper the ramp, the harder it is to handle climate impacts. Faculty in C-JUSTICE workshops find this wedge framework to be helpful for developing a "lens" or critical consciousness for recognizing inequities that arise from climate impacts.

Preliminary C-JUSTICE student survey data collected at BC and NSC are compelling (Remington Doucette and Price, unpublished). They show that top issues for students are climate change, racial inequality, and mental health and that students want these issues taught in their courses. Most have a desire to be more socially, politically, and civically engaged in their communities, but are not presently engaged because they don't know how. Finally, students agree about the need for equity, but there are gaps in their understanding of the systemic causes.

Survey data also showed that after experiencing a C-JUSTICE module in a STEM course, more students see STEM as a tool for achieving social justice and that it can be used to help solve problems in communities they care about and serve racially and economically marginalized communities. They also have a much greater understanding of climate justice and know how to become involved. More students also see STEM as useful for informing

FIGURE 3. C_JUSTICE framework for recognizing vulnerabilities and inequities related to from climate impacts, and energy extraction and development activities. Adapted from Making Partners: Intersectoral Action for Health, 1988 Proceedings



and taking civic action, and they intend to become more involved in their communities. Finally, learning STEM in the context of climate justice increased their interest in STEM and their motivation to learn STEM.

Beyond the efforts at BC and NSC, this work is being disseminated to 34 community and technical colleges (CTCs) across Washington state through a Climate Solutions effort led by the State Board of Community and Technical Colleges (SBCTC) and funded at $1.5 million by the WA state legislature (Washington SBCTC, 2022). On average, more than 320,000 students enroll in a community or technical college across the state per year. More than half of those students are Students of Color. With statewide coordination and resources supporting this climate solutions effort, systemic inequities can be overcome to empower Students of Color from frontline communities who, due to structural racism, disproportionately experience the burdens and risks of a changing climate, are the least economically resourced to enact change in their communities and are the most excluded from the benefits from the green economy. Utilizing this specific educational lever for systemic change—expanding climate solutions education and green workforce development in CTCs and making our colleges more sustainable—has the greatest potential to increase equity in all areas—in higher education, in the workforce and economy, and in frontline communities across the state of Washington. This work expands climate solutions education and green workforce development to ensure that all people can be sustainability and equity minded leaders in their communities and professions, can respond to the impacts of a changing environment, benefit from the green economy, and can contribute to community-based and industry-led climate solutions.

The SBCTC is working to integrate climate solutions education into curricula, align green workforce development programs with climate solutions, and develop a system-wide climate action plan. The SBCTC's goal is to promote greater economic vitality in the green workforce for the state of Washington, generate community based climate solutions, and make CTCs in Washington state more sustainable. It has four focus areas: Climate Solutions Education, Green Workforce Development, Sustainability Colleges, and Centering Equity. The climate justice faculty professional development (PD) curriculum developed by BC and NSC, both across the curriculum and as part of C-JUSTICE, is being integrated into the Climate Solutions Education focus area. The goals of this focus area are to establish faculty leadership, provide training and PD for college faculty and staff to develop integrated curricula across disciplines, in concert with local community-based organizations, employers, and tribal communities that address the needs of frontline communities and support students in building the problem solving, social justice, and civic engagement related skills to be climate solutions leaders in their fields.

Resources for Engaging in Climate Justice Teaching and Learning

How can we teach climate justice in STEM? In order to resource learning in the areas of STEM, equity, climate change, and climate justice, there is a demand for resources to help address emerging questions of practice. Several initiatives have been working to provide such resources across the United States including: the STEM Teaching Tools and the CLEAN Network.

The STEM Teaching Tools collection, initiated in 2014 by the Institute of Science and Math Education at the University of Washington, provides such learning supports. In the last few years, more of the STEM Teaching Tools resources have centered around issues of climate learning with a justice lens, as educators have expressed increasing needs for resources in this area. Additionally, resources that help educators communicate with families and administrators, engage with communities, and foster more equitable place-based learning opportunities that center sustainability or climate mitigation and adaptation efforts are also in need. All these resources are being developed in collaboration with educators, researchers, and community organizations working at the intersection of climate change education, spanning K-12 to higher education contexts. A special mention should be made of the Washington State ClimeTime effort and the more recent Climate Teacher Education Collaborative, that have brought those involved in climate change education in the state together in deep collaboration with the Institute of Science and Math Education to foster resources for use in diverse socio-political teaching contexts.

The CLEAN Network, which stands for the Climate Literacy and Energy Awareness Network, began building resources in 2010 as part of the National Science Digital Library Pathways project work. Today the CLEAN Network provides extensive scientist and educator vetted resources on climate change learning, teacher learning resources on climate change science and age-appropriate equitable pedagogies, and a community of practice to connect those engaged in climate change education nationally. The Institute of Science and Math Education has been in partnership with CLEAN for the last five years around resource development collaborations and these two organizations continue to seek co-generative opportunities to collaboratively build and resource the capacity of educators seeking to learn and implement climate change related education.

The teaching of climate justice in STEM is rapidly expanding, yet the disparate pockets of climate justice STEM teaching resources can be difficult to locate. In 2021, the National Science Teaching Association published a Special Issue on Climate Change (NSTA, 2021). This is one of the best set of STEM-specific climate justice examples to date for K-12. Other resources emerging from the C-JUSTICE project, developed at the community college level, will be published in the form of course modules within the next two years to the Curriculum for the Bioregion's Activity Collection on Carleton College's Science Education Resource Center (SERC) site. There is currently one existing STEM-specific climate justice module for General Chemistry focused on systems thinking and civic engagement around CO_2 and PM 2.5 emissions from coal combustion in Ulaanbaatar, Mongolia.

Strategies for Engaging in Climate Justice Teaching and Learning

When planning out climate justice teaching, there are three principles that are important to keep in mind. First is the idea of nurturing hope and action. In order to help students, and ourselves, work through the feelings of despair that come along with learning about climate justice issues, we must teach climate justice within a solution-centered or action-centered framework. This means starting with and focusing on solutions or actions, rather than tacking them on in a very small way to the end of a climate justice lesson that is mostly focused on the problem. For example, starting with alternative energy and having students analyze the social impacts of one particular form of alternative energy over another. Centering teaching around phenomena such as alternative energy centers both the STEM issues and the social issues. *The People's Curriculum* for the Earth is a social studies curriculum that STEM educators in Washington State have begun to draw from to think about how to teach STEM within the context of a complex, unresolved societal issue and social phenomena.

The second major principle is addressing controversy and indoctrination. Talking about social issues in the STEM classroom seems out of bounds for many educators. However, it is important to understand that climate change is not a scientific controversy. While there may be some areas of the science and technology that emerge as undecided and lacking consensus, such as alternative energy, there is scientific consensus about the fact that climate change is human-caused. Therefore, the controversy is around social solutions, not climate science. If we accept that humans cause climate change, then we need to accept that humans must find solutions and that solutions often have economic, political, and social repercussions. These are the things that are controversial. If we don't acknowledge and name the economic, political, and social controversies in our teaching, then students get confused about where the controversy actually lies. As part of bringing these controversies into our classrooms, we need to address issues of equity because those social and historical understandings of past inequities are built into the system due to our use of petroleum products. For example, the environmental justice impacts that have long been documented in Cancer Alley in Texas and Louisiana caused by the petrochemical industry are now being amplified by climate change.

A third principle is age-appropriate climate learning. We cannot talk to a 7-year-old about climate change in the same way we would talk to an adult. Some resources for finding age-appropriate climate learning include Talk Climate, the Climate Literacy and Energy Awareness Network (CLEAN), and the STEM Teaching Tools developed at the University of Washington.

There is no universal curriculum resource for climate justice—instead learning needs to be contextualized for local places and social contexts in collaboration with community members and organizations. We often make assumptions about what a given community knows or is interested in, but instead of making these assumptions we need to engage in conversation with community members and organizations. This will help us center inquiry-based phenomena that they will be interested in investigating. Washington State's ClimeTime initiative provides "Portraits of Projects" and other Open Educational Resources (OERs) where you can find examples of how climate justice learning is being designed in and with the community to be adaptive to local contexts. The ClimeTime Portraits and OERs provide examples of the challenges faced by educators when engaging with local issues and communities and how they addressed those challenges. It is important to think about local context when teaching about climate justice, such as focusing on a green transition and jobs or regenerative agriculture or sustainability forestry rather than social justice in some regions.

It is also important that educators are supported to understand and implement culturally responsive learning practices. While no universal culturally responsive climate justice curriculum exists, it is important to provide resources for professional learning, climate change education, and community conversations. Learning in Places is rooted in indigenous knowledge and environmental justice, and have very helpful resources for elementary and secondary educators.

STEM Teaching Tools is funding teachers and community partners to write resources describing tips and resources for teaching about climate, how to work with community partners, and how to build supports with administrators and families. These resources are freely available online, to make sure that everyone has access to high-quality teaching materials (STEM Teaching Tools, 2022; Elmi et al., 2022). STEM Teaching Tools has pulled together Climate Learning Resources that are grounded in culturally-responsive and justice-centered pedagogies, including videos of seminars, into a single portal to make information easier to locate and use.

CLEAN provides an incredible breadth of resources and examples to learn about climate science, including principles of climate science literacy. CLEAN is building resources to help facilitate age-appropriate instruction, teacher learning about climate change, and student learning about climate change concepts. Talking about climate justice, learning climate science, and working with local communities to lift ways they are engaging in climate change mitigation and adaptation are all critical aspects of localized justice-centered climate learning.

There is an enormous amount of climate science to learn and professionals also need help in how to share climate information in ways that minimize emotional harm and empower learners. Talk Climate is a community organization that seeks to address this need. The Talk Climate community organization brings together educators, mental and medical health professionals, youth activists, artists, and climate scientists to create and share resources and publications on age appropriate ways for teachers, parents, and other professionals who work with young people, to share climate information with age and emotional development in mind.

Conclusion

Climate justice is justice for everyone on Earth. Finding a sustainable future where we are not at war with each other, where we have balance and equity, is our shared future. Justice is not something for someone else alone. It is our shared future. It is our students' future. We need to raise their awareness about the risks and vulnerabilities they will face, and empower them with the knowledge and tools they will need to adapt to and mitigate the climate crisis and nurture climate justice.

About the Authors

Sonya Remington Doucette is a sustainability leader at Bellevue College, where she is Chair of the Sustainability Curriculum Committee and the Sustainability Concentration Coordinator. She is the author of Sustainable World: Approaches to Analyzing and Resolving Wicked Problems (2017), which is used by institutions at the cutting edge of sustainability in higher education Prior to BC, she was a Senior Lecturer in the School of Sustainability at Arizona State University. She has also conducted sustainability education research at ASU. Two of her manuscripts were highly commended as Outstanding Papers in the International Journal of Sustainability in Higher Education's Annual Awards for Excellence. From 2008 -10, she was a post-doctoral teaching fellow in the Program on the Environment at the University of Washington. She began her academic sustainability career in 2007 when she became active in the Curriculum for the Bioregion (C4B) initiative at Evergreen State College. C4B seeks to infuse sustainability into all curricula, in all disciplines, at institutions of higher education in Washington State.

Heather U. Price earned her Ph.D. in Analytical and Environmental Chemistry studying the long-range transport and photochemistry of air pollution. Her postdoctoral atmospheric chemistry research was conducted with the Program on Climate Change at University of Washington, incorporating the isotopes of hydrogen into a global chemical transport model of the atmosphere. She has developed a number of courses on climate change: for undergraduate students at UW, a summer program for high school students, continuing science education courses for elementary and 6-12 grade teachers. Her latest research and teaching focus is the development of short courses and workshops for faculty to help them incorporate climate justice with civic and/or community engagement into their existing STEM, arts, and humanities curriculum. She is also on the leadership team of the Seattle 500 Women Scientists organization and is co-founder of the climate resources community hub, TalkClimate.org.

Deb L. Morrison works at the intersection of justice, climate science, and learning. She is a climate and anti-oppression activist, scientist, learning scientist, educator, mother, locally elected official, and many other things besides. Deb works in research-practice-policy partnerships from local community to international scales. She works to iteratively understand complex socio-ecological systems through design-based and action oriented research while at the same time seeking to improve human-environment relationships and sustainability. Dr. Morrison draws on an eclectic range of justice theory to inform her work in the world and to foster her continued journey for transformative liberation. She is a well-published author on diverse topics that intersect with climate justice learning and continues to foster collaborative writing partnerships across disciplines and communities that have historically been disconnected. Information about Dr. Morrison's work can be found at www.debmorrison.me.

Irene Shaver is the newly appointed Program Manager of the Climate Solutions Program at the Washington State Board of Community and Technical Colleges. The program focuses on climate solutions education across the curriculum, green workforce development, and making our colleges more sustainable. This program has several opportunities this year for community and technical colleges to deepen their work in sustainability and climate education that she will share. Shaver spent six years at Bellevue College working as a program manager for undergraduate research, and also was a high school teacher in Idaho, and worked at the Institute of Community Research in Connecticut as a program coordinator. She earned her doctorate in environmental science and sociology from the University of Idaho.

References

Climate Literacy and Energy Awareness Network (CLEAN). (2022). https://cleanet.org/index.html

ClimeTime. (2022). *Climate Science Learning Initiative*, https://www.climetime.org/

Elmi, I., Harper, T., Slade, M., & Price, H. (2022). *Let's Talk Climate! Bridging Climate Justice Learning and Action Across School, Home, and Community*, STEM Teaching Tool #84, , Seattle, WA: Institute of Science and Math Education, University of Washington, Retrieve from: https://stemteachingtools.org/brief/84

First National People of Color Environmental Leadership Summit. (1991). *The Principles of Environmental Justice (EJ)*. Defined by delegates to the summit held October 24027, 1991 in Washington, DC. Retrieve from: https://www.ejnet.org/ej/principles.pdf

Hammond, Z. (2020). *A conversation about instructional equity with Zaretta Hammond*, Collaborative Classroom, Retrieve from: https://www.collaborativeclassroom.org/blog/instructional-equity-with-zaretta-hammond/)

Hammond, Z. (2015). *Culturally Responsive Teaching and the Brain: Promoting Authentic Engagement and Rigor Among Culturally and Linguistically Diverse Students*, Thousand Oaks, CA: SAGE Publications.

International Climate Justice Network. (2002) *Bali Principles of Climate Justice*. Created by delegates to the preparatory meeting for the Earth Summit held in Bali, Indonesia, August 2002. Retrieved from: https://www.corpwatch.org/article/bali-principles-climate-justice

Jaquette Ray, S. (2020). *A Field Guide to Climate Anxiety: How to Keep Your Cool on a Warming Planet*, Oakland, CA: University of California Press.

Mary Robinson Foundation. (2011). *Principles of Climate Justice*, Adopted by the Mary Robinson Foundation in August 2011, Retrieve from: https://www.mrfcj.org/principles-of-climate-justice/

McGee, E., & Bentley, L. (2017). The Equity Ethic: Black and Latinx College Students Reengineering Their STEM Careers Toward Justice, *American Journal of Education*, 124: 1-36.

Muñiz, J. (2020). *Culturally Responsive Teaching: A Reflection Guide*, Policy Paper, New America, Retrieve from: https://www.newamerica.org/education-policy/policy-papers/culturally-responsive-teaching-competencies/

National Research Council. (2012). *A Framework for K-12 Science Education, Next Generation Science Standards*. https://www.nextgenscience.org/framework-k-12-science-education

National Science Teaching Association. (2021). Climate Change (Special Issue), *Connected Science Learning*, 3(5), Retrieve from: https://www.nsta.org/connected-science-learning/connected-science-learning-september-october-2021

Patterson Williams, A., & Gray, S. (2013). *Social justice issues as phenomena*. Next Generation Science Standard panel discussion, Retrieve from: https://www.youtube.com/watch?app=desktop&v=IkiF-qDqUx4

Pew Research Center. (2022). Younger evangelicals in the U.S. are more concerned than their elders about climate change. Retrieve from: https://www.pewresearch.org/fact-tank/2022/12/07/younger-evangelicals-in-the-u-s-are-more-concerned-than-their-elders-about-climate-change/

Pew Research Center. (2020). Millenial and Gen Z Republicans stand out from their elders on climate and energy issues. Retrieve from: https://www.pewresearch.org/fact-tank/2020/06/24/millennial-and-gen-z-republicans-stand-out-from-their-elders-on-climate-and-energy-issues/

Remington Doucette. S. (2021). *Hope is Not Optional: Managing Emotions in a Changing World, A Climate Justice Case Study*, Bellevue College Opening Day Session, Retrieve from: https://www.youtube.com/watch?v=hYZe1fB4mE4

Remington Doucette, S. (2022). *Systems thinking and civic engagement for climate justice in General Chemistry: CO2 and PM 2.5 pollution from coal combustion*, Curriculum for the Bioregion Activity Collection, Science Education Resource Center (SERC), Carleton College, Retrieve from: https://serc.carleton.edu/bioregion/examples/247629.html)

Rethinking Schools. (2014). *A People's Curriculum for the Earth: Teaching Climate Change and the Environmental Crisis*, B. Bigelow & T. Swinehart (Editors). Portland, OR: A Rethinking Schools Publication, Retrieve from: https://rethinkingschools.org/books/a-people-s-curriculum-for-the-earth/

SERC. (2022). *Carleton College Science Education Resource Center*, https://serc.carleton.edu/index.html

Seymour, E., & Hunter, A.B. (2019). *Talking About Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education*. Switzerland: Springer Nature.

Seymour, E., & Hewitt, N. M. (1997). *Talking About Leaving: Why Undergraduates Leave the Sciences*, Boulder, CO: Westview Press.

STEM Teaching Tools. (2022). *Teaching Tools for Science, Technology, Engineering and Math (STEM) Education*, Retrieve from: https://stemteachingtools.org/

Talk Climate. (2022). Retrieve from: https://talkclimate.org/

Wang, Y. & G. Jackson. (2005). Forms and Dimensions of Civic Involvement, Michigan Journal of Community and Service Learning, Spring 2005 Issue, Retrieve from: https://files.eric.ed.gov/fulltext/EJ848471.pdf

Washington State Board of Community and Technical Colleges. (2022). *Climate Solutions Program*. Retrieve from: https://www.sbctc.edu/colleges-staff/grants/climate-solutions

Weston, T., Seymour, E., & Thirty, H. (2006) Evaluation of Science Education for New Civic Engagements and Responsibilities (SENCER) Project. Retrieve from: http://sencer.net/wp-content/uploads/2016/09/FINAL_REPORT_SENCER_12_21_06.pdf

Acknowledgement

Much of this work was funded by an NSF IUSE grant (NSF DUE 2043535).

Sustainability Education and Civic Engagement through Integration of Undergraduate Research with Service Learning

GUANG JIN
Department of Health Sciences, Illinois State University

THOMAS BIERMA
Department of Health Sciences, Illinois State University

Abstract

Integrating service learning with undergraduate research, the student biodiesel project converted all waste vegetable oil (WVO) from campus dining centers into a sustainable biofuel used by campus vehicles, allowing half of the campus diesel energy needs to be met by a material (WVO) that was formerly a waste. Biodiesel reduced air pollution from campus diesel vehicles, including the emission of greenhouse gases. This project connected students to their community and increased students' awareness of the *social/economic* aspects of environmental challenges in the world around them. Students felt a *great sense of responsibility to make a real product that would make a difference* in the real world. Students who participated in the research course became teaching assistants for another regular course in which biodiesel production was a component. This allowed biodiesel to be produced sustainably and provided additional students with hands-on bioenergy experience. Specific challenges and suggestions for future practices are also reported.

Introduction

Sustainably harnessing biomass and converting it into usable fuels (bioenergy) is a critical part of combating climate change and addressing other environmental problems associated with fossil fuels. The success of bioenergy depends upon well-informed professionals, consumers, and citizens. Universities play a unique role in addressing climate change and creating a sustainable society through demonstrating best practices, researching solutions to real-world problems, educating future communities and leaders, and promoting sustainability (Brundiers et al., 2010; Bacon et al., 2011; Barth et al., 2014; Ralph & Stubbs, 2014; Evans et al., 2015; Moura et al., 2021).

Producing biodiesel fuel from campus waste fryer oil offers an outstanding opportunity for bioenergy education and civic engagement through community service. Biodiesel is a clean-burning, renewable substitute for petroleum diesel that can be manufactured from new and used vegetable oils, animal fats, and waste restaurant grease. Using biodiesel as an alternative petroleum diesel reduces lifecycle carbon emissions (U.S. Department of Energy [US DOE], 2017) and the emission of harmful air pollutants such as asthma-causing soot (U.S. Environmental Protection Agency [US EPA], 2018). Waste fryer oil retains almost all its energy content even after it is discarded from cooking. Illinois State University (ISU) creates about 6000 gallons per year of waste vegetable oil (WVO) that the university must pay to dispose. If properly treated, this WVO can be used to make biodiesel. Producing biodiesel fuel from campus waste fryer oil presents several advantages as a bioenergy and sustainability education topic (Christiansen, 2008; Jin & Bierma, 2013) because

1. It converts a waste into a valuable product.
2. It involves a feedstock that is very familiar to students (fryer oil).
3. The fuel can be utilized to operate campus vehicles.
4. It provides opportunities to educate the campus as well as local communities about bioenergy and sustainability.

In this paper, we present our experience of a campus biodiesel project where students who were enrolled in the undergraduate research course at ISU converted WVO from campus dining centers to biodiesel fuel used in university vehicles. Students who participated in the undergraduate research course were later recruited as paid teaching assistants for another regular course in which biodiesel production was a component. This allowed biodiesel to be produced continuously and provided additional students with hands-on bioenergy experience. This project is unique in that it is completely student-driven, student-run and financially sustainable once the initial capital cost is in place, whereas other similar projects require full-time personnel, paid from a separate budget (Christiansen, 2008; Waickman, 2022).

Project Description and Outcomes

The student biodiesel project began a few years ago as an idea of environmental health (EH) students and faculty. The EH undergraduate curriculum has an elective research course with variable hours (1–3 credits). After successfully completing this course, students should be able to

- use library and other tools to search for existing body of research relevant to a given research topic,
- collect and analyze data using appropriate techniques,
- apply problem-solving skills to constructively address research setbacks, and
- communicate research to others in the field and to broader audiences through presentations.

We integrated this research course with service learning and civic engagement in mind by guiding students through producing biodiesel fuel from campus waste vegetable oil (WVO). Learning activities included sampling and analyzing WVO from campus dining centers (Figure 1); producing and testing small-scale (1-gallon) batches of biodiesel; researching large-scale (50- gallon) biodiesel production technology; producing and testing large-scale batches of biodiesel (Figure 2); researching recovery technology of methanol and glycerin from biodiesel glycerin waste; designing and building a solar-powered methanol and glycerin recovery unit; and presenting research findings in classrooms as well as community outreach activities.

FIGURE 1. Students Sampling and Analyzing WVO

FIGURE 2. Students Producing Biodiesel

Faculty worked closely with students throughout the undergraduate research course with a typical enrollment of 8–10 EH students each semester (about 60% females). In addition, faculty had weekly classroom meetings with students to discuss literature and data interpretation and analysis and to brainstorm with students on problem-solving ideas when there were research setbacks; faculty also worked with students in the lab and field to troubleshoot process/equipment. Students formed a close relationship with faculty in this course, evidenced by frequently dropping by during faculty office hours to discuss academic and career plans.

After several semesters of efforts, biodiesel has been produced in 50-gallon batches and has received American Society of Testing Methods (ASTM) certification. Approximately 6,000 gallons of biodiesel have been produced per year and have been used in a variety of campus diesel vehicles.

Students in this undergraduate course also hosted tours and demonstrations for junior high and high schools in the community. Signs on the truck, as well as in dining halls, have educated ISU students about the waste-to-fuel practice on campus. News media coverage educated the community about local bioenergy and sustainability practices (Figure 3). Biodiesel production has also become part of another regular course called Renewable Energy and Agriculture (AGR 225). Students in the three STEM majors (about half females) typically take AGR 225 in their junior and senior years. ISU students

FIGURE 3. Students Doing Education Outreach Activities

who participated in the undergraduate research course were recruited as paid teaching assistants for AGR 225 providing approximately 30–50 students per year with hands-on bioenergy experience while allowing continuous production of campus biodiesel fuel.

Student Feedback

Student feedback was collected from standard college course evaluation with one open-ended question: "Write a short paragraph about your experience with the biodiesel project. How did this experience influence your connection to the community?" In addition, instructors' observations of student comments during the biodiesel production process, classroom discussions, and education outreach activities are also presented as anecdotal evidence.

In the standard college course evaluation, students were asked to rate in a Likert scale of 1 to 5 with 5 being the highest score. Over 90% students rated their progress on relevant course objectives as 4 or 5. All students rated learning to apply knowledge and skills to benefit others or serve the public goods as 4 or 5.

In addition, students felt a *great sense of responsibility* to *make a real product* (i.e. biodiesel fuel) that had to pass a fuel quality control test run by themselves … and when it didn't, they had to figure out what went wrong and *how to fix it*! It was a lot of work, but students felt *inspired to do it* and it felt *rewarding to help people in the wider community*. Students also feel that they are more aware of *community needs* and have a deeper understanding of the social and economic impact of environmental problems on *a community*. Students felt *strongly connected to the local community*, because they *took actions and were able to serve* the local community.

Discussion and Suggestions for Future Practice

Integrating service learning with undergraduate research, the student biodiesel project allowed half of the campus diesel energy needs to be met by a material (WVO) that was formerly a waste (N. Stoff [Illinois State University Facilities Management], personal communication, July 31, 2018), an example of greater sustainability through resource-conserving technologies and practices. Biodiesel reduced air pollution from campus diesel vehicles, including the emission of greenhouse gases. This project allowed students to learn basic laboratory and research skills and apply them in a campus sustainability challenge, connected students to their community, taught civic responsibility, and increased students' awareness of the *social/economic* aspects of environmental challenges in the world around them. Students felt *empowered* by being trusted to work on a research project that is *meaningful* and *important* because it is *real* research and *makes a difference* in the real world. Students developed a profound personal attachment to achieving positive change in both the environment and their communities. These student outcomes were consistent with many studies that showed that service learning resulted in gains in academic engagement (Covitt, 2006; Mpofu, 2007), self-efficacy and interpersonal and problem-solving skills (Chen et al., 2018; Bielefeldt & Lima, 2019), civic responsibility and attitudes toward community service (Kahne & Sporte, 2008; Manning-Ouellette & Hemer, 2019).

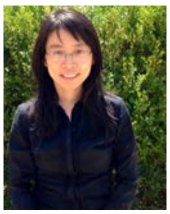
The student biodiesel project leveraged funding and support from several sources to establish biodiesel production on campus. Besides a gift from the Omron Foundation and a grant from ISU Student Sustainability Fund, space in the department of agriculture shop was provided for production without charge. A used pickup truck for WVO collection was donated by the university. Finally, ISU purchased our biodiesel at market price. This revenue paid for materials and supplies, student teaching assistants, and recapitalization of equipment, with the result that biodiesel production on campus was financially self-sustaining.

Specific challenges encountered in this project included substantial initial capital investment, the requirement for campus-wide support in infrastructure and logistics, and the fact that financial self-sustainability of the project was subject to changes in the price of materials, product/ biodiesel as well as labor cost of student teaching assistants. Despite the challenges, we believe this type of service-learning on university campuses presents great opportunities for sustainability education and civic engagement through community service.

Our next steps will be seeking methods to make the process more labor efficient, recover more methanol, and find a way to generate more revenue from glycerin, for example by using it to make soap. We will also seek donations of WVO from local small business to increase our biodiesel output to further serve the local community.

Institutions with limited resources could implement an adapted form of the project such as Biodiesel on Wheels, where a flatbed trailer could be used to house all components required for making biodiesel. This setup requires much less space and fewer resources but could produce good-quality biodiesel from campus WVO, and it could be used as an excellent community education outreach tool.

About the Authors



Guang Jin (Sc.D. in Environmental Health Sciences) is Professor of Environmental Health & Sustainability in the Department of Health Sciences at Illinois State University, with areas of expertise and experience in pollution prevention, biomass energy, and sustainability. She is passionate about student engagement in STEM and about innovative pedagogies to enhance learning.

Thomas Bierma (Ph.D. in Public Health) is Emeritus Professor of Environmental Health & Sustainability in the Department of Health Sciences at Illinois State University, with research experience in sustainable business practices, bioenergy, waste management, and pedagogy for higher education.

References

Bacon, C. M., Mulvaney, D., Ball, T. B., DuPuis, E., Gliessman, S. R., Lipschutz, R. D., & Shakouri, A. (2011). The creation of an integrated sustainability curriculum and student praxis projects. *International Journal of Sustainability in Higher Education*, 12, 193–208.

Barth, M., Adomßent, M., Fischer, D., Richter, S., & Rieckmann, M. (2014). Learning to change universities from within: A service-learning perspective on promoting sustainable consumption in higher education. *Journal of Cleaner Production*, 62, 72–81.

Bielefeldt, A. R., & Lima, M. (2019). Service-learning and civic engagement as the basis for engineering design education. In Nur Md. Sayeed Hassan and Sérgio António Neves Lousada (Eds.), *New innovations in engineering education and naval engineering* (pp. 17–36). INTECHOPEN LIMITED. http://dx.doi.org/10.5772/intechopen.83699

Brundiers, K., Wiek, A., & Redman, C. L. (2010). Real-world learning opportunities in sustainability: From classroom into the real world. *International Journal of Sustainability in Higher Education*, 11, 308–324.

Chen, T., Snell, R. S., & Wu, C. X. (2018). Comparing the effects of service-learning versus nonservice-learning project experiences on service leadership emergence and meaning schema transformation. *Academy of Management Learning & Education*, 17(4), 474–495.

Christiansen, R. C. (2008, September 16). Biodiesel on campus. *Biodiesel Magazine*. https://biodieselmagazine.com/articles/2774/biodiesel-on-campus

Covitt, B. (2006). Self-determination and student perceptions in environmental service-learning. *Applied Environmental Education & Communication*, 5(3), 171–181.

Evans, J., Jones, R., Karvonen, A., Millard, L., & Wendler, J. (2015). Living labs and co-production: University campuses as platforms for sustainability science. *Current Opinion in Environmental Sustainability*, 16, 1–6.

Jin, G., & Bierma, T. (2013). STEM for non-STEM majors: Enhancing science literacy in large classes. *Journal of College Science Teaching*, 42(6), 20–26.

Kahne, J. E., & Sporte, S. E. (2008). Developing citizens: The impact of civic learning opportunities on students' commitment to civic participation. *American Educational Research Journal*, 45(3), 738–766.

Manning-Ouellette, A., & Hemer, K. M. (2019). Service-learning and civic attitudes: A mixed methods approach to civic engagement in the first year of college. *Journal of Community Engagement & Higher Education*, 11(3), 5–18.

Moura, P., Moreno, J. I., López, L. G., & Alvarez-Campana, M. (2021). IoT platform for energy sustainability in university campuses. *Sensors*, 21, 357–378.

Mpofu, E. (2007). Service-learning effects on the academic learning of rehabilitation services students. *Michigan Journal of Community Service Learning*, 14(1), 37–49.

Ralph, M., & Stubbs, W. (2014). Integrating environmental sustainability into universities. *Higher Education*, 67, 71–90.

U.S. Environmental Protection Agency (US EPA). (2018). *Biofuels and the environment: Second triennial report to Congress*. EPA/600/R-18/195F

U.S. Department of Energy (US DOE). (2017). *Biodiesel basics*. DOE/GO-102017-5048

Waickman, Z. (2022) Loyola University Chicago Senior Program Manager, School of Environmental Sustainability, Personal communication, October 24, 2022.

Mathematics Preparatory Workshops to Foster Student Success

SANDIE HAN
New York City College of Technology

DIANA SAMAROO
New York City College of Technology

JANET LIOU-MARK
New York City College of Technology

LAURI AGUIRRE
New York City College of Technology

Abstract

Mathematics preparatory workshops were offered to college students at a diverse urban undergraduate institution. The goal was to prepare students for their mathematics course, by offering non-credit bearing and free preparatory workshops. The lack of adequate preparation for mathematics courses is a barrier for student engagement in future STEM courses. We believe that by providing preparatory workshops, we can improve not only the success but access for students in foundational mathematics courses. The workshops allowed students to engage with the course content in a rigorous and intensive manner prior to the start of the semester. Students who participated in the workshops are more likely to be better prepared when enrolled in the credit-bearing course.

Introduction

New York City College of Technology (City Tech), a designated Hispanic-Serving Institution in an urban metropolitan area, provides education in science, technology, engineering, and mathematics (STEM) to a diverse student population. As of fall 2021, the student ethnicity/demographics at the college were 34.1% Hispanic students, 26.8% African American, 20.9% Asian, 11.4% White, 4.0% Nonresident alien, 2.2% two or more races, 0.4% American Indian or Alaskan Native and 0.2% Native Hawaiian or Pacific Islander. As a primarily undergraduate institution, the college offers associate and bachelor's degree programs. Some associate degree programs serve as a pathway towards a bachelor's degree with the advantage of enabling students to take prerequisite and developmental courses. Often referred to as "two plus two" (two-year associate and two-year bachelor's), this model enables students to start in an associate degree program while taking prerequisite and developmental courses and continue into the bachelor's program. This model provides a path for students to enter a STEM program even if there are gaps in their mathematics and science coursework in high school.

The college's mission is to prepare students for applied and technical careers by providing access to opportunities which include interdisciplinary and 'place-based learning'. Celebrating its 25th year as a Hispanic Serving Institution, the college fosters practices which promote equity for its diverse student population (City Tech, n.d). Furthermore, students are often engaged in high impact practices, such as undergraduate research, which can focus on community-based or local issues, such as water quality (Galford, 2017; Samaroo, 2022) or integration of STEM into the elementary school curriculum (Samaroo, 2018), alongside other projects that include peer led team learning (Han, 2022).

The mathematics department at our college offers more than two hundred sections of mathematics classes, with two-thirds of them considered gateway[1] classes to a student's chosen degree path. These include quantitative reasoning, college algebra and trigonometry, precalculus, calculus 1 and calculus 2, and are taken by 4,000-5,000 students every semester. In STEM disciplines, this often results in a lengthy sequence of courses where one is a prerequisite to the next. Worse yet, these courses are often ranked among the most failed courses at the institution. Gateway mathematics courses with high failure rates is likely to deter students in their STEM pursuit, leading to high attrition and low graduation (Sithole, 2017).

The preparation of students for college courses is more problematic than ever due to the well-documented learning loss experienced by students in recent years (Gordon, 2021; Moscoviz, 2022). One of the key areas of significant learning loss is in mathematics (NEA, 2022). The problem also points to increased inequity in access to quality education during the pandemic among underrepresented minorities and underserved populations (NEA, 2022). Examining the demographics found that minority students and students with financial needs tended to be those starting at developmental level or needing prerequisite content support (Attewell, 2006; Logue 2016).

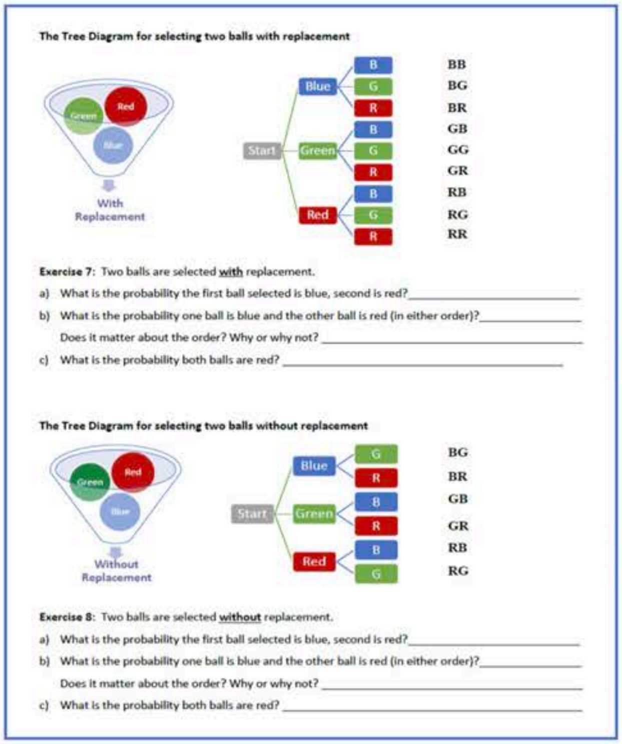
Recognizing that mathematics is the foundation of any STEM program, and that student success and timely completion of prerequisite mathematics courses strongly impact their ability to complete the STEM major (Frost, 2017), we implemented at our institution low-stakes, high-impact preparatory workshops designed to help bridge the learning gaps. In literature review, we found only few articles reporting on "preparatory workshops", "bootcamps" or "bridge programs". Most reported that there is a strong need to prepare and support students especially in the first year of college (Alavi, 2020; Campbell, 2015; Frost, 2017; Jura, 2022; Reisel, 2014). Some bridge programs range from three to four weeks. Clune et al. reported on the success of a mathematics bootcamp for graduate students (2022). Such programs, whether workshops or bootcamps, benefit students beyond the subject matter; they help provide study skills, critical thinking, college resource awareness, and they are important in the transition and the mental preparation for college (Alavi, 2020; Jura, 2022). The goal of this paper is to disseminate the work from our mathematics preparatory program for undergraduate students and to provide a model for practitioners.

Workshop Design

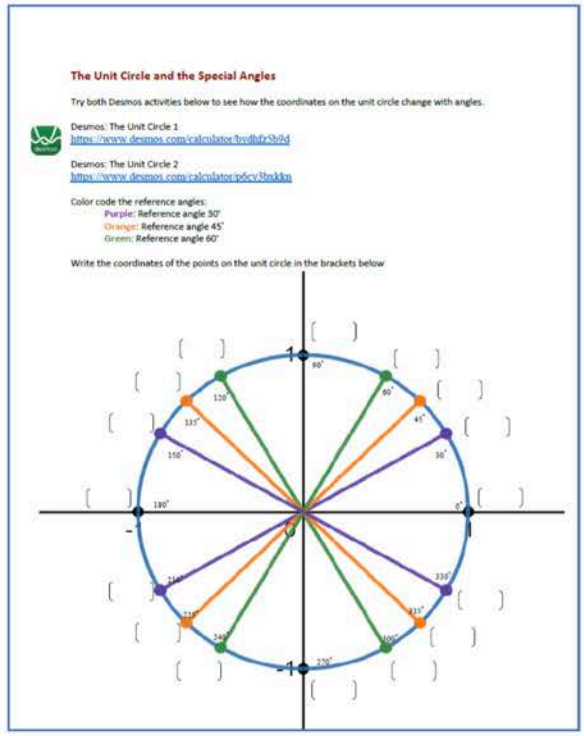
The key goal for our preparatory workshop is to improve student success in mathematics courses. We identified those courses that are gateway in degree programs and designed a week-long workshop to provide a review of the prerequisite materials and an introduction to the course. The typical design of the workshop is for four

1 We define gateway mathematics courses as the foundational courses students need to complete in their first year of studies for a specific degree program. These courses can also be a pre- or co-requisite to other major courses required for a degree. For example, calculus is a prerequisite to certain engineering courses at our college. Calculus can also be considered a gateway course in the Applied Mathematics major, for example, as it is the first required course in a sequence of courses for that degree.

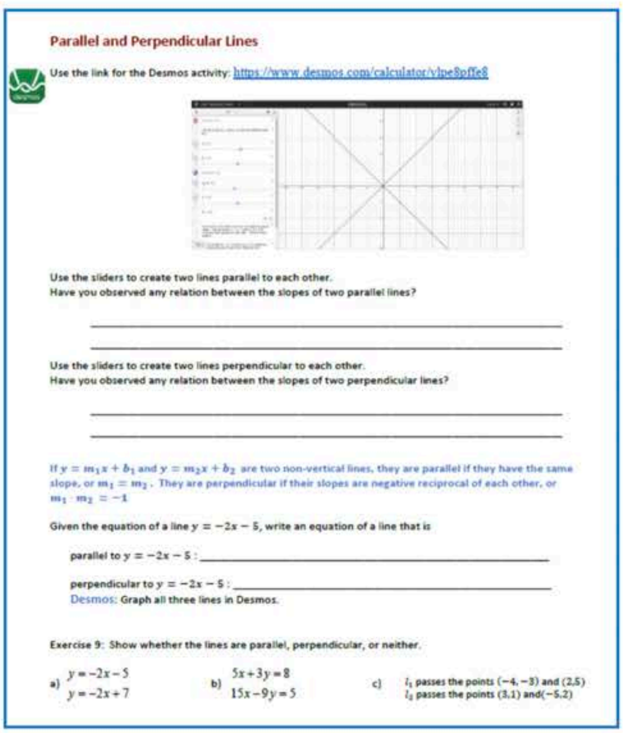
FIGURE 1. Samples of Workshop Materials



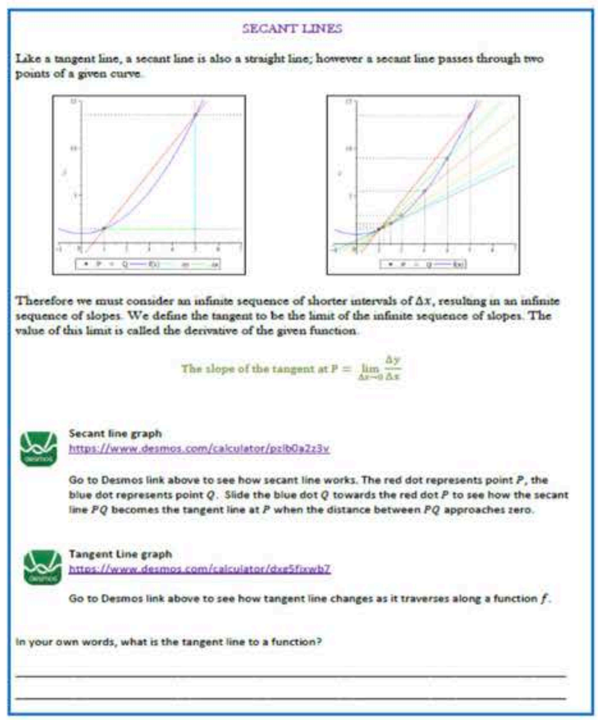
Quantitative Reasoning: Demonstrating the concept of probability with or without replacement



Trigonometry: Introducing unit circle using Desmos and the color-coding of the special angles



College Algebra: Observing the relations of parallel and perpendicular lines using Desmos



Calculus: Introducing the concept of tangent line by observing the changes in secant line graphs on Desmos days at three hours a day for a total of twelve hours. For our college algebra and trigonometry with corequisite, designed for students with greater needs for remediation and reviews, we offer a slightly longer workshop for five days at three hours a day for a total of fifteen hours. The workshops are strategically scheduled right before the beginning of the semester (in summer, August and in winter, January), so students would be motivated and mentally ready on the first day of class.

The workshops are low stakes in the sense they do not bear any credits or grades, and are completely voluntary and open to all students. At our institution, the workshops are funded by First Year Programs and are offered free of cost to students. Recruitment for the workshops is through college email announcement, recommendations by the instructors or departments, or through First Year Programs and other support services. There is a required registration process for the workshop which allows us to identify the students and follow their progress in the semester.

In designing the workshops, we considered the following aspects:

- **Content support.** Each workshop is specifically designed to prepare students for a particular course. A corresponding workbook is created for each workshop to provide the content materials which include prerequisite review as well as introductory topics that students may see again in the course. The workshop instructors are recruited from among the mathematics faculty, typically those with experience teaching the course.
- **High-impact pedagogies.** High-impact active learning pedagogies are incorporated into the workshop and the workbook design, such as exploratory learning, collaborative learning, hands-on problem-solving, real-world applications, and the use of visualization for the demonstration of concepts (Abate, 2022; Presmeg, 2006).
- **Peer-support system.** The peer-led team learning (PLTL) is an important component of the support system where peer leaders recruited from among the upper-class students in various STEM majors to support and facilitate either one-on-one learning or group discussions in the workshops (Liou-Mark, 2015). Another importance of the PLTL program is the "role modeling" impact by the peer leaders whom we made strong efforts to recruit from women and underrepresented minorities.
- **Equitable and inclusive access.** The workshop design considers academic, financial, and emotional support in providing equitable and inclusive access, adopting high impact strategies to support women and underrepresented minority students. The pedagogical strategies mentioned above, as well as tuition-free workshops, the open-access resources, the PLTL support, and the use of visualization in the workbook design are all aiming to increase learning opportunities and reduce challenges.

Developed over the years, we have expanded our workshops to support six mathematics courses. Other than Quantitative Reasoning, which is considered the gateway mathematics for non-STEM majors, the other five courses are part of the STEM sequence required by engineering, mathematics, computer science, and some sciences such as computational physics and applied chemistry. Students who begin their mathematics with college algebra (based on college placement exams), often face a lengthy mathematics sequence. The college algebra course is the most enrolled course in the mathematics department. We present below a brief description of each course and its corresponding workshop:

1. **Quantitative Reasoning** is a course designed for non-STEM majors who need a review of equations, problem-solving and basic probability, and statistics. The workshop incorporates real-world data such as COVID-19 or Census data which are relevant to students and their communities.
2. **College Algebra and Trigonometry with Corequisite** is a course with additional hours of corequisite support designed for students who can benefit from additional algebra review. For many STEM majors, this is the first of their STEM mathematics sequence. The workshop starts with a review of elementary and intermediate algebra topics with emphasis on addressing common mistakes and pitfalls.
3. **College Algebra and Trigonometry,** same as (2) above, is the first of STEM mathematics sequence. The workshop puts greater emphasis on introduction to trigonometry because students tend to have difficulties with trigonometric concepts.

4. **Precalculus.** The workshop focuses on the studies of functions and their characteristics using graphs and visualization tools such as Desmos.
5. **Calculus I.** The workshop incorporates numerous graphs and visualizations to demonstrate the related concepts. The workshop provides "just in time" review of algebra.
6. **Calculus II.** The workshop focuses on both concepts and techniques, as well as provides "just in time" review of algebra and trigonometry needed in integration.

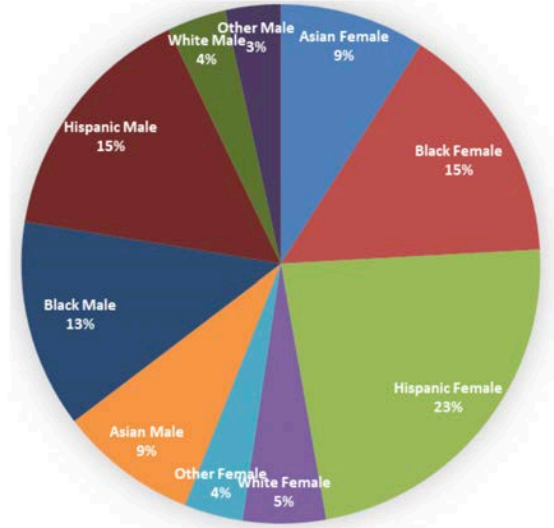
The freely accessible corresponding workbooks focus on concept understanding through visualization, hands-on problem solving, and real-world applications. The design of the curriculum offers targeted lessons that anticipate the immediate needs of the student providing relevant review materials with new content. This not only helps review a topic but also applies it right away in problem-solving. Below, we share some sample workbook materials.

Effectiveness of the Workshops

Presented in this section is a summary of findings from the workshops offered in summer 2019, summer 2020, and summer 2021. The workshops were in person in summer 2019 and online in summer 2020 and 2021. Of the total 464 participants in the workshops, 417 registered for the corresponding courses in the Fall semester immediately after the workshops, while the remaining 47 students either did not take math in the immediate semester or took a course different from the workshop in which they participated. These 47 students were included in the demographic data but excluded from the grade distribution data.

1. The demographic data of the workshop participants from summer 2019, 2020, and 2021 shows that 56% were female, and 73% were African American, Hispanic, or other (Native American, Pacific Islander, two or more races). These numbers are significant compared with the institution's enrollment data which consists of 46% women and 67.7% African American, Hispanic, and other (Figure 2). Given that

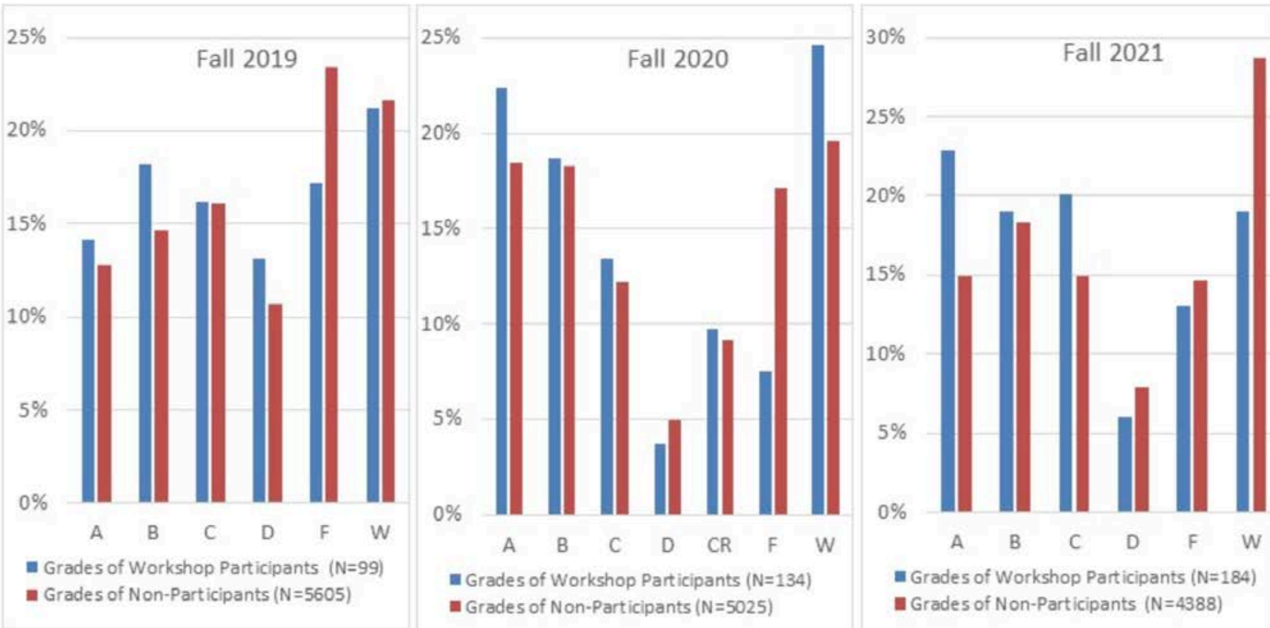
FIGURE 2. Demographics of Workshop Participants During Summers 2019, 2020, 2021 (N=464)



registration for the workshop is voluntary and self-selected, the high participation rate among women and underrepresented minority groups, particularly Hispanic and African American women and men, suggests the preparatory workshops respond to the needs of women and underrepresented minority students for learning support.

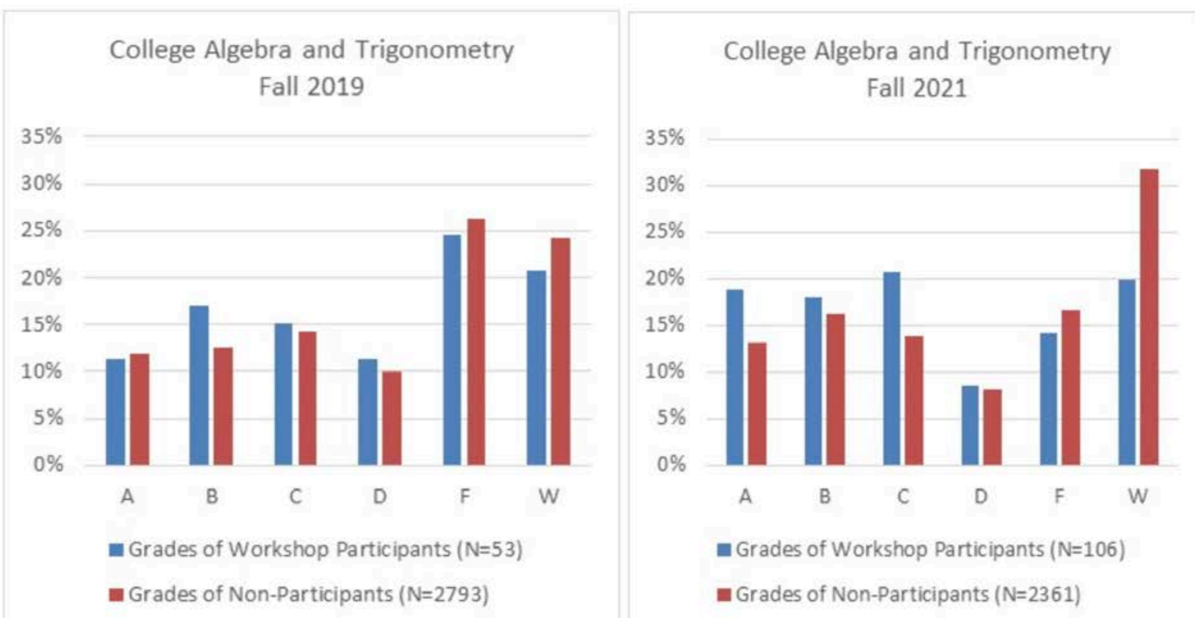
2. The grade distribution comparison indicates that students who participated in the workshop generally had a higher percentage of A, B and C grades and a lower percentage of failure (F grade) in the corresponding course as compared to students who did not participate in the workshops (see Figure 3). Overall, 56% of the workshop participants earned a grade of A, B, or C in the corresponding course in the immediate semester after the workshop.
3. While we had hoped workshop participants would show a lower withdrawal rate (W grade), a possible explanation for the higher withdrawal rate observed in Fall 2020 may be due to the special allowance for Credit (CR) and No Credit (NC) grades during the pandemic semesters. The college data grouped NC with F, rather than W grade, which may have resulted in skewed F and W grade distribution.
4. Using Chi square test to see if there is a significant difference in the grade distribution pattern of the workshop participants compared to the non-participants, we found no significant difference in the Fall 2019 and

FIGURE 3. Grade Distribution Comparison of Workshop Participants versus Non-Participants in the corresponding courses during the Fall semesters.[1]



[1] (City Tech Office of Assessment, Institutional Research & Effectiveness (AIRE), http://air.citytech.cuny.edu/data-dashboard/)

FIGURE 4. Grade Distribution Comparison of Workshop Participants versus Non-Participants in College Algebra and Trigonometry (with or without corequisite) (Fall 2019 and Fall 2021)[1]



[1] (City Tech Office of Assessment, Institutional Research & Effectiveness (AIRE), http://air.citytech.cuny.edu/)data-dashboard/data-dashboard/)

Fall 2020 data; but there is significant difference in the Fall 2021 data.

5. In desegregated comparison, students who participated in the workshops for College Algebra and Trigonometry (including both the extended course with corequisite and the regular course without the corequisite) showed a higher percentage in earning A, B, C grades and a lower percentage of earning F and W grades. See Figure 4, which also provides a pre-pandemic (Fall 2019) and post-pandemic (Fall 2021) comparison for the same course. The post-pandemic data shows an exceedingly high withdrawal rate (32%) among students who did not participate in the workshops.

6. The participation rate of the workshop among registered students in the course has increased from 1.7% in Fall 2019 to 2.6% in Fall 2020 and to 4.0% in Fall 2021. This seems to indicate that more students feel the need for course review and learning support. We think changing the workshop to the online format in 2020 and 2021 may have contributed to the increased participation. Students have also indicated that they preferred online workshops.

At the conclusion of the winter 2022 preparatory workshops, students were asked for (voluntary) feedback. Of the 55 students who responded, a significant majority agreed or strongly agreed that the workshop was helpful. Overwhelmingly, students strongly agreed that the instruction was helpful, an indication that students connected with the instructor despite this being a short one-week program.

We also asked the workshop instructors to gauge their student response or receptiveness towards the workbook; they reported positive responses and that the visual activities and graphs from the workbooks were very helpful. Regarding student engagement, instructors reported that students were actively engaged. One instructor commented, "Best online workshop that I've taught."

Conclusion

Student access to the preparatory workshops described in this paper seems to show an increase in student success in mathematics courses. Students who participate in preparatory workshops are more likely to be better prepared and show better results when taking the credit bearing course. In addition, these students are taking responsibility for their own learning since participation in the non-credit bearing workshops is completely voluntary. The preparatory workshop offered at our college focuses on bridging learning gaps in mathematics, however, this should not be exclusive to mathematics. Preparatory workshops in other first-year courses can be just as beneficial, especially those in STEM requiring foundational knowledge, such as chemistry, biology, or writing.

We share this work because it is low stakes with measurable impact and can be easily replicated for colleges who seek to address equity in student learning. We summarize additional benefits here for those who consider designing and implementing a preparatory workshop:

- A preparatory workshop may be offered in targeted discipline support based on needs.
- A preparatory workshop is easy to develop and flexible in length. The workshops may range from a few hours of review to a more extensive course prep.
- A preparatory workshop not only helps students review for a course, but it also helps prepare students with college readiness skills and mental state.
- The cost-benefit analysis shows a preparatory workshop before the semester is an efficient way to support students on a limited budget.
- Since there is no requirement for grades, the curriculum can be more creative and customized to students' skill level.

We believe that students respond favorably to the workshop because they view the instructors as helping instead of judging and are more likely to bond and enjoy the experience of learning.

In conclusion, we found that the one-week mathematics preparatory workshops just prior to the start of the semester were helpful in building motivation, increasing learning success, and providing equitable and inclusive support for students, in particular women and underrepresented minorities. Although we could not fully determine whether the post-pandemic workshops had more impact than the pre-pandemic workshops, we believe the need for learning support is stronger than ever, and the workshop is an effective way of providing a valuable foundation.

Acknowledgements

First Year Programs is thanked for sharing the compiled data. We thank the instructors for their participation in the workshops. The authors also acknowledge the editors for their feedback.

About the Authors

Sandie Han is a Professor of Mathematics at New York City College of Technology. She has extensive experience in program design and administration, including serving as the mathematics department chair for six years, PI on the U.S. Department of Education MSEIP grant and Co-PI on the NSF S-STEM grant. Her research area is number theory and mathematics education. Her work on Self-Regulated Learning and Mathematics Self-Efficacy won the CUNY Chancellor's Award for Excellence in Undergraduate Mathematics Instructions in 2013. She is passionate about increasing student engagement and participation in STEM, particularly to empower women and underrepresented minorities. She started the CUNY Celebrates Women in Computing conference and is currently the 2022 – 23 faculty leadership fellow in CUNY Office of Undergraduate Studies, Academic Programs and Policy serving in the role of Assistant Dean for Academic Technology & Pedagogy.

Diana Samaroo is a Professor in the Chemistry Department at NYC College of Technology in Brooklyn, New York. She has experience in curricular and program development, as well as administration as the Chairperson of the Chemistry Department for six years. She has mentored undergraduates under the support of Emerging and Honors Scholars program, CUNY Service Corps, Louis-Stokes for Alliance Minority Participation (LS-AMP) and the Black Male Initiative programs. She serves as co-PI on several federal grants, which include NSF S-STEM, NSF RCN-UBE, and NSF HSI-IUSE grants. With a doctoral degree in Biochemistry, Dr. Samaroo's research interests include drug discovery, therapeutics and nanomaterials. Her pedagogical research is in peer led team learning in Chemistry and integrating research into the curriculum.

Janet Liou-Mark was a Professor Emeritus of Mathematics at NYC College of Technology. Her research interests included peer-led team learning, mentoring, interdisciplinary learning, and enhancing diversity in STEM. Dr. Liou-Mark received thirteen awards for her excellence in education, which included the 2011 CUNY Chancellor's Award for Excellence in Undergraduate Mathematics Instruction and the Mathematical Association of America Metropolitan New York Section 2014 Award for Distinguished Teaching of Mathematics. Dr. Liou-Mark was co-principal investigator on several National Science Foundation grants, as well as Department of Education Minority Science and Engineering Improvement Program grant.

Lauri Aguirre is the Director of First Year Programs (FYP) at New York City College of Technology. In this role, she has administered and designed programs for new students, focusing on their acclimatization of basic academic skills, college preparedness and student success. Programming has included the First Year Summer Program immersion courses and workshops in English and mathematics, First Year Learning Communities, City Tech 101: A Student Success Workshop, the FYP Peer Mentoring program, and the student handbook, *The Companion for the First Year at City Tech.*

References

Abate, A., Atnafu, M., Michael, K. (2022). Visualization and Problem-based Learning Approaches and Students' Attitude toward Learning Mathematics. *Pedagogical Research.* 7(2). em0119. 10.29333/pr/11725.

Attewell, P., Lavin, D., Thurston, D. & Levey, T. (2006). New Evidence on College Remediation. *The Journal of Higher Education.* 77. 886-924. 10.1353/jhe.2006.0037.

Alavi, Z., Meehan, K., Buffardi, K., Johnson, W. R., & Greene, J. (2020), Assessing a Summer Engineering Math and Projects Bootcamp to Improve Retention and Graduation Rates in Engineering and Computer Science. Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual Online. 10.18260/1-2—34172

Campbell, A. (2015). Exploring Boot Camps for 'Gatekeeper' Service Courses in Mathematics. *Pythagoras* 36 (2). doi:10.4102/pythagoras.v36i2.298

Clune R., Cohen O., Das A., Jasrasaria D., Rossomme E., Baranger A.M. (2022) Competence and confidence: addressing inequity among incoming chemistry graduate students through a week-long mathematics intervention. *ChemRxiv. Cambridge: Cambridge Open Engage DOI* 10.26434/chemrxiv-2022-dl84f

Frost, J.L. & Dreher, J.P. (2017) Impact of Online Summer Mathematics Bridge Program on Placement Scores and Pass Rates. *Universal Journal of Educational Research* 5(6): 1039-1044.

Galford, G., Trun, N., Deiner, L.J (2017) Interdisciplinary Course Collaborations in Community-Based Learning. *Science Education and Civic Engagement* 9(1): 5-9.

Gordon, L. (2021) *Colleges prepare for incoming freshmen with high school learning loss* Retrieved from EdSource: https://edsource.org/2021/colleges-prepare-for-incoming-freshmen-with-high-school-learning-loss/656980

Han, S., Kostadinov, B., Liou-Mark, J. & Thiel, J. (2022) Curricular and Strategic Changes in mathematics to Enhance Institutional STEM Education. American Society for Engineering Education (ASEE) 2022 Conference Proceedings, Paper ID #37007.

Jura, M. & Gerhardt, I. (2022) Examining the Effectiveness of an Online Summer Bridge Course to Prepare Students for Calculus. *PRIMUS* 32 (7), 755-763, doi: 10.1080/10511970.2021.1919256

Liou-Mark, J., Dreyfess, A., Han, S., Yuen-Lau, L. & Yu, K. (2015) Aim for success: peer-led team learning supports first-year transition to college-level mathematics. *Journal of Learning Development in Higher Education*. Vol. November: 1-24. doi: 10.47408/jldhe.v0i0.312.

Logue, A.W., Watanabe-Rose, M., & Douglas, D. (2016) Should Students Assessed as Needing Remedial Mathematics Take College-Level Quantitative Courses Instead? A Randomized Controlled Trial. *Educational Evaluation and Policy Analysis* 38 (3), 578–598.

Moscoviz, L., & Evans, D. K. (2022) Learning loss and student dropouts during the covid-19 pandemic: A review of the evidence two years after schools shut down. Center for Global Development (CGD), Washington DC, Working Paper, 609, Retrieved from: https://www.cgdev.org/publication/learning-loss-and-student-dropouts-during-covid-19-pandemic-review-evidence-two-years

National Education Association (NEA) (2022) *'Nation's Report Card' Shows Pandemic Exacerbated Opportunity Gaps*. Retrieved from https://www.nea.org/advocating-for-change/new-from-nea/nations-report-card-shows-pandemic-exacerbated-opportunity-gaps

New York City College of Technology (City Tech, n.d) Retrieved from: https://www.citytech.cuny.edu/about-us/mission.aspx

Presmeg, N. (2006) Research on visualization in learning and teaching mathematics. *Handbook of Research on the Psychology of Mathematics Education: Past, Present and Future.*

Reisel, J.R., Jablonski, M., Kialashaki, A., Dupe-Munson, E. V., & Hosseini, H. (2014). Analysis of the Impact of Participation in a Summer Bridge Program on Mathematics Course Performance by First-Semester Engineering Students. Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana. 10.18260/1-2--20074

Samaroo D., Villatoro M., Narine S., Iqbal A., Natal K. (2018) A Multitier Approach To Integrating STEM Education into a Local Elementary School. *Science Education and Civic Engagement: An International Journal 10(1)*: 35-42.

Samaroo, D. Tsenova, L., Han, S., Ghosh-Dastidar, U. (2022) Promoting STEM Learning through a Multidisciplinary SENCER Framework at a Minority-Serving Institution. *Science Education and Civic Engagement: An International Journal 14(1)*: 55-63.

A Novel Course-Based Experience to Promote Ecological Field Skills During the COVID-19 Pandemic

R. DREW SIEG
Truman State University

JOANNA K. HUBBARD
Truman State University

RACHEL M. PENCZYKOWSKI
Washington University in St. Louis

MADISON WILLIARD
Truman State University

ZACHARY A. DWYER
Truman State University

Abstract

Providing safe access to functional field experiences during the early stages of the COVID-19 pandemic was a distinct challenge. However, these experiences are critical to train students in ecological methods and provide an opportunity for open-ended, authentic research. Here, we report on a multi-week lab designed for an introductory ecology course, which was adapted for hybrid instruction during the pandemic. In the lab sequence, students independently surveyed basic phenological, population, and community dynamics of easily identifiable, cosmopolitan plant species in the genus *Plantago*. Students used this crowd-sourced dataset to develop, analyze, and report on unique research questions regarding interactions between *Plantago* and the local environment. The new lab sequence effectively met course learning objectives in experimental design, field methods, statistics, and science communication, while being accessible to both in-person and online learners. We conclude by discussing the evolution of this design for other audiences.

Introduction

Course-based undergraduate research experiences (CUREs) promote early and expanded student engagement in scientific research that improves science literacy, analytical skills, and inclusivity within STEM majors (e.g., Bangera & Brownell, 2014; Olimpo et al., 2018). Incorporating academic research interests and novel pedagogies benefits both student and faculty development (Shortlidge et al., 2016). However, the transition to online education during the COVID-19 pandemic posed many challenges to the implementation of such lab experiences (Tsang et al., 2021).

Institutions adopted myriad strategies for course delivery early in the pandemic, including distanced labs, hybrid formats, and asynchronous learning. Purely online simulations or recordings of experiments did not maintain student engagement and led to a superficial understanding of lab methodology or purpose (Sansom, 2020). Several methods to promote active participation in remote labs were later adopted, including computer simulations and ecological field research (Abriata, 2022; Creech & Shriner 2020), although it was important to ensure equal accessibility for all students using hands-on modalities (Jawad et al., 2021; Kelley, 2020). These rapid shifts to new modalities and implementation of new technologies induced anxiety and revealed inequity among students (Tsang et al., 2021). Feelings of isolation were common, making it difficult for students to establish a routine and remain motivated from home (Feldman, 2020). The pandemic also triggered emotional stressors caused by direct illness, grief, financial instability, and loneliness and led to physical and mental health issues including disordered eating and depression (Flaudias et al., 2020; Mushquash & Grassia, 2020). Within a semester of teaching during COVID-19, it became clear that pedagogical modalities should acknowledge and accommodate evolving student needs.

Independent field experiences using cosmopolitan organisms are one option to combat accessibility and equity issues associated with remote learning. Organisms that are easy to find and identify can be used by students to crowd-source data collection, address ecological research questions, and connect to their local community (Penczykowski & Sieg, 2021). Having students or community members assist in the collection of observational data can generate robust datasets while promoting bioliteracy and data management skills in participants (Hitchcock et al., 2021; Jones et al., 2021; Putman et al., 2021). Hands-on exposure also tackles "plant awareness disparity" and "biodiversity naivety" problems (Niemiller et al., 2021; Parsley, 2020; Wandersee & Schussler, 1999), whereby students fail to recognize the identities or functions of floral and faunal community members (Schuttler et al., 2018; Soga & Gaston, 2016). Engaging in field work may also lead to greater student retention or interest in ecological careers.

In approaching our first hybrid academic year (2020-2021), we recognized that traditional labs would be rendered non-functional due to social distancing procedures, safety concerns, and unpredictable attendance. Many labs were reconfigured or condensed to accommodate these challenges, but we wanted to maintain a field experience despite the challenges with hybrid instruction. We elected to build a new experience based on an accessible plant genus (*Plantago* spp.) that could be observed by both in-person and remote students while promoting skills in experimental design, data management, statistics, and science communication. In this report, we outline the pilot project and preliminary outcomes, discuss its limitations within our changing institutional curriculum, and describe how the fundamentals of this project have led to "second-generation" projects for other audiences on campus.

Methodology

The Institution and Course

Truman State University is a rural public liberal arts university of under 4,000 undergraduate students located in Kirksville, MO. During this study (2020), Truman State had a 72% acceptance rate, the gender identity at Truman was 40:60 identifying male:female, and approximately 80% were white, in-state, and received financial aid. Truman has a long-standing reputation in the Midwest as an affordable, quality public college option. As at many universities across the United States, enrollment has been steadily declining at Truman; undergraduate enrollment is down approximately 35% in the past five years. Biology is a consistently popular major that accounts for 12% of incoming freshmen, but enrollment has declined more than 50% since 2017. Recently, the Biology department implemented a new curriculum for the major. Biology majors who started before fall 2019 were required to take Introduction to Ecology (BIOL 301);

TABLE 1. General Comparison of Course Delivery Components During Fall 2019 (In-Person)

FALL 2019 (PRE-COVID)	FALL 2020 (COVID)
No weekly quizzes	**Weekly reading quizzes posted on learning management software**
No discussion boards	**Weekly discussion boards alternating between course concepts and student wellness / metacognition**
Lectures delivered in person	**Weekly asynchronous, recorded lectures**
Sporadic case studies and active learning during lecture	**Weekly synchronous "in-Zoom" case studies and activities**
Three physical problem sets (individual, smaller point value)	**Two online problem sets (completed in pairs, larger point value)**
In-person exams (1 hr 20 min)	**Online exams accessed on learning management software (2-hr timer)**
Sporadic email contact as needed to update students	**Consistently formatted weekly updates depicting upcoming tasks and deadlines**
EcoPhoto (local): Student blogs of ecological observations on campus	**EcoPhoto (community): sharing and commenting on blogs with peers at three different institutions (UT, MO, NY)**
Field experiences to quantify stream biodiversity or human demography	**Analysis of pre-collected data on these topics to accommodate distancing**
Written grant proposal and analysis of national water quality datasets	**No change from fall 2019**
Multiple disjointed single week lab activities	***Plantago* survey CURE**

after the curriculum change, BIOL 301 was one of four organismal biology course options. With many Truman students pursuing careers in medicine or healthcare, microbiology has proven more popular than ecology or the other two organismal courses (evolutionary biology and eukaryotic diversity). Since the new curriculum has been implemented, student demand for ecology has steadily decreased from six 24-seat sections per year in 2017 to a single section in 2022.

Course Structure Amidst the Pandemic

At the onset of the COVID-19 pandemic, Truman transitioned to a fully remote modality to conclude the spring 2020 semester. During the 2020–2021 academic year, faculty could select from several delivery options, including fully asynchronous, online, or hybrid instruction. Four hybrid sections of BIOL 301 were offered during fall 2020, with two asynchronous recorded lectures and one synchronous Zoom activity per week. Lab sections were split into three groups (two in-person sections, one virtual) that each met for 50 minutes of the nearly three-hour period to accommodate social distancing. Excluding the new *Plantago* project, labs were modified from established protocols used in previous semesters.

Course instructors (Drew Sieg and Joanna Hubbard, hereafter RDS and JKH) collaborated extensively to develop materials for this model; they restructured the learning management system, co-developed asynchronous recorded lectures and lecture activities, and held weekly meetings to discuss how the hybrid course was supporting student success and wellness. A full comparison of course changes to accommodate a hybrid delivery are listed in Table 1. Pre- and post-surveys evaluating student skills in science communication, statistics, and graphical interpretation were issued, but IRB approval was not established until after implementation of this project. Thus, evaluative feedback on this study is limited to voluntary course evaluations administered for all Truman courses and reflects the pedagogy of the course as a whole, rather than just the new lab experience. As both instructors taught sections in 2019 and 2020, comparisons between years were made to evaluate changes in student perceptions due to both COVID-19 and the intervention.

Experimental Study System

In pre-COVID semesters, BIOL 301 students would survey water quality and macroinvertebrate diversity from local streams to acquire field experience (modified from Doherty et al., 2011). Sampling sites were located up to 30 minutes from campus, which required university transportation and longer lab periods, neither of which were feasible using a hybrid model. For the new field experience, we expanded on a survey protocol for *Plantago lanceolata* and *P. rugelii* used by Rachel Penczykowski (RMP) to train students in the Tyson Undergraduate Fellows program at Washington University in St. Louis. *Plantago* are short-lived perennials commonly found in human-disturbed habitats, including lawns, parks, paths, and pastures. The geographic distributions of these species span gradients in latitude, elevation, urbanization, and other environmental factors. They are easy to find and identify, are regionally abundant, of low conservation concern, and extremely accessible (Penczykowski & Sieg, 2021). They are suitable for addressing research questions at the population or community level, due to their distinct phenological stages and easily recognizable evidence of interactions with both herbivores and fungal pathogens (Penczykowski & Sieg, 2021).

Project Outline

Three labs interspersed throughout the semester were developed to encompass the *Plantago* field experience. In addition to the instructional goal of providing an effective hybrid learning experience, student outcomes from the experience included the ability to

- quantify the abundance and status of local plants to combat plant awareness disparity,
- develop novel research questions regarding local variation in *Plantago* dynamics, and
- analyze data, address challenges with crowd-sourcing data, and practice visual science communication.

Activities and assessments for each lab session are summarized below and in Table 2.

Lab 1: Introducing the Study System and Tackling Plant Awareness Disparity

The first lab established the utility of *Plantago* as a model organism for ecological research. Students watched a 13-minute recorded video by RMP discussing how the species can be used to address questions at multiple spatial scales across varying environment types. Connections to climate change and urban development were stressed, along with the use of cosmopolitan *Plantago* species in

TABLE 2. Activity Summary for *Plantago* Survey CURE

Lab	Learning Objective	In-Lab Activity	Assessments
1	Outline utility of *Plantago* to address ecological interactions	Introductory video about *Plantago* study system	Upload photo of focal species from local environment
1	Differentiate between plants exposed to ecological threats	Training on species ID, phenology, infection, herbivory	Worksheet with sample images to confirm ability to ID species characteristics
2	Explain best practices in data management	Discussion on data management in Excel	Critique example datasets to develop rules for management
2	Conduct an ecological field survey	Training on survey protocol	Independently conduct *Plantago* surveys
2	ID mechanisms to manage crowd-sourced datasets	Build consensus on data management strategy	Upload survey data to learning management software
3	Generate a novel ecological question	Group discussions to develop research questions	Outline null and alternative hypotheses and justify research question
3	Conduct statistical analyses on crowd-sourced data	Training in statistical analysis methods	Upload formatted dataset containing analyzed data
3	Communicate scientific findings in visual formats	Discussions on effective use of design in science communication	Create graphical abstract and post to Padlet; post feedback on peer abstracts

global collaborations including PlantPopNet and HerbVar. This video also emphasized the value of community science engagement and collaborative research across universities.

Following the video, students were trained to identify focal species, their flowering status, types of herbivory damage, and evidence of infection by a fungal pathogen (powdery mildew). These skills were practiced as a group for in-person students, followed by an individual homework assignment. Remote students participated in the training, but practiced individually. Example images were provided via PowerPoint, so that students could participate in synchronous group work in person or via Zoom. Groups also brainstormed research questions and hypotheses, generally focusing on variation in herbivory or infection between species or survey locations.

TABLE 3. Parameters Reported to Course-Wide Dataset for Each Surveyed Plant (N=60 Plants per Student)

Parameter Measured	Options
Date	Mid-September 2020
Latitude / longitude	Determined via Google Maps or equivalent
Location type	Campus, yard, road, sidewalk, farm, state park, city park, other
Location image	Google Earth screenshot at 50-ft altitude
Species	*P. lanceolata, P. rugelii*
Light status	Sun, shade
Flowering phenology	None, budding, flowering, seeds immature, seeds mature, seeds dispersed
Evidence of powdery mildew infection	Yes, no
Evidence / type of herbivory	None, chewing, leaf mining, multiple
Evidence of mowing damage	Yes, *no*
# of conspecifics in 1.5-m radius	0, 1-10, 11-50, 51-100, 100+
# of infected conspecifics in 1.5-m radius	0, 1-10, 11-50, 51-100, 100+

Lab 2: Field Surveys

After completing a series of guided online tutorials and discussing a paper on common issues in data management (Broman & Woo, 2018), each student independently conducted a field survey of *P. lanceolata and P. rugelii* using a modified line transect protocol. Students identified a local site containing both *Plantago* species, noted environmental conditions, and then recorded observations regarding flowering phenology, neighbor density, and evidence of community interactions for a single *Plantago* individual (summarized in Table 3). Students advanced 2 m to another individual *Plantago* and repeated the process a total of 30 times for each focal species.

Students could complete surveys at any accessible site in their vicinity on their own schedule within a one-week window. Most surveys were conducted in parks or neighborhoods in Kirksville, but remote students provided data from across Missouri. Students recorded data on a data collection sheet provided by the instructor, entered handwritten data into a spreadsheet, and uploaded the file as a homework assignment. A teaching assistant compiled each unedited dataset into a master "crowd-sourced" spreadsheet for use in lab 3.

Lab 3: Experimental Design, Analysis, and Reporting

For the final lab activity, students accessed the master spreadsheet and worked in teams either in person or via Zoom to analyze their research questions. Tutorials on statistics were provided, and each group framed questions as testable hypotheses with their instructor prior to analysis. Groups worked over two weeks to organize their data set, conduct analyses, and synthesize their findings into a graphical abstract. A major component of this assignment was recognizing the amount of time and effort associated with organizing large datasets.

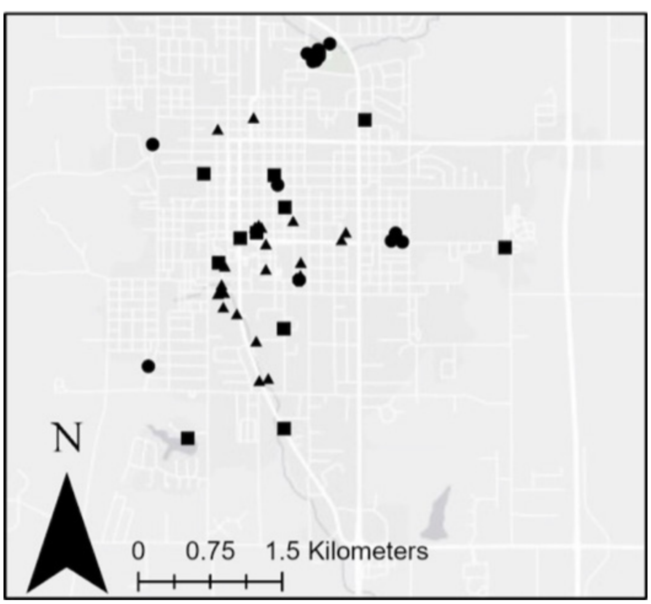
Graphical abstracts were a novel concept for most students. Therefore, the class initially evaluated examples from scientific journals and discussed their use in comparison to written abstracts. Instructors then provided a tutorial on building graphical abstracts in PowerPoint. Student products were posted to Padlet (padlet.com), which allowed students to asynchronously provide and receive feedback on their research questions, analyses, and abstract designs. In practice, most products took on a form resembling a research poster, probably because students had greater familiarity with that medium and a fear of leaving information out.

Results and Discussion

Novel Research Outcomes from the Lab Activity

Via this lab activity, 3360 plants were surveyed by 55 students, primarily in Kirksville. A map displaying *Plantago* distributions in the city was generated from these data (Figure 1), which has subsequently been used by independent research students to conduct follow-up studies on *Plantago* community dynamics. Survey locations were clustered around Truman State, as it is primarily a residential campus. The majority of student-generated questions and hypotheses focused on comparisons of herbivory and/or fungal infection across plant species, sunny vs. shaded microhabitats, or location types (e.g., roadsides vs. parks). Primary findings included a significantly higher likelihood of infection on *P. rugelii* than *P. lanceolata*, particularly in shaded habitats, while infection frequency was not affected by mowing or herbivory.

FIGURE 1. Transect Sites Within Kirksville, MO City Limits



Note: Circles represent parks, squares represent roadsides, and triangles represent yards. Each icon represents 60 plants surveyed.

Undergraduate research students (Madison Williard and Zachary Dwyer) working with RDS independently evaluated the dataset and confirmed these patterns, presenting their research at Truman State's Student Research Conference (Dwyer et al., 2021).

Due to restrictions on social gatherings, students in the course did not disseminate their findings in the broader Kirksville community. However, this pilot study demonstrated that data collection within the *Plantago* system is tractable for novices. Elements of this project have been incorporated into submitted research proposals that incorporate community science, public outreach, and civic engagement as broader impact objectives (RDS & RMP, personal communication).

Student Responses to the Course

Beyond the *Plantago* project, other activities were implemented to promote an active classroom amidst a hybrid redesign. These included weekly interactive case studies using Zoom and Google Docs, a semester-long "EcoPhoto" project on Flickr to document local ecological interactions, discussion board prompts that pushed students to reflect on their wellness or creatively discuss course concepts (such as a knockoff of "Dear Abby" called "Dear Ecology"), a month-long lab that used EPA datasets to estimate water quality in wadable streams (modified from Nuding & Hampton, 2012), and team-based problem sets instead of virtually proctored traditional exams. We communicated with students through consistently formatted weekly announcements on our course management software and email, aiming to keep students on track without bombarding them with disparate notices. Collectively, these activities made our redesign distinct from previous versions of BIOL 301, but also from other hybrid courses at Truman.

Evaluative Likert-scale data and representative free responses reported in Table 4 pertain to the fall 2020 hybrid course redesign, including the *Plantago* CURE. While some outcomes are likely driven by the *Plantago* experience, we acknowledge that other elements of our redesign influenced student perceptions of the course. Total responses to the course survey (n=48) represent approximately 85% of the class. Since submissions were anonymous, we cannot directly compare different demographic responses to the redesign, but we can assume that the makeup of students roughly matches that of Truman State as described in the methodology section.

Students valued the applicability of the course, with more than 97% of respondents agreeing that the course related concepts to real-world issues or everyday life (Table 4). Informally, students noted that they found themselves spotting *Plantago* between classes, and felt a sense of pride that they could better identify the plants around them. Extended engagement and sense of familiarity with focal plants is a key component to combat plant awareness disparity (Krosnick et al., 2018; Niemiller et al., 2021); thus this new lab experience appears to have promoted greater bioliteracy and plant awareness.

The general organization, approach, and transparency regarding expectations in BIOL 301 was viewed by students as exemplary in comparison to other courses that transitioned to hybrid instruction (Table 4). Whether the new approach led to long-term positive feelings about ecology is less clear, as 29% of respondents indicated that they would not want to take additional ecology courses (Table 4). This may be a product of the hybrid design: students viewed asynchronous assignments (quizzes, readings, discussion boards) as busy work. Hybrid courses require a distinct mindset from both the instructor and the student in order to be effective (Shea et al., 2015), and most of our students took hybrid courses out of necessity rather than desire. Animosity towards materials used to maintain asynchronous engagement makes sense considering the rapid transition to online modalities. However, lessons learned from similar experiences are leading to new evaluations of best practices in hybrid or online instruction in a post-COVID era (e.g., Singh et al., 2021).

Using course evaluations, we also statistically compared student responses to these questions in fall 2019 (the pre-pandemic version of the Plantago project) and fall 2020 (during the pandemic, with the hybrid changes

TABLE 4. Introduction to Ecology Course Evaluation Data (N=48 Respondents).

Survey Question	Disagree	Agree	Strongly Agree	Representative Free Responses
I can relate topics in this class to my everyday life.	1	27	20	I [am] more conscious of my environment and surroundings. I never thought of ecology as something that is always around me. I look at what happens around me differently now.
The instructor demonstrated the relevance of course material to real-world issues.	0	14	34	I learned a lot about animal and plant interactions … and the environment in general, which has already been useful when talking to my friends about environmental issues. I feel that I have a more in-depth, new perspective when it comes to evaluating biological interactions. I have a better appreciation for how wide the field of Biology is.
This course challenged students intellectually.	4	31	13	I liked that reading scientific literature and statistics were consistently reinforced. Those skills are valuable. I relearned a lot of statistics which I found incredibly helpful. I really did not know anything about Ecology outside of food webs, so I came out of this course having learnt a lot.
Reasonable changes to instruction and assignments were made [for hybrid instruction in the pandemic].	2	15	26	The instructor was able to understand … COVID restrictions and make appropriate adjustments. The class was delivered as well as it could be virtually. Expectations were clearly organized. Organization and communication were the best of any [course] I've taken by a mile. It was so helpful.
As a result of this class, I would be interested in taking more courses in the subject.	14	18	15	Sometimes assignments did not seem beneficial and took up a lot of time that I didn't have. There were assignments that felt like busy work … to keep students engaged [in] distance learning but did not contribute to my learning.

Note: The options "disagree" and "strongly disagree" have been collapsed into a single column due to small reported numbers in these categories.

described in this study; Table 5). However, there are extrinsic factors that should be accounted for, such as general stress and COVID fatigue, which make direct comparisons between these two student populations tenuous.

For three of four questions, no significant difference between semesters was seen (Table 5), suggesting that students perceived equal course rigor and relevance with the traditional in-person delivery and hybrid instruction. It is encouraging that objectives related to real-world application of ecology were maintained in the hybrid delivery, despite the new format and disruptions to instruction during the pandemic. We also take this to mean that the course structure and activities were seen as equivalent to a non-disrupted semester by upper division students who had taken college courses both before and during the pandemic.

In contrast, there was a significant increase in student willingness to take other courses in ecology (Table 5, p=0.020). The new lab module, coupled with accommodations made for hybrid instruction, may have made ecology a more tangible sub-discipline for students relative to the traditional mechanism of instruction. As a result, several of the activities used to improve the use of learning management software, communicate with students, and check in on student wellness have been continued by RDS and JKH in other courses, and have been formally presented to other university faculty.

TABLE 5. Student Perceptions of the Course Before (2019) and During (2020) the COVID-19 Pandemic

Survey Question	Fall 2019 (Pre-COVID) n=89-90	Fall 2020 (During COVID) n=48	P-value
I can relate topics in this class to my everyday life.	3.29 +/- 0.59	3.40 +/- 0.54	0.31
The instructor demonstrated the relevance of course material to real-world issues.	3.72 +/- 0.45	3.71 +/- 0.46	0.90
This course challenged students intellectually.	3.26 +/- 0.64	3.15 +/- 0.68	0.33
As a result of this class, I would be interested in taking more courses in the subject.	2.59 +/- 0.93	2.98 +/- 0.91	0.02

Note: Averages based on 4-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). Comparisons between years conducted via 2-tailed t-test; error represents +/- one standard deviation.

Current and Future Status of the Project

Despite the effort to restructure BIOL 301 as a hybrid course, reduced student enrollment, curricular changes, and interest in the topic remains low, such that the department now offers only a single, in-person section per year. That section is not scheduled to be taught by RDS or JKH in the near future, and thus many changes are not trackable beyond the pilot implementation. The *Plantago* field experiment continues to be offered by the current BIOL 301 instructor, but a lower number of participants reduces the crowd-sourcing project elements. Since our pilot delivery, the project has been conducted two more times, with minimal changes to the established protocol. The instructor has considered widening the project to tackle other core skills in ecology related to estimating other population dynamics.

We had previously used social media (e.g., Flickr) in observational ecology projects to connect our students with peers enrolled in similar courses across the country (RDS and JKH, personal communication) and intended to build out a similar network with this project that would allow students to compare *Plantago* demographics across wider urban-rural, latitudinal, climatic, or temporal gradients. While we encourage interested parties to reach out if the modules would fit their course needs, the restructuring of BIOL 301 has limited our ability to further develop broader community engagement aspects of this project.

We recognized the benefit of using open-ended projects to promote observational and data management skills in students majoring in biology at

Truman, and we have since modified the *Plantago* project for an introductory biology course (BIOL 104) that RDS and JKH regularly teach. Introductory courses are a wise target for open-ended inquiry, as it introduces bioliteracy, statistics, and communication skills needed to succeed academically and in STEM-related careers. Early exposure to authentic research eliminates "cookie-cutter" experiences that do not accurately reflect the challenges associated with research (Wood, 2009), providing students with a better representation of the scientific process.

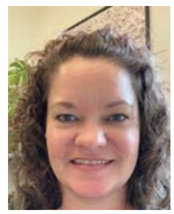
In the new introductory biology module, students mine iNaturalist (inaturalist.org) to quantify global images of infection or herbivory on *Plantago* and address questions that are thematically similar to those emphasized in BIOL 301. The pilot implementation of this version of the project occurred in spring 2022, resulting in 13,700 images processed by 105 students (RDS, personal communication). This new initiative has the potential to be expanded both at Truman and in the wider community and has been a core component of new grant proposals written by RDS and RMP. We intend to build this database annually and embrace iNaturalist as a tool for community science, while tracking student perceptions of effective science communication and assessing challenges associated with community-sourced data (e.g., Dickinson et al., 2010). Ultimately, this introductory version of the *Plantago* project is likely to be a more impactful initiative than the original pilot project outlined in this manuscript.

Conclusions

The transition to online learning due to the COVID-19 pandemic was difficult for students and faculty alike, and we are now assessing which instructional approaches are most effective. The adjustments we made to maintain an accessible and rigorous field experience were largely successful within a hybrid undergraduate course. The pilot implementation of this project has evolved into a more robust project that targets new biology majors.

About the Authors

Drew Sieg is an assistant professor of biology at Truman State University. He is a SENCER Leadership Fellow whose traditional research examines chemically mediated ecological interactions among plants, fungi, algae, and herbivores. He is also involved in educational research, particularly examining how authentic research experiences and other novel pedagogies affect student engagement in STEM.



Joanna Hubbard is an assistant professor of biology at Truman State University. Her research interests include questions related to animal behavior, animal coloration, and evolutionary ecology in birds. She has conducted education research examining how different question formats provide insight into student misconceptions and understanding.

Rachel M. Penczykowski is an assistant professor of biology at Washington University in St. Louis. Her research focuses on effects of climate change and urbanization on plant-pathogen interactions and food webs. She mentors graduate, undergraduate, and high school students in this work, including through summer field research programs at Washington University's Tyson Research Center.

Madison Williard is currently a first-year student at Southern College of Optometry located in Memphis, TN. She graduated from Truman State University in 2021 with a BS in biology.

Zachary Dwyer is currently a first-year medical student at A.T. Still University, located in Kirksville, MO. He graduated from Truman State University in 2022 with a BS in biology and a minor in psychology.

References

Abriata, L. A. (2022). How technologies assisted science learning at home during the COVID-19 pandemic. *DNA and Cell Biology*, 41(1), 19–24. https://doi.org/10.1089/dna.2021.0497

Bangera, G., & Brownell, S. E. (2014). Course-based undergraduate research experiences can make scientific research more inclusive. *CBE Life Science Education*, 13, 602–606. https://doi.org/10.1187/cbe.14-06-0099

Broman, K. W., & Woo, K. H. (2018). Data organization in spreadsheets. *The American Statistician*, 72(1), 2–10. https://doi.org/10.1080/00031305.2017.1375989

Creech, C., & Shriner, W. (2020). DIY ecology class: Transitioning field activities to an online format. *Ecology and Evolution*, 10(22), 12437–12441. https://doi.org/10.1002/ece3.6656

Dickinson, J. L., Zuckerberg, B., & Bonter, D. N. (2010). Citizen science as an ecological research tool: Challenges and benefits. *Annual Review of Ecology, Evolution, and Systematics*, 41, 149–172. https://doi.org/10.1146/annurev-ecolsys-102209-144636

Doherty, J. H., Harris, C., & Hartley, L. (2011). Using stream leaf packs to explore community assembly. *Teaching Issues and Experiments in Ecology*, 7, Experiment #3 [online]. http://tiee.esa.org/vol/v7/experiments/doherty/abstract.html

Dwyer, Z., Roberts, C., Schaefer, C., Willard, M., & Sieg, R. D. (2021, April). Microenvironmental predictors of herbivory or infection status on herbaceous *Plantago* in Kirksville, MO [Poster presentation]. Truman State University Virtual Student Research Conference, Kirksville, MO.

Feldman, J. (2020). An ethics of care: PGCE students' experiences of online learning during Covid-19. *Critical Studies in Teaching and Learning*, 8(2), 1–17. https://doi.org/10.14426/cristal.v8i2.326

Flaudias, V., Iceta, S., Zerhouni, O., Rodgers, R. F., Billieux, J., Llorca, P., Boudesseul, J., deChazeron, I., Romo, L., Maurage, P., Samalin, L., Begue, L., Naassila, M., Brousse, G., & Guillaume, S. (2020). COVID-19 pandemic lockdown and problematic eating behaviors in a student population. *Journal of Behavioral Addictions*, 9(3): 826–835. https://doi.org/10.1556/2006.2020.00053053

Hitchcock, C., Sullivan, J., & O'Donnell, K. (2021). Cultivating bioliteracy, biodiscovery, data literacy, and ecological monitoring in undergraduate courses with iNaturalist. *Citizen Science: Theory and Practice*, 6(1), 1–13. https://doi.org/10.5334/cstp.439

Jawad, M. N., Bhattacharjee, A., Lehmann, R., Busza, A., Perez-Pinera, P., & Jensen, K. (2021). Remote laboratory exercise to develop microbiology skills. *Journal of Microbiology and Biology Education*, 22(1), ev22i1.2399. https://doi.org/10.1128/jmbe.v22i1.2399

Jones, D., Foshee, B., & Fitzgerald, L. (2021). A herpetological survey of Edith L. Moore Nature Sanctuary. *Check List*, 17(1), 27–38. https://doi.org/10/15560/17.1.27

Kelley, E. W. (2020). Reflections on three different high school chemistry lab formats during COVID-19 remote learning. *Journal of Chemical Education*, 97(9), 2606–2616. https://pubs.acs.org/doi/full/10.1021/acs.jchemed.0c00814

Krosnick, S. E., Baker, J. C., & Moore, K. R. (2018). The pet plant project: Treating plant blindness by making plants personal. *The American Biology Teacher*, 80(5), 339–345. https://doi.org/10.1525/abt.2018.80.5.339

Mushquash, A. R., & Grassia, E. (2020). Coping during COVID-19: Examining student stress and depressive symptoms. *Journal of American College Health*, 70(8), 2266–2269. https://doi.org/10.1080/07448481.2020.1865379

Niemiller, K. D. K., Davis, M. A., & Niemiller, M. L. (2021). Addressing 'biodiversity naivety' through project-based learning using iNaturalist. *Journal for Nature Conservation*, 64, 126070. https://doi.org/10.1016/j.jnc.2021.126070

Nuding, A. & Hampton, S. (2012). Investigating human impacts on stream ecology: Locally and nationally. *Teaching Issues and Experiments in Ecology*, 8, Practice #1 [online]. http://tiee.esa.org/vol/v8/issues/data_sets/nuding/abstract.html

Olimpo, J. T., Pevey, R. S., & McCabe, T. M. (2018). Incorporating an interactive statistics workshop into an introductory biology course-based undergraduate research experience (CURE) enhances students' statistical reasoning and quantitative literacy skills. *Journal of Microbiology and Biology Education*, 19(1). https://doi.org/10.1128/jmbe.v19i1.1450

Parsley, K. M. (2020). Plant awareness disparity: a case for renaming plant blindness. *Plants People Planet*, 2(6), 598-601. https://doi.org/10.1002/ppp3.10153

Penczykowski, R. M., & Sieg, R. D. (2021). *Plantago* spp. as models for studying the ecology and evolution of species interactions across environmental gradients. *The American Naturalist*, 198(1), 158-176. https://www.journals.uchicago.edu/doi/full/10.1086/714589

Putman, B. J., Williams, R., Li, E., & Pauly, G. B. (2021). The power of community science to quantify ecological interactions in cities. *Scientific Reports*, 11, 3069. https://doi.org/10.1038/s41598-021-82491-y

Sansom, R. L. (2020). Pressure from the pandemic: pedagogical dissatisfaction reveals faculty beliefs. *Journal of Chemical Education*, 97(9), 2378-2382. https://doi.org/10.1021/acs.jchemed.0c00657

Schuttler, S. G.,Sorensen, A. E., Jordan, R. C., Cooper, C., & Shwartz, A. (2018). Bridging the nature gap: Can citizen science reverse the extinction of experience? *Frontiers in Ecology and the Environment*, 16(7), 405–411. https://doi.org/10.1002/fee.1826

Shea, M., Joaquin, E., & Gorzycki, M. (2015). Hybrid course design: promoting student engagement and success. *Journal of Public Affairs Education*, 21(4), 539–556. https://doi.org/10.1080/15236803.2015.12002219

Shortlidge, E. E., Bangera, G., & Brownell, S. E. (2016). Faculty perspectives on developing and teaching course-based undergraduate research experiences. *BioScience*, 66(1), 54–62. https://doi.org/10.1093/biosci/biv167

Singh, J., Steele, K., & Singh, L. (2021). Combining the best of online and face-to-face learning: Hybrid and blended learning approach for COVID-19, post vaccine, and post-pandemic world. *Journal of Educational Technology Systems*, 50(2), 140–171. https://doi.org/10.1177/00472395211047865

Soga, M., & Gaston, K. J. (2016). Extinction of experience: The loss of human-nature interactions. *Frontiers in Ecology and the Environment*, 14(2), 94–101. https://doi.org/10.1002/fee.1225

Tsang, J. T. Y., So, M. K. P., Chong A, C. Y., Lam B. S. Y., & Chu, A. M. Y. (2021). Higher education during the pandemic: The predictive factors of learning effectiveness in COVID-19 online learning. *Education Sciences*, 11(8), 446. https://doi.org/10.3390/educsci11080446

Wandersee, J. H., & Schussler, E. E. (1999). Preventing plant blindness. *The American Biology Teacher* 61, 82–86. https://doi.org/10.2307/4450624

Wood, W. B. (2009). Innovations in teaching undergraduate biology and why we need them. *Annual Review of Cell and Developmental Biology*, 25, 93–112. 10.1146/annurev.cellbio.24.110707.175306