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About the Journal

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

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

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Contents

From the Editors

For the Winter 2021 issue of this journal, we are delighted to feature a research article, a project report, and an extensive book review. These contributions reflect a variety of creative connections between science education and civic engagement.

Jackson Miner and **Rona Robinson-Hill,** both at Ball State University, examine the impact of integrating feminist pedagogies into secondary science education. Drawing on a rich interview with an African-American female scientist, who teaches a secondary education science course at a predominantly White institution, this research article explores how inclusionary feminist principles influenced the pedagogical development of pre-service teachers. The outcomes of the project included a commitment to representation, recognition and discussion of bias, and motivation for reconceptualizing lesson plans and teaching philosophy. The authors provide a valuable case study for using inclusive educational principles to broaden interest in science among students and teachers.

Carrie Buo and **Rebecca Eagle-Malone**, colleagues at the University of Akron, provide a project report on urban ecology as a strategy for engaging urban youth with environmental education. They describe a four-week after-school program that provided fifth-grade students with the opportunity to explore their local environment from an ecological perspective, Assessment of the project was based on student drawings of "nature," which showed an increased focus on the biological realm and a reduction in depictions of humans, buildings, and vehicles. This project report demonstrates that introducing young children to urban ecology changes their perception of their environment.

The third contribution to this journal issue is a book review essay from one of us (**Matthew A. Fisher,** Saint Vincent College) that discusses how various authors are analyzing our current experiences with the COVID-19 pandemic. Ranging from scientific principles to public policy, these books provide insights into the origin, spread, and impact of the novel coronavirus. A common theme in several of these books is the systemic failure to mount an adequate response to containing COVID-19, which has now caused more than 2 million deaths worldwide. The book review concludes with references to works of fiction and poetry, which provide a literary lens for processing the personal and societal toll of the pandemic.

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

PROJECT REPORT

Urban Ecologists: A New After-School Program Teaching Inner-City Children about Urban Ecology

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Abstract

Children in urban environments tend to have limited exposure to environmental education programs for many reasons. This paper describes the development of a short-session after-school program, created to introduce children in an inner-city school to the concept of urban ecology. In this program, we met with a class of 20 fifth graders once a week for four weeks and evaluated students' perceptions of nature with a pre-post-intervention activity that asked students to draw a picture describing "nature." Researchers evaluated the drawings together. The results indicated an increase in the instances of animals and insects in drawings with fewer anthropic influences, such as people, buildings, and vehicles. Overall, the program achieved its goal of exposing urban children to the ecology all around them.

Introduction

Connecting students with nature offers many benefits, including positive effects to physical, mental, and emotional well-being (Frumkin, 2001; Nisbet & Sleep, 2001; Seymour, 2016; Ulrich, 1984). Studies also suggest that the student-nature connection results in advances in learning, such as increases in creativity, problem-solving

abilities, and higher test scores (Camasso & Jagannathan, 2018; Kirnan, Ventresco, & Gardner 2018; Rowland, 2017; Swall, Ebbeskog, Hagelin, and Fagerberg, 2017). With increasing urbanization, educators should consider ways to connect students, particularly those in urban areas, with nature so that they can experience the myriad benefits nature provides.

Around the world, urban populations are increasing. UNICEF predicts that at least two thirds of all people will reside in urban environments by 2050, with over a billion of the world's children living in urban areas as of 2012 (UNICEF, 2012). Increasing urban sprawl means decreasing large-scale natural areas. This might create a disconnect between some urban dwellers and nature;

TABLE 1. Alignment Table Comparing NGSS Standards and Expectations with Components of the UE Program

Grade Level	Educational Standard	Performance Expectation	Urban Ecologists Application
3-5	LS4.D Biodiversity and Humans: 3-LS4-4: Biological Evolution and Diversity (NGSS)	Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change. (LS4.D) Populations live in a variety of habitats and change in those habitats affects the organisms living there. (3-LS4-4)	The program introduces students to nature that exists in urban areas, not just in nature preserves or rural areas. Students learned that some plants tolerate toxins in the environment and remove toxins from the soil, demonstrating the resilience of nature. Students used this information to critically evaluate different ways insects might respond to different arrangements of plants in the student-developed mazes before and during maze development. During insect collection, students had opportunities to discuss the different types of shelter used by different organisms, given the wet, snowy, and freezing temperatures of the day.
5	LS2.A Interdependent Relationships in Ecosystems: 5-LS2-1 Ecosystems: Interactions, Energy, and Dynamics (NGSS)	The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. (LS2.A) Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. (5-LS2-1)	The program introduces students to ecosystem interactions by demonstrating the importance of plants as food and shelter for a variety of species, including many insects. We discussed the abilities of plants to decontaminate soil and water, as well as sequestering carbon dioxide from the air to provide breathable oxygen for humans. Maze development aided in students' understanding as the planted seeds took up water and nutrients from the soil to develop, providing shelter and food sources for insects on the final day of the program.
3	CCSI.ELA-Literacy. RI.3.3. (Common Core State Standards Initiative)	Describe the relationship between... scientific ideas or concepts... using language that pertains to time, sequence, and cause/effect.	Using information provided by the program facilitators, students created a maze and discussed different ways to test insect intelligence using student-developed mazes. Students tested these hypotheses on the final day after insect collection by placing insects in the student-developed mazes.

they might fail to recognize that nature exists all around them—even in urban environments (Ardoin, Gould, Lukacs, Sponarski, & Schuh, 2019; Dillon et al., 2006). Educators, spending 6-8 hours per day with students, might offer students experiential, nature-based learning opportunities to connect with nature. Exposing urban students to science-based educational opportunities might also allow students to make deeper connections to scientific content and recognize the scientist within—connections sometimes missed in marginalized populations (Harnik & Ross, 2004; Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2009). We believe our program provides one type of opportunity to get students exposed to and excited about nature, while still meeting Next Generation Science Standards.

We developed Urban Ecologists as a way to connect elementary-aged students in urban school districts to nature through experiential, nature-based learning. In our program we wanted students to explore urban ecology through an inquiry-based program to increase understanding of the world around them (Berkowitz & Hollweg, 1999). To determine whether our program was effective for helping students recognize nature all around the urban environment, we focused on the following research question: would participants' perspectives of nature change after exposure to nature in an urban environment?

Further, to make this program relevant to classroom science standards, we aligned the content with Next Generation Science Standards (NGSS) LS4.D: Biodiversity and Humans, LS2.A: Interdependent Relationships in Ecosystems, and Common Core State Standards Initiative CCSI.ELA-Literacy.RI.3.3.: "Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect" (Table 1; NGSS Lead States, 2013; National Governors Association Center for Best Practices, Council of Chief of State School Officers, 2010).

Methods

We created a program to introduce the concept of urban ecology to a classroom of 20 fifth-grade students at a school in northeast Ohio that serves children who live in an urban environment. Our program, called Urban Ecologists (UE), was built to increase the students' understanding of nature found in their urban environment, specifically around the school. The program consisted of 45-minute meetings, occurring once a week for four consecutive weeks during the last hour of school, in October and November of 2019. Program lessons were conducted in the students' regular classroom each of the four days except on the final day, when we took them outside to collect insects on school property.

The education group included two graduate and four undergraduate students. The undergraduate students worked in rotating groups of two to develop each day's activities using general outlines provided by the graduate student leaders. Each weekly meeting consisted of a short presentation to cover background material, followed by activities. If time permitted, the education group led the students in a discussion of information related to the day's activities. As an incentive for participating in the program, we gave students program t-shirts and art supplies.

Program Description

The schedule consisted of four separate but related days of activities. Day One started with a brief introduction of the program and researchers; the students were then asked to draw what they thought of when they heard the word "nature." We provided students with approximately fifteen minutes to complete the drawing exercise. Several students chose to share their drawings with the class before the research group collected the drawings. After the drawing exercise, the research group asked the students to sit in a circle and participate in a game toss. Students tossed a stuffed toy plant around in the group, and each student who caught the toy called out a word they associated with nature. After the game (~five minutes), the research group asked the students to create a picture of themselves as scientists using construction paper and drawing instruments provided by the research group (Figure 1a). These activities acquainted us with the students' understanding of nature before learning new facts and concepts from the UE program.

Beginning with the second week, we used an inquiry-learning model to encourage personal connections with nature among the students. Day Two focused on plants

native to northeast Ohio, especially those found in urban environments. In the presentation, we shared with students several images of plants that they might see near their homes. We also shared with students some ways plants can remove harmful toxins from the soil. Following the presentation, we provided students with trays, soil, and seeds of plants native to Northeast Ohio: switchgrass (*Panicum virgatum*), goldenrod (*Solidago canadensis*), chicory (*Cichorium intybus*), and upland cress (*Barbarea verna*). We asked each student to fill one tray with soil and encouraged the students to sow the seeds in a maze shape. We explained to the students that we would share a fun activity related to the maze the following week (Figure 1b). Students tended to the seeds and plants for two weeks in their classroom.

On Day Three, we discussed the differences between human and insect brains and why learning would be important to navigating an insect's natural environment. We then asked the students to consider how to test insect learning ability within an experiment—in a maze, for example. We discussed the types of tests that would be appropriate in a maze, such as recording the amount of time it would take an insect to complete a maze with a food reward at the end, and then directed the students to draw a maze for an insect of their choice.

The final day of the program brought all the lessons together. The research group provided students with replacement plant mazes, as needed. Prior to heading outdoors, the research group gave each student a net and a small plastic container to hold insects. The group went to a grassy slope on school grounds where the research group demonstrated proper net sweeping techniques for insect collection. After fifteen minutes of searching for insects, the students placed insects in the plant mazes and observed the insects for one minute (Figure 1d). For students unable to catch insects, we provided lady beetles (*Hippodamia convergens*) for the plant mazes. After this exercise, we released collected insects back into the same natural area and collected all lady beetles from the students. Finally, we asked the students to repeat the nature drawing exercise from Day One. This day ran longer than expected, and students had only about five minutes to complete the drawing prior to school dismissal. We collected the drawings at the end of the day.

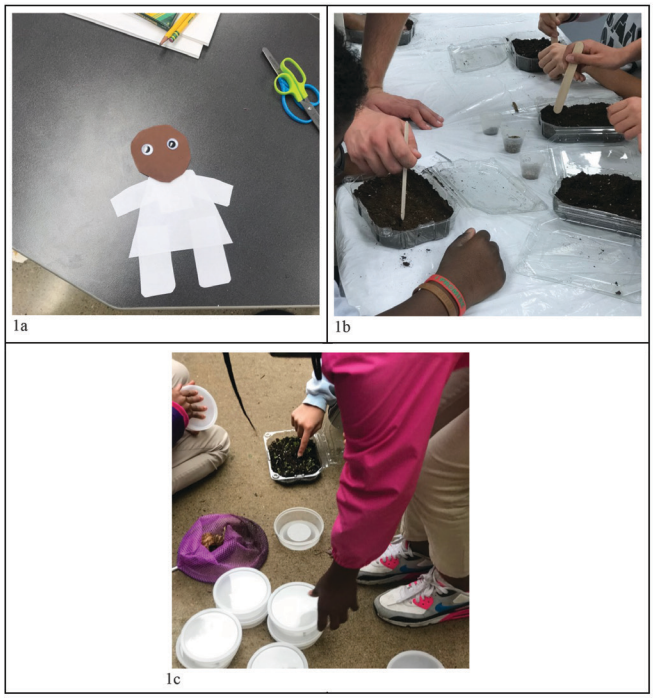


FIGURE 1. Photographs of activities students participated in during the Urban Ecologists program **1a)** A student's representation of himself as a scientist **1b)** Students planting seeds to create mazes for insects **1c)** Students placing insects in plant mazes on the final day of the program

Analysis

To evaluate the UE program, we employed a simple pre-post-intervention task. As previously stated, on the first day of the program we asked each student to draw a picture that reflected what they thought about when hearing the term "nature." We created inventories according to items represented (Sanford, Staples, &. Snowman, 2017; Flowers, Carroll, Green, & Larson, 2015). We repeated this task on the last day of the program before the students were dismissed. Because of unforeseen time constraints (see Limitations, below), we provided students with just five minutes to complete the post-program drawings. We chose to employ this evaluation method after speaking with a school liaison, who expressed concern about the ability of these children to express their opinions in written form. This type of evaluation has been successfully employed with children through eighth grade (Sanford et al., 2017).

Using an emergent thematic coding analysis, researchers analyzed each drawing and developed codes to compare pre-program drawings to post-program drawings in order to determine whether the intervention changed

perceptions of what "nature" means to the students. Because of the small sample size (n = 20), each researcher coded all drawings, and the group worked together to reach full agreement. To determine statistical significance, we used a chi-square analysis.

Results

Through our program, we planned to explore any influence that urban nature-based inquiry could have on student perspectives of urban nature. To determine any influence, we started by asking students to verbally state things that reminded them of nature. Waterfalls, trees, and animals ranked at the top of the list (17% each). For the complete list, see Table 2.

Next, we asked students to draw nature. Implementing our iterative, thematic coding analysis, we identified a variety of codes which we narrowed down into categories. (See Table 3 for a complete list of categories and codes.) Prior to being exposed to urban nature by our program, students more commonly described nature using images of Plants (37%), Celestial sphere (18%), Geology (12%), Animals (10%), Anthropic influences (8%), and/or Water (5%). Comparatively, after our program exposed students to urban nature, students most commonly described nature using images of Plants (34%) Animals (17%), Celestial sphere (14%), Geology (11%), Water (7%), Insects (6%), and/or Weather (6%). For brevity, we include only categorical themes with ≥ 5 % frequency. See Figures 2 and 3 for categorical comparisons, with frequencies.

TABLE 2. List of Words Students Use to Describe Nature

Words	Frequency (%)
Waterfall	17
Trees	17
Animals	17
Flowers	6
Plants	6
Rainbows	6
Leaves	6
Nets	6
Squirrels	6
Nature, "That's All"	6
People sit in sun	6
River	6

Comparing the results of the pre-program drawing to the post-program drawing, we observed an increase in a few categories: Animals, Insects, Water, Weather, and Animal Structures. Categories that decreased in frequency after the urban nature intervention included Anthropic influences (↓ 5%), Celestial sphere (↓ 4%), Plants (↓ 3%), and Geology (↓1%). See Figure 4 for pre- and post-program comparisons.

The most common biotic categories emerging from the drawings include Plants > Animals > Insects, regardless of proximity to the urban nature intervention (see Figure 5).

We compared the frequencies of image categories from pre-program to post-program drawings using the $p \leq 0.05$ threshold. We found no significant differences between the frequencies of image categories in the pre- and post-program drawings (chi-square $p \geq 0.176$).

FIGURE 2. Frequencies of most common nature images produced by students before the urban ecology program.

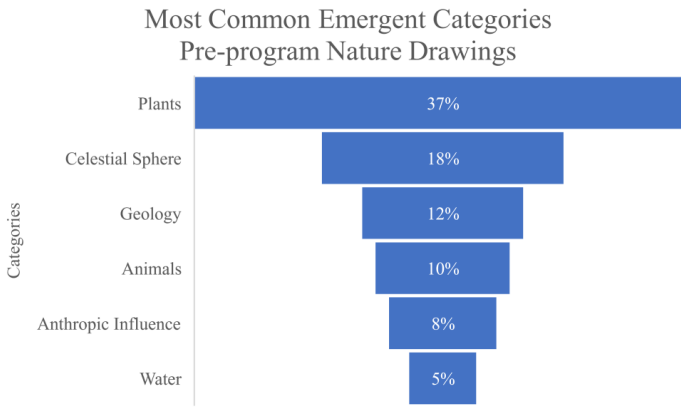


FIGURE 3. Frequencies of most common nature images produced by students after the urban ecology program.

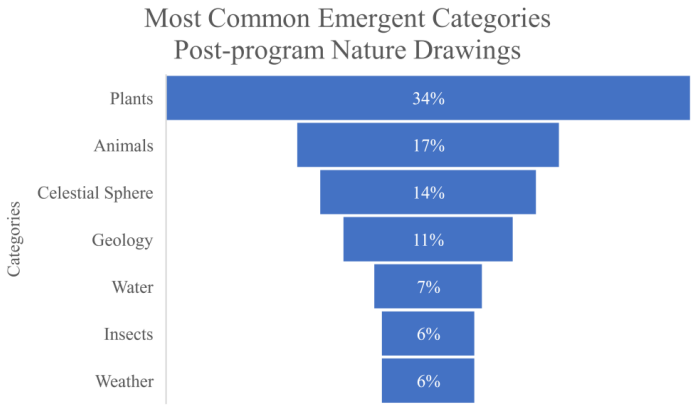


TABLE 3. List of Categories with Associated Codes

Categories	Codes
Plants	Plants
	Trees
	Fruits
	Bushes
	Flowers
	Grass
	Moss
Animals	Birds
	Amphibians
	Worms
	Reptiles
	Mammals
	Fish
Insects	Insects
	Arthropods
Celestial Sphere	Sun
	Moon
	Stars
	Rainbows
	Blue Sky
Geology	Soil
	Rocks
	Mountains
Water	Pond
	Waterfall
	River
Anthropic Influence	Buildings
	Stores
	Humans
	Trails and Parks
	Insect Nets
	Vehicles
Spiritual/Religious	Verbal explanation
Weather	Clouds
	Rain
Animal Structures	Nests
	Ant Hill

FIGURE 4. Comparison of the frequencies of nature images in the students'drawing, pre-program versus post-program. Stars indicate an increase in frequency of this category after students participated in the urban ecology program

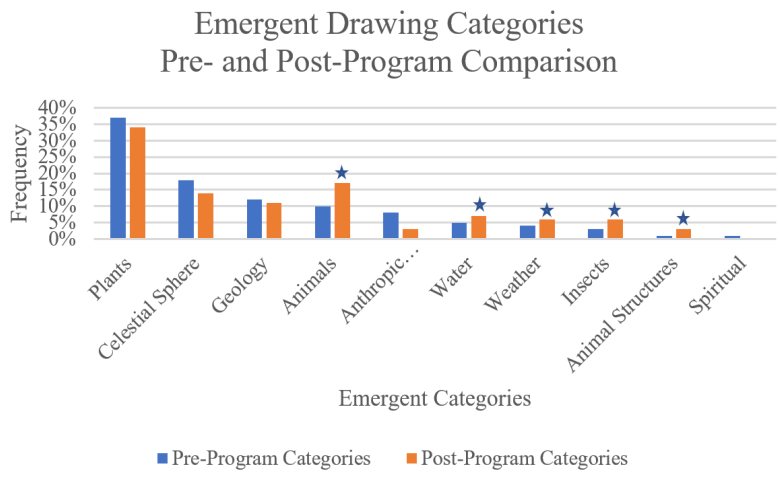
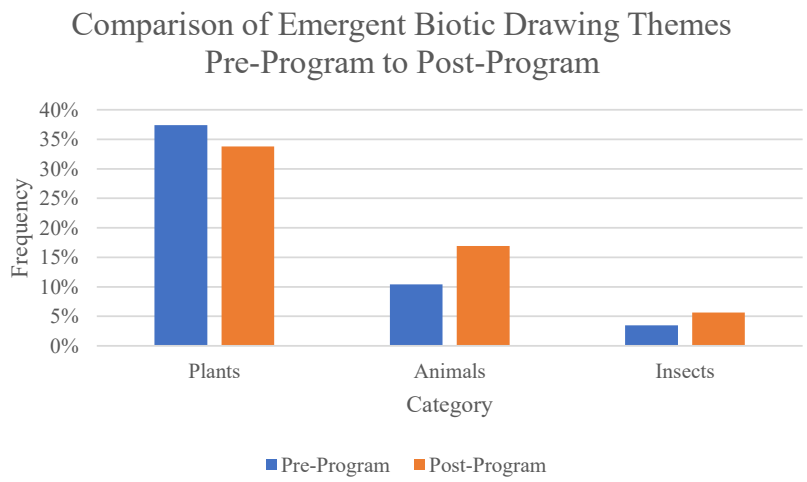


FIGURE 5. Comparison of the frequencies of biotic images in the student drawing, pre-program to post-program.



Discussion

The results of our study provide some indication that an urban nature-based intervention could influence the nature perspectives of young urban public-school students. Before experiencing urban nature, students most often associated nature with plants, the celestial sphere, geology, animals, anthropic influences, and water, based on student drawings. Following the urban nature experience, the most commonly drawn images included plants, animals, the celestial sphere, geology, water, insects, and weather. (Note: in the post-program drawings, insects and weather images both occurred with 6 % frequency.) After the intervention, the frequency of animals and insects increased.

The category Animals included birds, amphibians, worms, reptiles, mammals, and fish. During our time outdoors, students visually observed or physically interacted with several species of animals.

For example, students saw birds, such as robins, on the ground. As we turned over rocks, we found amphibians, such as salamanders. Many students became very excited to observe, study, and touch the salamander. Many, if not all, had never seen a salamander in real life prior to this experience. Now students understand that finding salamanders in nature is as easy as turning over a rock or a log.

The category Insects included all insects and other arthropods, such as spiders, lady beetles, ants, and butterflies. During our time indoors, we taught students about plants and insects, encouraging students to build plant mazes for insects to traverse. During our time outdoors, we taught students proper insect collection techniques (net sweeping and hand collection) and provided lady beetles for students to introduce into plant mazes on the last day of the program. Students had opportunities to visually observe or physically interact with several species of insects and arthropods. In addition to the lady beetles supplied by us, students observed ants, spiders, and more. Many students appeared to enjoy working with these organisms, and some even changed perspectives once given the opportunity to touch an insect.

When comparing pre-program drawings to post-program drawings, we identified a shift from an idealized view of nature (Figures 6a and 6b) to one that included items observed by students during the outside portion of the program (Figures 6c and 6d). The increase in the frequency of animals and insects on the post-program drawings, compared to the pre-program drawings, suggests the success of our program in influencing student perspectives of nature. Prior to our program, students less frequently included animals and insects in drawings of nature. After students had directly experienced urban nature via our program, the frequency of animals and insects included in drawings increased.

The categories that decreased in frequency between pre- and post-program include Anthropic influences (↓5%), Celestial sphere (↓ 4%), Plants (↓ 3%), and Geology (↓ 1%). Anthropic influence saw the greatest decrease (approaching significance at the $p \leq 0.10$ threshold with $p = 0.176$). Contrastingly, the p-values for the other decreasing categories calculate well above the 0.1 threshold with p-values ≥ 0.5). While we cannot boast any significant difference between the frequency of these changes between pre- and post-program drawings, the decrease

FIGURE 6. Examples of pre- and post- program drawings by students. **6a** and **6b** were drawn on the first day before the program began and show a more idealized version of nature with exotic animals (giraffe) and uncommon weather (rainbow). **6c** and **6d** were completed at the end of the program and show examples of creatures encountered by the students during the outdoors part of the program (worm, ants, ladybug).

in frequency might be enough to suggest perspective changes among the students. This could be important if we consider that the students might less frequently associate anthropic influences, such as buildings and vehicles, with the natural world in urban environments. This is an important outcome for our program.

It is worth noting that our results failed to determine any statistically significant differences between the pre-program and post-program drawing renditions. We suspect two factors contributed to this result. First, we had a relatively small sample size. This is typical of classroom-based interventions. To obtain statistical significance, we would increase our sample size by offering this program in other urban fifth-grade classrooms. Second, the time allotted to students for the post-program drawing activity differed from the pre-program drawing activity. For the post-program drawing, students received approximately five minutes to complete the activity, compared to fifteen minutes for the pre-program drawing. We discuss this in greater detail in Limitations, below. However, even without obtaining statistical significance, we find our results to be thought-provoking; we believe they indicate that nature-based interventions influence student perspectives of nature.

Limitations

We experienced a few limitations to our study methods and analysis. When we designed the program, we planned to use our final day with the students to take them outdoors to interact with nature. We also planned to use this day to implement the post-program drawing exercise. However, we failed to realize the length of time each of these activities would take, including preparing students for outdoor time by putting coats on and navigating students to and from the outdoor area. As well, the children needed time to prepare for end-of-day dismissal. Having facilitated the learning activity, we ran short of time for the drawing exercise. This resulted in significantly less time for students to provide detailed drawings (down from 15 minutes to five minutes), compared to the pre-program drawings (down from 115 items to 71 items). One student failed to complete the drawing given the rush at the end of the day. For future studies, we discussed different possibilities, including adding a day to the program strictly for evaluation and unpacking the experience. Another possibility would be asking the teacher to provide students with time to complete the drawing on a subsequent day.

Another limitation we experienced was some difficulty interpreting the drawings without the students present. During the drawing exercises, our staff interacted with students to gather more information on some of the drawings. These staff members made notes on these drawings to help guide our coding methods. However, we were not able to talk directly with each student during both pre- and post-exercises given our short time with them. This led to a bit of uncertainty as we attempted to analyze the drawings. For future studies, we believe it could be helpful to invite each student to explain drawings verbally or by writing on the drawing itself. Researchers and educators would need to assess age-related and cognitive abilities when deciding on the best strategy for each group of students.

Future Directions

We believe this is a program that can continue to develop and expand to additional classrooms, with some improvements. As stated above, we would add a fifth day to the experience as a final wrap-up session with the students. This would allow us to capture more detail in the final assessment and would also include discussion time in the classroom to tie all of the program days together. We could also expand the amount of planning by the undergraduates for each day's activities, to give them more experience in creating informal education programs. Finally, we would move the program earlier in the school year when the insects are naturally more plentiful. Overall, this is a promising pilot that has the ability to grow into a larger, recurring outreach program.

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About the Authors

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Carrie Buo is an Integrated Biosciences doctoral candidate and Mentoring Fellow at The University of Akron. Her research focus is on informal educational experiences for children, animal behavior, and molecular biology. She is the creator of Camp Bioscience, a summer camp program for gifted upper-elementary children at the University of Akron's Field Station. *buocl@yahoo.com*.

References

Ardoin, N. M., Gould, R. K., Lukacs, H., Sponarski, C. C., & Schuh, J. S. (2019). Sense of place among urban dwellers. *Ecosphere*, 10(9), e02871.

Berkowitz, A. R., & Hollweg, K. S. (1999). Understanding urban ecosystems: A new frontier for science and education. *Urban Ecosystems*, 3, 3–4. doi:10.1023/A:1009565627087

Camasso, M. J., & Jagannathan, R. (2018). Nurture thru nature: Creating natural science identities in populations of disadvantaged children through community education partnership. *The Journal of Environmental Education*, 49(1), 30–42. doi: 10.1080/00958964.2017.1357524

Dillon, J., Rickinson, M., Teamey, K., Morris, M., Choi, M.Y., Sanders, D., & Benefield, P. (2006). The value of outdoor learning: Evidence from research in the UK and elsewhere. *School Science Review*, 87(320), 107–111.

Flowers, A. A., Carroll, J. P., Green, G. T., & Larson, L. R. (2015). Using art to assess environmental education outcomes. *Environmental Education Research*, 21(6), 846–864. doi:10.1080/13504622.2014.959473

Frumkin, H. (2001). Beyond toxicity: Human health and the natural environment. *American Journal of Preventative Medicine*, 20(3), 234–240.

Harnik, P. G., & Ross, R. M. (2004). Models of inquiry-based science outreach to urban schools. *Journal of Geoscience Education*, 52(5), 420–428. doi:10.5408/1089-9995-52.5.420

Hurtado, S., Cabrera, N. L., Lin, M. H., Arellano, L., & Espinosa, L. L. (2009). Diversifying science: Underrepresented student experiences in structured research programs. *Research in Higher Education*, 50(2),189–214. doi:10.1007/s11162-008-9114-7

Kirnan, J., Ventresco, N. E., Gardner, T. (2018). The impact of a therapy dog program on children's reading: Follow-up and extension to ELL students. *Early Childhood Education Journal*, 46,103–116.

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common Core State Standards* (English Language Arts Standards, Reading, Informational Text, Grade 3).

NGSS Lead States. (2013). *Next generation science standards: For states, by states. Life Sciences*. Washington, DC: National Academies Press.

Nisbet, E. G., & Sleep, N. H. (2001). The habitat and nature of early life. N*ature*, 409, 1083–1091.

Rowland, R. (2017). Biomimicry step-by-step. *Bioinspired, Biomimetic and Nanobiomaterials*, 6(2),102–112.

Seymour, V. (2016). The human-nature relationship and its impact on health: A critical review. *Frontiers in Public Healt*h 4:260.

Sanford, R. M., Staples, J. K., & Snowman, S. A. (2017). The draw-an-ecosystem task as an assessment tool in environmental science education. *Science Education and Civic Engagement*, 9(1), 35–40.

Swall, A., Ebbeskog, B., Hagelin, C. L., & Fagerberg, I. (2017). Stepping out of the shadows of Alzheimer's disease: A phenomenological hermeneutic study of older people with Alzheimer's disease caring for a therapy dog. *International Journal of Qualitative Studies on Health and Well-Being*, 12(1347012), 1–8.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, 224(4647), 420–421.

UNICEF. (2012). *The state of the world's children 2012: Children in an urban world*. Retrieved from https://www.unicef.org/sowc2012/

Valentine, S. 2016. The human-nature relationship and its impact on health: A critical review. *Frontiers in Public Health*, 4(260), 1–12.

RESEARCH PROJECT

Integrating Feminist Pedagogy into Science Teacher Education

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Abstract

With a growing need to give underrepresented populations equitable opportunities in science, less traditional pathways for science instruction must be considered. Incorporation of feminist pedagogies into secondary science teacher education provides an opportunity for pre-service teachers (PSTs) to help underrepresented minority groups connect to and build an interest in science. A civic engagement project was designed for undergraduate students in a capstone course in a Women and Gender Studies program, in which students were charged with identifying and interviewing a person in their dream career who was involved in feminism. This paper discusses the responses from an interview with a secondary science education methods professor with an intersectionality as an African-American female scientist in a predominately White institution in the Midwest. The interview focused on how different feminist principles affected her goals for the science education courses she teaches, and included a critical analysis and discussion of activities completed in the secondary methods course. In this paper we discuss how a secondary science methods course grounded in inclusionary feminist principles led to the development of activist pre-service science teachers with a commitment to representation and to recognition and discussion of

bias. The data supporting the project are excerpts from the interview questions as well as specific activities implemented in the secondary science methods course that influenced the first author's lesson plan development and philosophy of teaching. Clearly, experiences for PSTs that are grounded in exposure to and awareness of pre-service teacher activism, representation, and recognition and discussion of bias are necessary if we are to create equitable opportunities and to foster an interest in science that is accessible to all students and teachers.

Keywords: feminist pedagogy, secondary pre-service teachers, activism, secondary science education, feminism, inclusion, diversity, STEM

Introduction

The purpose of this paper is to discuss how incorporation of feminist pedagogies and principles such as representation, recognition, discussion of bias, and science educator activism in a secondary science methods course provides a framework for future science educators. The current demographics of the STEM workforce reveal that Black and Hispanic workers are underrepresented, and this indicates a need to ensure that STEM pedagogy is made available to underserved students (Funk & Parker, 2019). Teachers are on the front lines when it comes to encouraging and fostering student interests and must therefore be prepared to meet the diverse needs and experiences of the students in their classrooms. In science education, minority representation is lacking in both the curriculum and in those who teach it. Over 90% of science educators are White, and in the progression from middle school to high school, the percentage of female teachers in science drops from 70% to 54% (Wilson, Schweingruber, & Nielsen, 2015).

Uplifting the next generation of scientists and science educators starts with breaking the cycle of traditional teaching methodology, in which White teachers are prepared to inspire only White students. This shift can occur through applying feminist pedagogy to science education. Many feminist scholars of science education desire a change in how and what students are taught—with a shift in favor of inclusive practices and curricula that encourage underrepresented populations to connect and thrive in science (Brotman & Moore, 2008; Capobianco, 2007; Richmond, Howes, Kurth, & Hazelwood, 1998). Another feminist scholar Karan Barad (2001, p. 237) argues that most scientific literacy projects have failed because society is so scientifically illiterate and believes that scientific literate information is irrelevant. Thus, attempting to help students see science as significant to their lives is paramount and requires practices that fully engage them with the nature of science as a social process (Barad, 2001). This feminist and African-American professor attempted to move toward these goals in her secondary science methods course. The project, called the Training Future Scientist Program (TFS), is embedded in a secondary methods course using culturally responsive teaching and feminist pedagogies to explore how these pedagogies can influence traditional White secondary science pre-service teachers (PSTs) who will teach secondary students during student teaching and in their future classrooms.

This paper highlights how integration of feminist pedagogy into a secondary science methods course will prepare secondary PSTs with the skills they need to foster a passion for science in all students. Using this pedagogy will equip these future secondary school teachers with the tools they need to motivate students who are often underrepresented in the STEM curriculum and in the STEM workforce. For our discussion, "underrepresented" includes both females and students of diverse ethnic groups.

Feminist Pedagogy in PST Education

There are many different approaches to the incorporation of feminist pedagogy into science education. Broadly defined, "the tenets of feminist praxis [are combined] with the principles of science teaching" (Barad, 2001, p. 3); at its core, feminist pedagogy focuses on utilizing educational practices that support the diverse needs and experiences of all students, while examining and dismantling the biases within the current educational system (Capobianco, 2007). Examples range from (a) incorporating practices that encourage more female participation and (b) utilizing methods with an emphasis in activism, to (c) analyzing what aspects of science education are currently excluding women and minorities (Capobianco, 2007). Teo (2014) reports newer approaches toward feminist studies

in science education that focus on activism, in which feminist principles like intersectionality, identity, and positionality are used to empower students to take control of their understanding of science. Jackson and Caldwell (2011) attempted a project for non-major biology students that coupled the Science Education for New Civic Engagements and Responsibilities (SENCER) approach with feminist pedagogy. The goal of this project was to encourage students to (a) investigate the production of knowledge, (b) participate in construction of knowledge, and (c) apply these skills to issues requiring civic engagement and responsibility. Through the connection of civic importance to science information, many students gained increased confidence and engagement with the material (Jackson & Caldwell, 2011). Our goal of implementing feminist pedagogy in PST education is similar to the goals of the Jackson and Caldwell project, and includes making the content and connections meaningful and relevant to students and their community.

Our idea of feminist pedagogy for PST education draws upon all students' interests, experiences, and preconceptions. We want to validate the voices and experiences of all, while challenging oppressive practices and structures that are currently in place, in order to eliminate the historic inequity found within the education system (Capobianco, 2007). With that foundation, our PST education would incorporate the following four approaches presented by Brotman and Moore (2008) in an effort to engage underrepresented populations more effectively and meaningfully in science: (a) equity and access (the need to eliminate inequities and provide equitable science opportunities in the classroom), (b) curriculum and pedagogy (changing what is taught to include the experiences, learning styles, and interests of all students), (c) reconstructing the nature and culture of science (changing how science is viewed and defined in school and society), and (d) identity (encouraging all students to incorporate science as a component of their identity) (Brotman & Moore, 2008).

Description of the Interview

For a capstone course in a Women and Gender Studies program, the students were given the following charge: *Identify and interview a person in your dream career involved in feminism.* The first author selected the second author, a Black female secondary science methods assistant professor, because the experiences he had in her secondary science methods course and her research interests published on the university's website included "[providing] authentic science instruction to underrepresented students in grades K-5, by preparing elementary science PSTs in SCI 397" (Ball State University, 2020). This decision led to an interview and post-interview discussion concentrated around how science methods courses can authentically prepare PSTs to recognize and discuss bias, as well as to promote inclusivity in their future classrooms.

The interview included seven questions to reveal how feminist principles including diversity, inclusion, ethnicity, and gender contributed to her pedagogical reasoning. The questions were as follows:

1. What influenced your decision to become a science educator?
2. When and how did you develop an interest in creating a more positive space for underrepresented students in science classrooms?
3. What do you believe are the biggest issues schools are facing in terms of inclusion and diversity?
4. What are your recommendations for how science teachers can get more students, especially minority students, interested in further pursuing science?
5. How have race/ethnicity and gender impacted your goals and career path up to this point?
6. Do you consider yourself a feminist? Do you consider your work to be contributing to feminism?
7. If you could offer two pieces of advice to future science educators looking to pursue a similar pathway (i.e. increasing diversity in the science education classroom, getting more minority/ underrepresented students interested in science,…etc.) what would they be?

Following the interview, four projects that highlighted feminist principles the first author participated in while in the second author's secondary methods course were also discussed. Brief summaries of the projects are provided below.

- **"Shadow-A- Scientist":** Each student identified a STEM research interest, chose a scientist at the

university to shadow and spent a minimum of 12 hours working alongside the scientist in their research lab.

- **DAST (Draw-a-Scientist Test)**: Each student drew a scientist and chose a skin-colored crayon to shade in the reverse side of the image. An analysis and discussion of the images drawn, and colors chosen followed the assignment.
- **Black History Month Bingo:** Trivia presented during each class throughout the month of February educated students about prominent African Americans across many different career fields. Students actively participated in discussion and in a process of determining the identified person on their bingo board.
- **Precision versus Accuracy Lab:** Students were given a ruler and a block and asked to take measurements of the length, width, height, and volume. The measurements were compared to the expected results, followed by a discussion of why discrepancies occurred.

Outcomes of the Interview

Analysis of the responses to the interview questions and the activities completed in the course revealed three major themes that should be addressed in PST science methods courses. These themes include representation, recognition and discussion of bias, and creation of activist science educators.

Representation

In the interview, the following responses involved representation:

Responses

1. *"I was the first African American and female to earn a Ph.D. in my program and I am the first African American to pursue a tenure-track position in the biology department at BSU. So, a lot is riding on my success so I have to make it so others know they can do it."*

2. *"My ethnicity and gender have provided me access since being an African-American female places me in a diverse and marginalized group to earn a Ph. D. and work at a predominantly white university."*

3. *"Most of my work focuses on reducing the fears of White female PSTs to teach underserved diverse groups with confidence and competency.... I am producing teachers that are not afraid to work with diverse underserved groups."*

In her responses, Dr. Robinson-Hill focuses on how representation has affected her life firsthand (Response 1 & 2) and on the positive impact she is trying to make within the education system (Response 3). The experiences she has had throughout her career have allowed her to recognize the changes needed to create PSTs who are not only prepared to teach underrepresented groups (Response 3) but who can also inspire them to pursue careers in STEM themselves. Women and other underrepresented groups are often disinclined to choose careers in STEM because of the lack of role models (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001; Brickhouse, Lowery, & Schultz, 2000). Thus, having a Black and female professor for this secondary science methods course could potentially impact both underrepresented demographics of PSTs and inspire their future students to pursue a career in STEM. Boumlik, Jaafar, and Alberts (2016) have alluded to the important influence that role models in higher education can have on students' future academic and career choices. Research has also shown that a more diverse population of science educators can encourage PSTs of color to be more committed to multicultural teaching, social justice, and providing children of color with academically challenging curriculum (Sleeter, 2001, p. 95). Thus, diverse PST educators could lead to a more diverse population of teachers: the cyclical advancement begins when students also learn and connect to STEM because they see themselves represented (Brickhouse et al., 2000).

With her understanding of the need for representation in PST education courses, the second author implemented two activities mentioned above, "Shadow-A- Scientist" and Black History Month Bingo. Incorporation of the "Shadow-A-Scientist" project allow PSTs to be paired with professionals and share in an authentic and positive research experience. This firsthand research experiment and mentorship can affirm PSTs' commitment to pursuing careers in STEM, as it did for the first author. Estrada, Hernandez, and Schultz (2018) have also shown that authentic science research and mentorship have a

positive impact on underrepresented minorities who pursue STEM careers, and thus, recreating this experience in the PST's future classroom, can provide students with a reciprocal learning opportunity. The other representation activity, Black History Month Bingo, can serve as both an implicit and an explicit representation instructional activity, focused on highlighting the achievements and exceptionalities of hidden figures in a minority community. The adaptability of the activity for other meaningful cultural awareness months, including LGBTQ Pride, Women's History, Hispanic Heritage, and more, allows for in-depth coverage of many areas of diversity.

Recognition and Discussion of Bias

In the interview, the following responses involved recognition and discussion of bias:

Responses

1. *"What influenced me to become a science educator were the fears I saw in many of the White female teachers that were hired by my school district in STL. I felt I had the secret to their success in my tool belt, so I decided to leave secondary education and become a professor to train future teachers in grades K-12 that desire to work with underserved diverse groups."*

2. *"My desire to create a positive space for underserved students in science classrooms was to motivate these students to want to do science by allowing them a space to do science without being judged if they did not get the right answer."*

In further discussion of her responses, Dr. Robinson-Hill said that the secret to the success she had with her White female PSTs (Response 1) was providing them with an education grounded in authentic learning experiences coupled with activities preparing them to work and learn with underserved students. Many White PSTs do not understand the level of inherent bias and discrimination, especially regarding race/ethnicity (Sleeter, 2001). The DAST activity brought this phenomenon of inherent bias to light by exposing the stereotypes we hold about those who pursue science. As seen in other studies, even at a young age many students hold masculine ideals of a scientist (Brotman & Moore, 2008). The other bias that was analyzed by this activity was ethnicity. The crayons chosen represented skin tones, and the first author, as did much of the class, chose a color that closely resembled his own skin tone. This in combination with the drawings, allowed for an in-depth discussion about our subconscious association with things that are similar and how to be cognizant of our own inherent biases around gender and ethnicity.

Bias can be seen outside of gender and racial categories as well, as is exemplified by the Precision versus Accuracy lab. The Precision versus Accuracy lab addressed assumptions and misconceptions in science education regarding previously obtained knowledge. Even though using a ruler is a presumed basic skill, this activity revealed to the first author the diversity of knowledge on how to read and use a ruler, and thus the possibility for misunderstanding and confusion. This experience resulted in the first author's recognition of the inherent value of beginning a lesson with a basic fundamental skill review that provides every student an equitable foundation. Dr. Robinson- Hill mentioned in their discussion how the Precision versus Accuracy lab was so important in creating the infrastructure for success in a science classroom. Through this activity, Dr. Robinson-Hill instilled in the first author the need to provide students the opportunity to learn—no matter what their previous background knowledge—while supporting them through success and failure without judgement (Response 2). Creating an equitable base for all students to build their knowledge upon while thwarting biases is a central approach of our feminist pedagogy.

Creation of Activist Science Educators

In the interview, the following responses involved the creation of activist science educators:

Responses

1. *"The biggest issue we are facing in schools in terms of inclusion and diversity is the lack of access to authentic science instruction for diverse populations of students."*

2. *"Some possible recommendations for how science teachers can get more diverse students interested in pursuing science is allowing them access to*

inquiry-based science in their schools, then access to authentic science experiences in the summer at BSU and other universities."

3. *"Two pieces of advice I would give to future science education majors would be: 1) to make sure you advocate for diverse students in your school to have access to science and science enrichment opportunities: and 2) make sure you stay connected to university researchers that are willing to invite secondary students and/or teachers into their lab to perform research."*

The theme of activism was present in Dr. Robinson-Hill's responses through her determination to provide her students, and especially her underserved students, with the best possible instruction, (Response 1 and 3). Teacher preparation programs that emphasized advocacy for students and families and incorporated it into fieldwork led to PSTs who were advocates both in and out of the classroom (Whipp, 2013). By getting more underrepresented students interested in STEM, we create growth in schools and in the community. When students of color choose to pursue STEM, the experiences are usually service oriented, affording these students with opportunities to volunteer and participate in their communities (McGee & Bentley, 2017).

Dr. Robinson-Hill also instilled authentic science opportunities through guided and open inquiry (Response 2). Inquiry-based lessons focus on student engagement and give students the opportunity to find solutions through individual input and collaboration. Inquiry lessons allow teachers to function as facilitators of high-quality prompts while not dominating the classroom conversation (Bulba, 2015). It is highly effective in conjunction with feminist pedagogy, where teachers function as collaborators, negotiators, and facilitators (Capobianco, 2007). This process can amplify student voices and provide associated mentorship, which leads to students' investing in and impacting their own education.

It was important to analyze the topics of representation and bias in order to allow the first author, a White male secondary PST, the chance to grasp the value of advocating for and becoming an activist educator for underrepresented students. Studies have shown that many White PSTs rarely discern discrimination, especially racism, and these challenges can then appear in the classroom (Sleeter, 2001). It has also been noted that many PSTs and in-service teachers have low efficacy in terms of teaching African-American children successfully (Sleeter, 2001). Discussion about representation, bias, and equity are essential if PSTs are to appreciate the needs of all students and thus properly educate and advocate for them. Having a secondary methods course that incorporates modeled activities with a basis in the three themes mentioned above allows for the success of PSTs, especially those who are White, in realizing the changes that need to occur within science education in order to influence underrepresented groups to enter. This realization also comes with understanding the importance of transferring the knowledge and skills learned in their teacher preparation programs to their future classrooms.

Conclusion

As a result of this entire process, the first author realized the value of connecting research to real-life practice. The meaningful connections in one-on-one conversations with professionals in the field can have a greater impact on teacher pedagogy than traditional classroom instruction. The interview was an epiphany in the first author's own understanding of science education and comprehension of the skills needed to improve as a future science educator. Boumik et al. (2016) found that perceptions of gender inequalities in the sciences are related to a person's attitudes and behaviors, and, especially if their culture is different from the majority culture, this can impact their viewpoint in specific sectors of STEM. Indeed, further research may show that inclusion of personal reflection and direct interaction with passionate secondary science methods professors could have a significant impact on skill development and the future success of secondary science PSTs. Potential outcomes from these relationships might include the creation of meaningful experiences, the ability to directly relate to students, and an opportunity to bring real-world meaningful experiences into the classroom.

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References

Ball State University, Department of Biology, Biology Department. (2020). *Rona Robinson-Hill.* Retrieved from https://www.bsu.edu/academics/collegesanddepartments/biology/about/faculty-staff/biofaculty/robinsonhillrona

Bandura, A., Barbaranelli, Caprara, G, & Pastorelli, C. (2001) Self-efficacy beliefs as shapers of children's aspirations and career trajectories. Child Development (72), 187-206. doi: 10.1111/1467-8624.00273.

Barad, K. (2001). Scientific literacy → agential literacy = (learning + doing) science responsibility. In M. Mayberry, B. Subramaniam, and L. Weasel (Eds.), *Feminist science studies: A new generation*, 226–246. New York, NY: Routledge.

Boumlik, H., Jaafar, R., & Alberts, I. (2016). Women in STEM: A civic issue with an interdisciplinary approach. *Science Education and Civic Engagement, 8*(1), 66–88.

Brickhouse, N., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching, 37*(5), 441–458.

Brotman, J. S., & Moore, F. M. (2008). Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching, 45*(9), 971–1002. doi:10.1002/tea.20241

Bulba, D. (2015, November 10). What is inquiry-based science? Retrieved from https://ssec.si.edu/stemvisions-blog/what-inquiry-based-science.

Capobianco, B. M. (2007). Science teachers' attempts at integrating feminist pedagogy through collaborative action research. Journal of Research in Science Teaching, 44(1), 1–32. doi:10.1002/tea.20120

Estrada, M., Hernandez, P. R., & Schultz, P. W. (2018). A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. CBE—Life Sciences Education, 17(1). doi:10.1187/cbe.17-04-0066

Funk, C., & Parker, K. (2019, December 31). Diversity in the STEM workforce varies widely across jobs. Retrieved from https://www.pewsocialtrends.org/2018/01/09/diversity-in-the-stem-workforce-varies-widely-across-jobs/

Jackson, J. K. & Caldwell, J. (2011). Feminist interventions in less than feminist spaces applying feminist pedagogies to the large non-majors science classroom. *Science Education and Civic Engagement, 3*(1), 26–35.

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), 1–36. doi:10.1086/693954

Richmond, G., Howes, E., Kurth, L., & Hazelwood, C. (1998). Connections and critique: Feminist pedagogy and science teacher education. *Journal of Research in Science Teaching, 35*(8), 897–918. doi:10.1002/(sic)1098-2736(199810)35:83.0.co;2-p

Science Education for New Civic Engagements and Responsibilities. (2016–2017). *SENCER*. Retrieved from www.sencer.net

Sleeter, C. E. (2001). Preparing teachers for culturally diverse schools. *Journal of Teacher Education, 52*(2), 94–106. doi:10.1177/0022487101052002002

Teo, T. W. (2014). Inside versus outside the science classroom: Examining the positionality of two female science teachers at the boundaries of science education. *Cultural Studies of Science Education, 10*(2), 381–402. doi:10.1007/s11422-014-9581-4

Whipp, J. L. (2013). Developing socially just teachers: The interaction of experiences before, during, and after teacher preparation in beginning urban teachers. *Journal of Teacher Education, 64*(5), 454–467. doi:10.1177/0022487113494845

Wilson, S. M., Schweingruber, H. A., & Nielsen, N. (2015). Science teachers learning: Enhancing opportunities, creating supportive contexts. Washington, DC: The National Academies Press.Saint Vincent College

REVIEW

Pandemic Reading Roundup

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For almost 12 months, we have been living through the worst pandemic in more than 100 years. During that time, much has been written about the SARS-CoV-2 virus and COVID-19, especially by journalists writing for various media; I have been particularly impressed by the work of Ed Yong *(The Atlantic)*, Kai Kupferschmidt *(Science)*, and Carl Zimmer *(The New York Times)*. But now we are seeing books being published on COVID-19, and it is some of those that I want to look at more closely.

Raul Rabadan's *Understanding Coronavirus* (Cambridge University Press, 2020) is designed, as the title suggests, to help the reader comprehend some of the basic science involved in the coronavirus pandemic. The publisher describes the book as "a concise and accessible introduction to all the science and facts you need to understand how the virus works." That turns out to be a good description of the book. Rabadan is a Professor of Systems Biology and Biomedical Informatics at Columbia, and he describes the book as his attempt to inform a general reader (one who has very limited knowledge of biology, virology, or epidemiology) about the basic science important to understanding the pandemic. In 94 pages, he provides an overview of the molecular biology and epidemiology of the virus, a little bit of genomics connected to SARS-CoV-2 origin and evolution, and comparisons to other respiratory viruses like influenza and the coronavirus responsible for the 2003 SARS outbreak. There is also a chapter at the end that looks at therapeutic options such as drugs or vaccines, although I found it much more dated and incomplete than other parts of the book. Readers interested in learning more about the vaccines currently being deployed will have to look elsewhere, as the

chapter's description of vaccines is restricted to general concepts applicable to any vaccine. My second criticism of the book is the small size of some of the graphics, particularly some that portrayed genomic relationships. The organization of chapters and subsections as a series of questions makes it easier for readers to find information. I'm not sure how easy it would be for the general public to understand everything in the book; to me it seemed that a background equivalent to college general biology would be needed to grasp all the ideas that Rabadan presents. But for STEM faculty, particularly those in biology or chemistry or environmental science, I see Understanding Coronavirus as a useful way to get basic background information on epidemiology and virology.

Apollo's Arrow: The Profound and Enduring Impact of Coronavirus on the Way We Live by Nicholas Christakis (Little, Brown Spark, 2020) and *COVID-19: The Pandemic that Never Should Have Happened and How to Stop the Next One* by Debora MacKenzie (Hachette Books, 2021) take very different approaches than Rabadan. Both Christakis and MacKenzie set out to contextualize the experience of the COVID-19 pandemic. Christakis is a physician and sociologist on the faculty at Yale, where his research, as described on his group's website, "focuses on how human biology and health affect, and are affected by, social interactions and social networks." Not surprisingly, he takes an expansive approach to understanding COVID-19, one that places the current pandemic in the context of how humans have responded to pandemics and disease outbreaks over the past 2500 years. *Apollo's Arrow* is wide ranging in the different aspects of the current pandemic that it examines. Medicine, public health, social interactions, network science, human psychology, economics, and policy are all explored in this book. The last two chapters look forward to how the pandemic may end and how global society was changed by the experience. But Christakis is not a dispassionate narrator simply describing the events that happened; throughout the book he incorporates sharp and appropriate criticisms of how governments and organizations responded to the COVID-19 pandemic. When I finished *Apollo's Arrow,* I felt that I had gained a much broader and nuanced understanding of how pandemics, including the current one, impact human lives and societies. I also realized that while humanity has in some ways made significant progress since the Black Death of the Middle Ages, in other ways we seem to make the same mistakes again and again.

MacKenzie is a European science writer who has written for The New Scientist for many years, including articles on the subject of infectious diseases. She uses a different framework for her overview of the COVID-19 pandemic, placing it in the context of how we deal with emerging pathogens. Her narrative of how the current pandemic unfolded is connected much more to recent outbreaks such as the 2003 SARS and Ebola outbreaks than is Christakis's book (although *Apollo's Arrow* does make some reference to the first SARS outbreak). She also incorporates how governments around the world and international organizations have tried (with widely varying degrees of success) to be prepared for future pandemics. Like Christakis, MacKenzie is very critical of what she views as mistakes and oversights that contributed to the severity and global toll of COVID-19. As the title *COVID-19: The Pandemic that Never Should Have Happened and How to Stop the Next One* suggests, the book also looks at what actions need to be taken on a global scale to ensure that the world is prepared for the next pandemic. MacKenzie makes it very clear in her book that the question is not "Will there be another pandemic?" The question is when it will happen, and will the pathogen be one that we have encountered in the past or a new one that will have jumped from an animal to humans.

I found both *Apollo's Arrow: The Profound and Enduring Impact of Coronavirus on the Way We Live* and *COVID-19: The Pandemic that Never Should Have Happened and How to Stop the Next One* well worth reading. For STEM faculty teaching courses with a focus on microbiology and emerging infectious diseases, MacKenzie's book may be slightly preferable. On the other hand, faculty teaching courses with a broader focus (courses for nonscience majors, first-year seminar courses) may find Christakis's book more useful. Personally, I'm happy that I have both of them on my bookshelf.

While Christakis and MacKenzie set out to describe what happened and contextualize the events of the COVID-19 pandemic, two other books are more focused on just the analysis. Richard Horton is the longtime editor of *The Lancet*, a British weekly medical journal that is one of the oldest in the world. In June, he published *The COVID-19 Catastrophe: What's Gone Wrong and How to*

Stop It Happening Again (Polity Press, 2020), which may be best described as a combination of analysis and polemic. The dictionary definition of polemic is "an aggressive attack on or refutation of the opinions or principles of another"; as a longtime advocate for the importance of global public health, Horton is well prepared to present an aggressive refutation of how the world responded to COVID-19. He uses as examples how different countries responded to the pandemic, although he provides more details about actions/inactions in the US, UK, and China. Consequently, reading Horton's book may help US readers develop a better sense of how similar or dissimilar government reactions to COVID-19 were in different countries. *The COVID-19 Catastrophe* doesn't go into as much detail about global responses to other pandemics as MacKenzie's book does. When Horton does make comparisons between COVID-19 and other pandemics, it is typically to the SARS outbreak of 2003 and what was learned from that. The book was published in June 2020 and presents Horton's scathing critique of government responses to COVID-19 in the first six months of the pandemic. In the last two chapters of the book, Horton looks at the implications of COVID-19 for society in general, particularly in regard to the problem of inequality. I found the argument and analysis in this section significantly less compelling than the earlier sections of the book. A major difficulty is that Horton's argument comes across as much more abstract, theoretical, and unevenly supported. Faculty may find the *The COVID-19 Catastrophe* worth reading as one person's analysis of the mistakes that were made and how countries should respond differently in a future pandemic, but I think there is significant overlap between this book and the one by MacKenzie.

In *The Pandemic Information Gap: The Brutal Economics of COVID-19* (MIT Press, 2020), Joshua Gans approaches the pandemic from the perspective of economics. A recurring theme in his analysis is that responding to COVID-19 is, in many ways, an information problem. How do we know who has been exposed, who is infected, and who is capable of infecting others? Another recurring theme is the challenge of balancing human health and economic activity. Separate chapters look at a number of different topics: viral transmission and human behavioral responses, communicating public health information, distributing resources that are limited in quantity, restricting physical movement, testing, re-emerging safely from periods of mandated lockdowns, and the role of innovation. The final chapter asks what we should learn from the COVID-19 pandemic and how that knowledge can inform future actions. As an economist, Gans's perspective on these topics is markedly different from, although not opposed to, what I routinely encounter in the scientific literature. As I read the book, I found myself thinking in new ways about aspects of the COVID-19 pandemic that students and I had talked about during 2020.

There are, however, two chapters where I felt Gans's analysis fell far short: the question of wearing masks and the role of innovation. In his discussion of the changing recommendations on wearing masks, Gans writes that "[w]e, the public, were played. And we were played by those whom we were supposed to trust implicitly because of their expertise." Harsh words, which Gans tries to justify in a footnote, where he writes:

> I use the word "played" to refer to the fact that experts gave advice to prevent mask adoption by claiming that there were no public health benefits from using face masks when there was ample evidence that masks would prevent the spread of infections prior to COVID-19.

However, I think Gans is ignoring two important things. The first is how our understanding of COVID-19 infection was rapidly changing in the spring. Aerosol transmission, now viewed as a significant mechanism for infection, wasn't initially understood as well as it is now. The extent to which transmission involved people who were asymptomatic was also becoming clearer. Gans also makes no mention of the mixed and often contradictory messaging coming from public health and government officials and the politicization of wearing a mask. I'm not suggesting that there isn't room to criticize how public health messages related to masks were conveyed to the general public. There is. But I found Gans's analysis of this topic flawed and incomplete. In a later chapter focused on the role of innovation in combatting the pandemic, Gans's analysis completely ignores how scientific research on SARS-CoV-2 and COVID-19 built on a combination of prior research on other viral diseases

(AIDS, Ebola, SARS) as well as the development of new technologies long before the COVID-19 pandemic. For example, RNA-based vaccines have been an area of active research for at least a decade and were being actively discussed before Gans's book was published in November 2020. But even with these flaws, I would recommend *The Pandemic Information Gap: The Brutal Economics of COVID-19* to faculty interested in seeing how another discipline approaches the challenge of a pandemic.

All of the books that I've described up to this point are works of nonfiction, most of them in the category of science writing. I want to finish this reflection on pandemic reading by encouraging faculty to spend some time also looking for works that are more creative in nature. In *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree*[1], the National Academies of Science, Engineering, and Medicine encouraged faculty to continue efforts to integrate the arts and humanities with STEM in higher education. Such integration offers potential for increased student engagement and learning. Living through a pandemic certainly provides unique opportunities for such integrations. There are, of course, the obvious "classics": Daniel Defoe's *A Journal of the Plague Year* and Albert Camus' *The Plague*. But more recent works may also be of interest to faculty and students. Emily St. John Mandel's luminous *Station Eleven* is a novel set in a post-pandemic world that explores the idea embodied in the phrase "because survival is insufficient" (from a *Star Trek: Voyager* episode). Mandel's novel is wonderful exploration of the human spirit and ways we can bring meaning into our lives. *There Is No Outside: COVID-19 Dispatches* (published in June 2020) is a collection of essays that look at the experience of COVID-19 in a variety of contexts: prisons, emergency rooms, homeless encampments, migrant camps, and even in our homes. I will finish with two poems written in response to COVID-19. Paul Muldoon's "Plaguey Hill"[2] is set in a small village in central New York state but connects back to memories of the Plaguey Hill burial mound in Belfast, Ireland that contains the bodies of people who died in the cholera epidemic of the 1830s. Simon Armitage's "Lockdown"[3] connects an outbreak of bubonic plague in the English village of Eyam in the 17th century and the resulting quarantine to the experience of living in the UK during the COVID-19 lockdown.

List of Books Reviewed

Christakis, Nicholas A. (2020). *Apollo's arrow: The profound and enduring impact of coronavirus on the way we live*. Pp. 384. New York: Little, Brown Spark. ISBN 978-0316628211.

Gans, Joshua. (2020). *The pandemic information gap: The brutal economics of COVID-19*. Pp. 160. Cambridge, MA: MIT Press. ISBN 978-0262539128.

Horton, Richard. (2020). *The COVID-19 catastrophe: What's gone wrong and how to stop it happening again*. Pp.140. Cambridge: Polity Press. ISBN 978-1509546466.

MacKenzie, Debora. (2021). *COVID-19: The pandemic that never should have happened and how to stop the next one*. Pp. 304. New York: Hachette Books. ISBN 978-0306924248.

Rabadan, Raul. (2020). *Understanding Coronavirus*. Pp. 120. Cambridge: Cambridge University Press. ISBN 978-1108826716.

About the Author

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1 Summer 2018 issue of this journal (Vol 10 issue 2, pp 11-15)

2 Paul Muldoon's poem "Plaguey Hill" was published in the July 10, 2020 issue of the *Times Literary Supplement*.

3 Simon Armitage's poem "Lockdown" can be found at https://www.simonarmitage.com/wp-content/uploads/Lockdown-by-Simon-Armitage.pdf