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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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From the Editors

February 2024

For the Winter 2024 issue of *Science Education and Civic Engagement: An International Journal,* we are delighted to feature three project reports and an engaging conversation from the 2023 SENCER Summer Institute. These contributions reflect a variety of creative connections between science education and civic engagement.

Kerri Shelton from Columbus State University in Georgia reports on work done by a team of undergraduate researchers (chemistry and nursing majors) who worked to analyze 20th-century medical kits at the Columbus Museum. The analysis provided museum staff with information that will help in the proper curation and storage of the kits. In addition, the information gathered provided the Columbus community with a better understanding of medically related items in the 20th century. The work described in the project report is a good example of civic engagement benefitting a community by increasing the understanding of its own history.

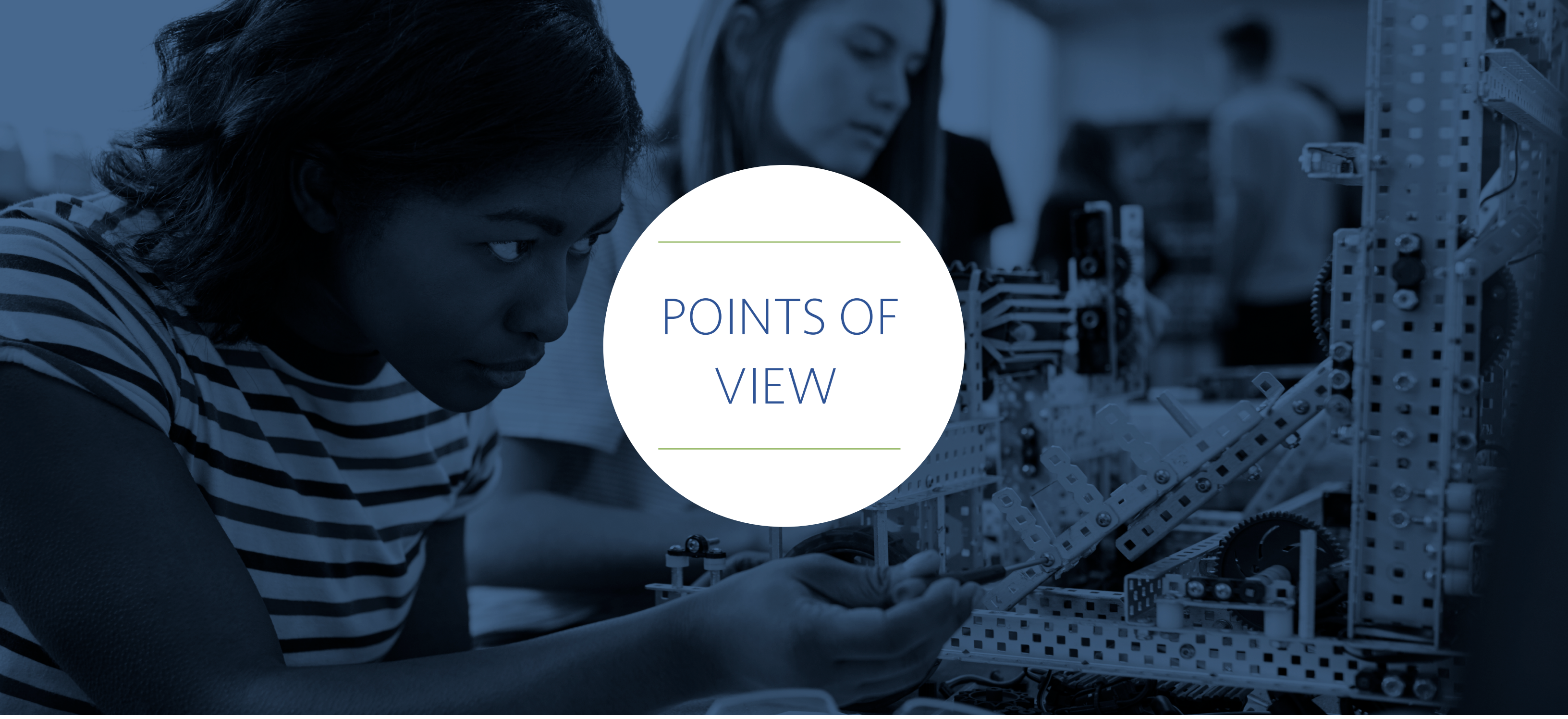
Grant Fore et al. (Indiana University—Purdue University Indianapolis, University of Michigan, Butler University) share a study of student learning outcomes in courses that utilized farm-situated place-based experiential learning modules. The authors also examine the potential influence of two significant external experiences—the COVID-19 pandemic and the protests against police brutality after the murder of George Floyd. The study used a combination of measures of characteristics such as environmental science literacy, civic-mindedness, and sense of place along with focus groups to explore how place-based experiential learning and these significant societal events impacted student learning.

We are also excited to feature a revised and adapted transcript of a conversation between **Sara Tolbert** and **Geraldine Mooney-Simmie** from the 2023 SENCER Summer Institute on the topic of science/STEM education, democracy, and civic engagement in a fast globalizing and increasingly unequal world. The dialogue draws from the four SENCER ideals to examine the complexity of constantly changing ethical, sociocultural, and political relations between STEM education and democracy. Tolbert and Mooney- Simmie explore commonly used phrases such as "teaching and learning," "problem-posing," "civic engagement," and "inclusion" in the context of STEM education policy in Ireland and New Zealand. The conversation provides an international perspective on ideas important to the larger SENCER community and argues for a reappraisal of how we frame the problem of STEM learning and democracy.

Our final project report from **Susmita Hazra** et al. (Cameron University and Tulsa Community College) discusses ways to include a greater number of girls in STEM. Hazra and her colleagues have been involved in several outreach activities, including the hosting of a one-week summer academy for middle school girls, Women in Leadership and STEM conferences, and several workshops involving middle and high school girls. Additionally, Tulsa Community College (TCC) recently inaugurated its high school summer academy to encourage more girls to gravitate toward STEM and to provide positive reinforcement.

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

Matt Fisher
Trace Jordan
Co-Editors-in-Chief



STEM Education, Democracy, and Civic Engagement in a Fast Globalizing and Unequal World:
Sara Tolbert in Conversation with Geraldine Mooney Simmie

SARA TOLBERT
University of Canterbury

GERALDINE MOONEY SIMMIE
University of Limerick

Abstract
The SENCER Summer Institute 2023 proceedings reported here are an adapted transcript of a conversation between Sara Tolbert and Geraldine Mooney Simmie on the topic of science/STEM education, democracy, and civic engagement in a fast globalizing and increasingly unequal world (2023, August 29). The dialogue draws from the four SENCER ideals to underpin the importance of what the feminist scientist Donna Haraway called "staying with the trouble," where the trouble in this case is implicit in the complexity of constantly changing ethical, sociocultural, and political relations between STEM education and democracy. The speakers aim to critically scrutinize the new framing and lexicon centered on STEM learning and civic engagement, including phrases such as "teaching and learning," "problem-posing," "civic engagement," and "inclusion" in STEM education policy texts in Ireland and New Zealand. Drawing from critical, philosophical, and feminist perspectives the speakers argue for an urgent reappraisal of the framing of the problem. We argue for the need to reorient STEM Learning toward an expansive view of education that is relational and emancipatory and a view of democracy that is upstream of the instrumental. The original conversation was edited for ease of readability, inclusion of a planning template, the addition of a number of relevant references, and a summary of key insights (see Tolbert Mooney Simmie Dialog).

Introduction

The proceedings from the SENCER Summer Institute 2023 reported here are an adapted transcript of a conversation held on Tuesday, August 29, 2023 between Sara Tolbert and Geraldine Mooney Simmie with a live online audience of science educators and policy decision makers in the USA and internationally. The topic for critical scrutiny was the contemporary framing of science/STEM education, democracy, and civic engagement in a fast globalizing and increasingly unequal world. The conversation draws from the four SENCER ideals to connect science education to matters of public interest and to do so in ways that take into account the power and limits of science for a complex and nuanced understanding of the problem in contemporary times. The four SENCER ideals are as follows:

1. SENCER connects science and civic engagement by teaching "through" complex and unsolved public issues "to" basic science.
2. SENCER invites learners to put scientific knowledge and methods to immediate use on matters of relevance to them.
3. SENCER reveals both the power and the limits of science in addressing the great challenges of our time.
4. SENCER helps all learners connect civic issues of local concern to national and global "grand challenges."

The SENCER ideals underpinned for the speakers the importance of what the feminist scientist and environmentalist Donna Haraway called "staying with the trouble," which is implicit in the complexity of constantly changing sociocultural and political relations between STEM education and democracy (Haraway, 2016). The conversation aimed to critically scrutinize the current framing and associated lexicon centered on STEM learning and civic engagement, including the four phrases: "teaching and learning," "problem solving," "civic engagement," and "inclusion" in science/STEM education policies in Ireland and New Zealand. Drawing from critical, philosophical, and feminist perspectives, the speakers assert the urgent need for an appraisal of this contemporary framing of STEM learning and civic engagement and the necessity to foreground intersectionalities, such as, gender, social class, race, ethnicity, and disability. This includes the need to reorient STEM learning and civic engagement for an expansive view of STEM education as relational and positioned within a dynamic and deep view of democracy. The original transcript of this conversation was edited for ease of readability, inclusion of the planning template designed by the speakers, the addition of relevant references, and a summary of key insights (see Tolbert Mooney Simmie Dialog).

SARA TOLBERT: This session is really meant to be more of a conversation, a generative dialogue around common yet under-interrogated discourses in STEM education. I'm Sara Tolbert, currently based in Aotearoa New Zealand, formerly in Arizona, and I'm professor of science and environmental education at the University of Canterbury, where I co-direct Learning for Earth/Ako Futures (LEAF), a transdisciplinary research initiative led by faculty from science and education.

I met Geraldine, who will introduce herself shortly, recently at the 2023 Annual Meeting of the American Educational Research Association in Chicago, at a session on science and democracy. She and I have very similar interests, and particularly in our critical feminist approaches to rethinking science and education. Our interests also resonate with SENCER, in that we are all centrally concerned with the sociopolitical and critical participatory dimensions of science and of education. And so I was just really taken with her work, and in the spirit of growing our international SENCER community, I was excited to reach out to her and find a way to partner with her and bring her into these conversations we are having at SENCER. This is just what Eliza and Davida have done with me since I started affiliating informally with SENCER in 2018, when Eliza and I met as keynote panelists for the Human Rights Coalition of the American Association for the Advancement of Science, and more recently in my role as a formally affiliated SENCER diplomat.

Last year during the SENCER Institute, I gave a keynote on thinking about our work as a social movement. I think this conversation today and how it came about is part of that, just continuing to find like-minded and very enlightened thinkers and doers in our fields. It's really my pleasure to be able to bring Geraldine with me into this conversation today and just talk with you all a little bit about what she and I have been thinking around these common discourses that we hear in STEM education—discourses that we sometimes maybe take for granted, even in this academic space. And so we thought this would be a good time to take a moment to revisit some of these common terms and phrases that we often hear, and to think together about what they actually mean and what these words and phrases actually convey. And then as we problematize them we want to use that as an opportunity to reflect on the SENCER ideals together with you.

GERALDINE MOONEY SIMMIE: Thank you very much, Sara. My name is Professor Geraldine Mooney Simmie and I am coming to you today from the School of Education in the University of Limerick in Ireland. I am chair of STEM education and director of the research-led center EPI•STEM National Centre for STEM Education positioned in the School of Education. We have more than 40 faculty in the school, and more than half of this faculty have a specialist research interest in some aspect of STEM education, democracy, and global citizenship education. We have circa 2,000 students in the School of Education (e.g., student teachers, teachers, school leaders), and we provide continuing professional development (CPD) to an online EPI•STEM Academy of STE(A)M teachers across Ireland.

In the school, we understand the importance of working in partnerships, national and international border-crossing partnerships for learning, what we refer to as upskilling in teacher knowledge(s) and advancing the professional conversations expected from an understanding of teaching as an advanced practice (Mooney Simmie et al., 2023). From my perspective, this aligns best within an intellectual tradition that takes account of the complexity and messiness of teaching and teacher professional learning and is always in the direction of human emancipation and for a future of uncertainty (Mooney Simmie, 2023; Mooney Simmie & Moles, 2020).

Holding hands metaphorically across the globe with Sara and other researchers, we have much to learn. We are experiencing common problems. We are hoping to make space to wonder aloud about how science education and democracy need to be reoriented in order to work toward saving the planet as well as humanity. We have challenges here too for justice and equality. We clearly need new thinking for public interest values that is not about a dominating narrative. We have problems that are bigger than can be solved singularly in each of our own countries, in Ireland and New Zealand.

We want to do the best for our countries. So meeting Sara, at AERA 2023 in Chicago this year prompted me to open a new type of productive conversation with colleagues in higher education and to convene a new Critical and Feminist Special Interest Group with the Educational Studies Association of Ireland (C&F ESAI SIG) (http://esai.ie/critical-and-feminist-special-interest-group-cf-esai-sig/).

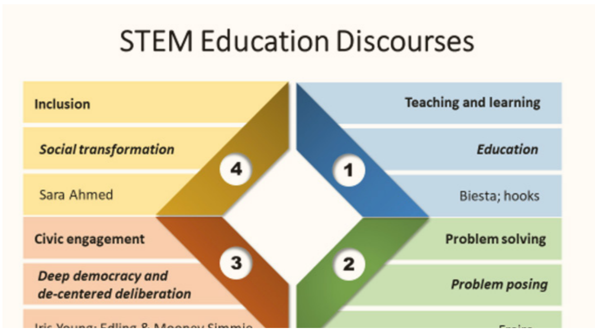
My research interest is in STEM Education, democracy, and civic engagement while researching and working with critical friends to advocate for a transformative difference in this regard. While there are numerous challenges, I am heartened that we are at a time where we can research and advocate for an emancipatory and transformative vision of science education and democracy. This demands a high degree of critical reflexivity on our part; otherwise we run the risk that what we are proposing will be about pushing an agenda of cruel optimism or some utopia that is simply unattainable (Pillow, 2003). Neither do we want to fall into a universalism that is deterministic and smacks of a dominating scientism rather than science working in an open and dynamic system where ethics, philosophy, sociology, and other situated ways of knowing and knowledge are included, valued, and celebrated.

If we look at the policy process in science education today, and the connectivity between science education and democracy, there is a lot taken for granted and normalized. Since the start of this century, education policy in Ireland and New Zealand, across the OECD and the globe, is drawn from a new assumed purpose and discourse of "learning" rather than "education," using phrases such as "teaching and learning," "problem solving," "inclusion," and "civic engagement." When policy decision makers in each of our countries use these terms, what exactly do they mean? What appears framed into the discourse, what is restricted, silenced, forgotten, or indeed erased?

What we want to do in this conversation, this cross-national conversation that Sara and I are having, is to

FIGURE 1. Our planning template for problematizing four discourses in STEM education and democracy

FIGURE 1. Our planning template for problematizing four discourses in STEM education and democracy



have a purposeful discussion that delves into this problem of discourse and critically scrutinizes the framing of the problem of language use and meaning making in science education and democracy.

You can see from our planning diagram that we will scrutinize the framing of four taken-for-granted words and phrases in relation to STEM learning and democracy (Figure 1). We will use the SENCER ideals to guide our critical and feminist scrutiny, to help us think anew with theory and to allow us to collaborate and to act differently. We are seeking new insights in order to reorient science education and democracy away from a narrow consensus framing that currently feeds the process of social reproduction rather than disrupting the discourse and making space for a new social contract in education and for new ways of being and acting in the contemporary world.

We will draw from critical, philosophical, and feminist perspectives to widen the discourse beyond a limited, narrow, and dominating worldview. We want to make sure that emancipatory science education and democracy gives all young people access to the big ideas and concepts in science, mathematics, and technology. We need to move beyond cognitive and affective development to take justice and equality into account and at the same time maintain an understanding of democracy as a constantly changing project of ethical and social (re)construction of the (political and economic) world we live in.

We need the changing gaze of education to support us doing better for ourselves individually, for our families, our communities, other humans, other species in the environment, and for the sustainability of the planet. We need to assert that education cannot continue to remain tethered to a mainstream narrative that today is centered on the primacy of the economy, the commodification of everyone and everything for a view of "sustainability" as merely "economic sustainability." We need "sustainability" to reflect public interest values and the greater good of humanity, society, and the planet. These educational emancipatory ideals interest us. I will now hand back to Sara.

Teaching and Learning

SARA TOLBERT: Okay, so as we mentioned, we're going to be dialoguing about some of these common discourses we hear in science, education, and STEM education more broadly, and probably across the disciplines in our various roles. And the first one we want to talk about, as Geraldine mentioned, is this concept of "teaching and learning." I've been talking with colleagues, currently in the midst of a science curriculum reform here in Aotearoa New Zealand, where we started trying to interrogate some of the words that we often use and to think more carefully about what we actually mean by these terms when we use them. And what are their histories? How are they positioned and what do they intend to do? And "teaching and learning" is one of those that we need to consider—and there are other scholars who have talked about this as well, such as Gert Biesta (2020) and bell hooks (1994).

It's this idea of "teaching and learning" that has almost become a technical isolation of the experience of what it means to be a student, or what it means to have an education. And so we will talk about the histories of this term and how it has come to be. But we are really proposing a refocus on the idea of "education" versus "teaching and learning," which has a much broader focus on the whole person. And education is holistic, inclusive of what it means to live well together for the greater good of society and within the world, and how important that is right now in the Anthropocene. So what we are doing in this conversation is this: we are going to bring up each of these phrases and terms, talk about them, and then offer a couple of scholars you may be familiar with, or may not be familiar with, and if not, who might be ones that you want to explore. For me, I love the work of bell hooks (1994), who talked about education as the practice of freedom, or, as she says, "teaching to transgress." Education is really about a process of becoming, and being, and not necessarily about internalization of content—not that teaching and learning necessarily means the internalization of content, but it really does focus on a very transactional, linear relationship sometimes—and then we might simply forget the whole experience of "education." I'll turn it over to Geraldine now for her thoughts.

GERALDINE MOONEY SIMMIE: Thanks Sara. Continuing our critique of "teaching and learning," we look toward the SENCER ideals, and we find the concepts of the learner and STEM learning gaining ground in a similar way in each of our countries, in policy documents in Ireland and New Zealand. There is equally a big emphasis on "teaching and learning" in the research literature.

The distinction between "teaching" and "learning" and the hidden assumptions behind "learning" is interrogated by Gert Biesta, a philosopher of education (Biesta, 2020). Biesta argues that "learning" is a concept that is restricted to the individual, as a private good for the individual rather than an inclusive and relational concept concerned with the common good or greater good of society. The latter more expansive view of education is that it is relational and emancipatory and is connected to our interdependencies with other humans, other species, and the planet. Education is a far broader construct that is about human becoming and the development of a cultured person, the formation of the person in far bigger ways than mere instruction, beyond cognitive and affective development.

Today, the assumed language connected to the discourse of "learning" and "teaching and learning" is positioned as something interactional and functional that is given to the individual learner, a private good for a lifelong evaluative journey of becoming a SMART learner (self-regulated, motivated, adaptable, responsible, and technologically competent; Lee, 2021). There is nothing in this view of "learning" that challenges the ongoing (trans) formation of social consciousness that is necessary for an understanding of education in relation to our human and non-human interdependencies in the world.

Our democratic responsibility involves constantly grappling with scientific and STEM literacies and at the same time stepping up as active ethical and politically engaged citizens to interpret and change the world in the direction of justice and equality. This concern reflects a growing body of research in the science education literature (Alsop, 2019; Erduran, 2014; Hodson, 2003; Gunckel, 2024) that is deeply concerned with a consensus view of science education and a narrow focus on "teaching and learning."

It begs the crucial question as to what is the purpose of STEM education and democracy in the contemporary moment, especially if reduced to "STEM learning." We are arguing here that science education is concerned with multiple and even contradictory purposes, such as a journey of human becoming as a subject (in one's own right), becoming socialized into the existing social, cultural, economic, scientific, and political world, and at the same time making space for the "new" to emerge.

According to Biesta (2020) there are at least three purposes for education, which he summarizes as qualification (knowledge question), socialization (culture question), and subjectification (becoming a person in one's own right while also becoming a responsible member of society, state, planet etc.). This latter captures something of educating for freedom, emancipation, and responsibility.

We clearly want young people to be qualified for the world they are going into, to have the knowledge, skills, attitudes, and dispositions needed for the contemporary social and material world. We want them socialized into society and into their culture and heritage. We also want opportunities for subjectification, i.e., learning to become a person in their own right and to own a sense of shared responsibility with others for making a difference in the wider world, in the democratic direction of justice and equality.

If we are doing that as educators and researchers, at this moment in time, we clearly need to work with others, in our own countries—and across the globe—to rethink how we should be together as human beings in non-dominating (egalitarian) ways and what it might mean today to say that someone is truly educated, in a world that is increasingly complex, a highly scientific and technological world. What might it mean to be educated today in that complex and contradictory space? I will hand back to Sara.

SARA TOLBERT: And one of the things we've been talking about here, and also in New Zealand, as we're working on refreshing the science curriculum for primary and secondary students, is the four purposes of education. That is how we have been framing it—the four purposes of education, which include the personal, the participatory, the pathway, and the planetary. The personal is your felt sense of wonder and joy, right? There is a lot of wonder and joy in science education, for example, learning about the natural world. The science pathway is what we often think about in terms of the STEM pipeline to degree programs and careers, but we're really thinking about a pathway, vs. pipeline, not just into science degree programs, though that could be one possibility. But how does science education for example, help cultivate multiple pathways that might be related to science and society, or just an interest in science that helps you pursue an interest in another subject area, for example, or another discipline, or thinking in between the disciplines as pathways into future careers or opportunities?

Participatory is really about how science education helps students be able to participate as members of multiple communities and collectives—including counterhegemonic communities (Tolbert & Bazzul, 2017). And then finally, planetary, how does a science education in Aotearoa New Zealand help prepare me to help sustain the planet? As Geraldine said before, science education has to help me think about how to protect the planet, because it is a really important consideration in this particular moment. It is interesting to think about the ways that we are revisiting these terms and notions in this particular moment in time in the Anthropocene. Now we will move into the next discourse that we wanted to talk about, which is "problem solving." And I am going to turn this one over to you, Geraldine.

Problem Solving

GERALDINE MOONEY SIMMIE: Yes, indeed, Sara. We noticed how in my country, in Ireland, and as you have noticed as well Sara, in New Zealand, that a new terminology of "problem solving" has entered into the lexicon of our national policy documents in STEM education and democracy. At this time it is tightly defined in ways that suggest we want students to become "mini-scientists" learning how to engage in inquiry, gathering evidence from reputable sources to justify and support their claims, to work in teams, to examine some new and unforeseen problems and come up with viable solutions.

There are few who would disagree that learning the skills of being a mini-scientist and "problem solver" is a good thing. However, what we have noticed is that while the skills and language of "problem solving" is located in all policy texts/documents, there is normally no mention of any requirement for a problem-posing science education. This absence concerns us. Stating the problem-posing aspect explicitly is important, because it opens science education outwards as relational and collaborative and as a sociological project, a social good for the greater good. It acknowledges that we do not have the answers to everything. We want our students to own a healthy skepticism, and not just to say to them that we have it all worked out, that it can all be controlled and predicted, and all you need to do in the science classroom is to follow a formula of plan, engage, execute, evaluate, end of story.

Sara and I do not want science teaching becoming a narrow black box of tools and skills. We want students to be able to reason with evidence and at the same time to draw on other ways of knowing, the ethical, philosophical, sociological, indigenous, and other situated and reflexive ways of knowing. This staying with a more complex struggle is grasped in the SENCER ideals as taking into account the power and the limits of science and the multiple and contradictory purposes of science education.

We both place a high value on science knowledge, nature of science, and access to a quality STE(A)M education. While we want young people to learn to become "mini-scientists," that is but a part of a bigger picture in any journey of human becoming. UNESCO asserts that a fast globalizing world needs a new social contract for a new view of knowledge in contemporary times (International Commission on the Futures of Education, 2021). What is the place of ethics, moral and political philosophy in a highly scientific and technological world that is placing such a high priority on the evidentiary and the empirical?

The concept of a problem-posing education for emancipation was brought into the education discourse by critical pedagogy theorists, such as Paulo Freire and more recently by Henry Giroux, Sheila Macrine, Donaldo Macedo, Antonio D'Arder and Peter McLaren (Freire, 2018). Human emancipation for (trans)formative action was also introduced by radical feminist theorists, such as bell hooks and others (hooks, 1994; Lynch & Crean, 2019). In recent times, Judith Butler, writing about the university, asserts the importance of this emancipatory view for education for the greater good of individuals, societies, and the future sustainability of the planet (Butler, 2017).

Our critique here shows that a policy demand for "problem solving" may become narrowly interpreted as students learning to think logically and laterally with others in order to fix problems by formulae. On the other hand, a problem-posing education acknowledges that some problems are bigger than the individual and that we need to work on a societal level in collaborative, reciprocal, and democratic ways that are upstream of the functional and instrumental, i.e, in ways that take the irreducibility of human dignity into account and the need for a pluralist view of a just democracy and a just global world.

For example, in working with crises such as climate change, there is something upstream of mere problem solving for "self." How will young people know they need to open these controversial conversations outward unless we teach them? For science education and democracy, we need not only to teach young people science but also to teach them about how science interacts as a sociological project in our cultural world in ways that require recognition of our interdependency with other humans, non-humans, the environment, and the planet. We are social beings living interdependent lives with others. The emphasis on a problem-posing aspect brings that into play. I will now invite Sara back in.

SARA TOLBERT: I think this one is really interesting for me, and particularly right now, in Aotearoa, we have been focusing a lot on the role of indigenous knowledge in science, for example. And so, for me, this really is a very deep and necessarily slow and thoughtful process of the different considerations, the ethical tensions in moving forward with this project, with integrity, making space for divergent perspectives, particularly those within Māori communities. I think I sometimes feel with students at the university level that this problem-posing space is very uncomfortable. I think there are unresolved tensions that we have to sit with in any problem-posing space.

Feminist scholars have written about this a lot, including the more recent work that has been done around matters of care, for example, by Maria Puig de la Bellacasa (2017). She writes about matters of care, building from Latour's notion of matters of ethical concern. For Latour, matters of concern shift discussions from matters of fact, which Latour views as unhelpful framings for democratic debate; matters of concern necessitate interconnected attention to facts and values. Puig de la Bellacasa focuses more specifically on care relations as a cornerstone of ethics in matters of concern. Matters of care are more explicitly about an acknowledgement of our interdependent existences but also of the gendered relations of power that constitute those existences. She writes of matters of care as thinking about and attending more thoughtfully to "neglected things," as well as neglected human and more-than-human[1] actors, which are not always apparent, or dimensions/entanglements of a matter of concern that are not often seen or heard. There will be necessary troubles that come up and emerge because of our interdependent existences and different histories and positionalities and agencies, so we have to slow down and really take time to think and to consider and to truly engage with each other (and with more-than-human actors) around those tensions and challenges.

If we think about problem solving, there is no perfect solution. A lot of these socio-scientific issues or environmental challenges do not have perfect solutions, as you all know, because you have all been engaging in this work. They are really messy. And so we have to slow down and think about ethics in more complex and nuanced ways and help students become a little bit more comfortable with slowing down— and with understanding that there is no perfect solution. But in order to think about these big challenges we need to really take time to consider the multiple perspectives and multiple potential outcomes at hand. So with that, we will turn it back over to you, Geraldine.

Civic Engagement

GERALDINE MOONEY SIMMIE: Thanks, Sara. What is wonderful about this SENCER Summer Institute 2023 on STEM education and democracy is the sophisticated and nuanced ways you are looking at the

1 More than human (versus non-human) is commonly used in fields such as feminist science studies and posthumanism. It is a subtle linguistic and ontological turn that rejects anthropocentrism and promotes an interconnected orientation to the world.

problem of civic engagement. We found it helpful to connect our examining of some phraseology of STEM learning to the SENCER ideals for a critical and philosophical scrutiny. We clearly need to find new ways to converse together in order to reorient this discourse, so that policies do not proceed with formulaic, dominating, and functionalist solutions. Functionalist solutions are prescriptive solutions that come from an atomistic view (sum of the parts) rather than a holistic view (more than the sum of the parts) of what it means to be human.

We now turn our interrogation to the assumed framing of the concept of civic engagement, mentioned in the SENCER ideals and in the actual title of this SENCER 2023 Summer Institute, and clearly connected to the wholesome project of STEM education and democracy.

I am deeply interested in researching the connectivity between STEM education and civic engagement for a view of democracy as a dynamically changing ethical, scientific, and political system that is concerned with public interest values, with the greater good of society, and with assuring equality and justice. The relations between STEM learning and civic engagement are complex, and we need to ensure that the framing of this social scientific problem as a contemporary policy and curriculum reform is not blocking the development of justice and equality.

I have worked with Professor Silvia Edling at the University of Gavle in Sweden for the last seven years, exploring the connectivity between teacher education and democracy and (science) teachers' democratic assignment to assure what has been referred to as "deep democracy" (Edling & Mooney Simmie, 2020; Mooney Simmie & Edling, 2019). Taking a holistic stance, deep democracy is dynamic and always in constant motion in a changing world and is always more than obedience to laws and regulations. We therefore need to interpret what it might mean for the (STEM) teacher in the classroom, and for our democratic societies, and what it might mean to be (science) educators in the world of today, what civic engagement might mean in theory, in policy, and in practice.

Therefore, we found that education and democracy go from one end of the spectrum, from a thin or electoral democracy—where peoples' passive participation in the political world involves voting—to a deep view of democracy—where people are actors, involved as activists assuring a dynamic view of democracy. This dynamic view rests on the constantly changing needs of society for a just global world.

The crucial question as science/STEM educators and researcher(s) is how we might move civic engagement from an assumed thin view of democracy to a deep view of democracy. Time is not on our side, given the crises gripping the world in relation to socio-scientific issues. We cannot afford for science/STEM education to get this wrong. We do not want reproduction of the status quo. We need to move beyond the primacy of the economy (Pederson et al., 2024).

It makes sense to us that every nation seeks to socialize young people into the history, culture, language, myths and narratives, rules and regulations of the society in which they live. The notion of civil engagement for civic responsibility/obedience aligned with the rules and regulations of a peaceful society is an important aspect of every educational intervention or reform.

However, what is often missing from this discourse is how we might also leave space for something new to emerge, so that we are constantly working with others seeking new ways of "doing" the world. This idea of democracy goes back to the American philosopher in the 1930s, John Dewey. Dewey said that education was actually the midwife of democracy and needed renewal with every generation (Dewey, 2011). What Dewey meant is that the needs of society change. They change rapidly nowadays. We therefore need to have an understanding of democracy as an organic, dynamic entity that can change course with the changing needs of society and for the greater good of society. Democracy, in the first instance, is about reason over power. It is not about powerful interests or an elite running the world, it is about the power of reason in the direction of justice and equality (Fraser, 2009; Lynch & Crean, 2019). This public interest value underpins my research work with Edling, and is found in the theorizing of Iris Young and Jesper Sjöström (Young, 1996; Sjöström, 2018).

Young (1996) provides us with a word of caution as we move from a thin and passive view of democratic participation to a more nuanced and activist view of democratic participation. At a base level, Young argues that democracy can merely be about voting for an aggregate view of self-interest (a narrow majority rule disconnected from the central tenets of justice and equality). Moving upstream of this base level, Young notes that Habermas and others advance a notion of deliberative democracy for the greater good. Deliberation involves a process of argumentation and is about winning the better argument based on the best evidence. However, taking this view, deliberation remains firmly in the hands of experts only, and often works to silence the voices of women and minorities. Instead, Young calls for a de-centered deliberation that foregrounds intersectionality and works to provide fruitful conversations for the greater good for all. So what kind of activist imaginary do we need nowadays in the science/STEM classroom for a new type of activist imaginary for civic engagement? I will leave you to ponder this question and hand back to Sara.

SARA TOLBERT: Thanks, Geraldine. I love your work on deep democracy and Iris Young's concept of decentered deliberation as well, because for me what it also represents is that, for example, if we bring everyone together as a public into conversation, let us say, as a town hall, often we have marginalized voices or underrepresented voices that do not get their fair share or fair say or are not heard in the same way as the majority. And so this idea of decentered deliberation is more about communities being able to have mechanisms for representing their interests and their voices, which then are brought forward to bear as part of this larger conversation in a sort of "multi-publics" approach. So there might be multiple spaces of deliberation. And then from those multiple spaces of deliberation, which are decentered, we can think collectively but from across those different communities to really deliberate over an issue of concern. Jesse Bazzul and I have also written about the role of dissensus (Tolbert & Bazzul, 2021), drawing from the work of Jacques Ranciere (1991)—and how science education should pay more attention to the struggles of marginalized communities, and how they, in their struggle for equality, reconfigure the social (and socio-ecological) world. By paying attention to these communities, we can move toward justice, in a way that protects the interests and agency of marginalized groups. Dissensus, versus consensus, is counterhegemonic. It goes beyond active participation or democratic citizenship. According to Ranciere, dissensus is critical to democracy, because it means that those who have been marginalized make themselves seen and heard to challenge hegemonic practices and make way for new possibilities. For Ranciere, this kind of disruption is essential to democracy.

And I think it also resonates with the conversations we had last year, around thinking like a movement as we talked about where we go from here—after we have this amazing and powerful experience at SENCER, where we all come together and everyone is doing this phenomenal work. And we all feel inspired. Where do we go afterward? How do we continue on with the momentum? And so this idea of thinking like a movement develops: we are all going back to our own communities where we are active members and are really continuing to bring people in, to try to make those connections across these different multiple communities that we're a part of. We want to continue to build trust and solidarity, engaging in counterhegemonic work together, which is really what we need to effect real and lasting change, i.e., building solidarity across different groups.

Diversity and Inclusion

So we now move to the last of our "discourses," which is this notion of "diversity and inclusion." This has become a big one, especially at the university level. It has even become an acronym, the whole idea of DEI, or diversity, equity, and inclusion. And so we draw here from the work of Sarah Ahmed (2012), who talks about the danger of overusing the words diversity and inclusion as non-performatives, in her book *On Being Included: Racism and Diversity in Institutional Life* and in her more recent book (2021) *Complaint!* She talks about how a lot of times diversity initiatives are actually superficial commitments that become a way of not doing things with words. So she calls them non-performatives. Essentially, what that means is that we have a statement now instead of action and activism. So we know we are all about justice. And we know we are all about diversity, equity, and inclusion. And we have this committee over here, and we have that office over there. So therefore, we do not actually have to fundamentally transform our policies and practices, because we have our statements, and we have our offices. And so she encourages us not only to think about what are the transformative elements of these inclusion initiatives but also to think about what they allow us to hide, or how they operate as window dressing for deep structural inequalities.

We also have to question the idea of "inclusion"—what are we recruiting into? Are we recruiting women and people of color into a toxic environment in STEM departments, for example? We simultaneously have to think about the transformative potential of diversity work, and how it disrupts versus reproduces the status quo. Expanding participation in STEM Education is one aspect of this work. But if we are not at the same time thinking about restructuring those fields, so that they are more justice oriented and less toxic and hostile to women and people of color, then we are actually doing a disservice to our students who we are trying to recruit into those fields. And I think that is a real challenge. And one that I know that many of us have called out in our institutions. I think it is important to think about inclusion as social transformation, disruption of the status quo, and really question what we are "doing" with the words, because if we are only writing the words and putting words on websites, for example, in our diversity statements that actually, potentially, can be more harmful than good. I'm going to turn it back over to Geraldine and have her chat about this one.

GERALDINE MOONEY SIMMIE: It is productive for me, and I hope for all of you, opening this cross-national conversation with you, Sara. Seeking a more cutting-edge and inclusive STEM education for democracy and civic engagement with young people remains a challenging issue for everyone today, especially because we have a very long history of not humanizing the science disciplines.

The natural sciences rest on a canon of powerful knowledge depicted as cool, objective, neutral, counter-intuitive, and universal knowledge. This canon, and the scientists who work within the disciplines, have traditionally prided themselves on their detachment, objectivity, and neutrality (Muller & Young, 2019). Now this presentation of the purity of intention connected to science neglects what the SENCER ideals regard as the power and limits of science. History has an abundance of examples that cast doubt on this apolitical view and show how science is indeed political (Hoeg & Bencze, 2017).

Moreover, the bigger issue for us as science educators is to bring into play not only the "hard science" but in addition another complexity, how to "educate" and "teach" science to (young) people? While teaching young people to become mini-scientists is necessary (e.g., inquiry, evidence, justification, source), it will not be sufficient if seeking to educate young people in science as a critical sociological and cultural problem. That is the great dilemma for the science educator. Besides, it is not a dilemma that needs to be solved, but rather one that must be lived with. Donna Haraway asserts that we need to "stay with the trouble" so that we can teach young people to care deeply for their environment and their fellow "kin" (other humans, other species), as custodians of the planet for a future of uncertainty (Haraway, 2018).

How might we humanize the disciplines of science and STEM in the classroom and laboratory in ways that foreground intersectionalities, such as gender, social class, race, disability? Maybe through storytelling, the philosophy and history of science, connecting science-in-context to the controversial socio-scientific issues of our times. How do we develop the social consciousness required for young people to appreciate at a deep level just how interconnected we are as a human species with one another, with non-humans, and with planet Earth as our collective dwelling home? This requires STEM education to include the arts and humanities as co-equal partners—ethics, philosophy, and politics—not just as a way of assuring creativity and critical thinking but also as a substantive way of interrupting the discourse. In this way, we strive to "stay with the trouble" and work proactively for a more just global world.

We have long gone from the day when science literacy is a privilege for just a few. The policy decision makers in Ireland are concerned more about STE(A)M education today rather than STEM education. We need the arts in STEM education as a co-equal partner, rather than as an add-on, so that we can stay with the tensions and living contradictions evoked by the clash between different forms of scientific knowledge, situated knowledge, and different ways of knowing. We want students wrestling with counter-intuitive knowledge, ethics, creativity, and critical thinking and the social consciousness that facilitates de-centred deliberation for political decision-making upstream of self-interest (Young, 1996). I will hand back to Sara now and look forward to opening our conversation with you all shortly.

SARA TOLBERT: Thank you, Geraldine. Your comments remind me of Myles Horton and Paulo Freire's (1990) book, *We Make the Road by Walking.* It is a really great book; in one part of it, they talk about the challenges of ensuring that students in science have the skills to be politically conscious beings while at the same time gaining familiarity with those core scientific concepts. For me, it is really about deliberating carefully over the question, what are the core concepts that are essential in the Anthropocene? It is a really tricky question. And it is causing a lot of angst I think, here in our curriculum reform at the moment, because you know, people are really worried that if you remove something from the science curriculum, students are going to be vastly unprepared to understand the science behind the socio-scientific issues. It is an ongoing debate, but I think someone mentioned that some of these debates are not new, right? These are debates that we have been having since the 1960s, or as Eliza mentioned earlier, probably since the early 1900s. I think it is interesting, because I think more and more, there are all kinds of new transdisciplinary and interdisciplinary programs that I think are going to help push us, and push the boundaries of our thinking about how science matters for all students in public education, in ways that open up spaces for students who see themselves as really interested in science and wanting to pursue STEM-related career pathways. But at the same time we need to help students and educators understand science—and really, transdisciplinary science, alongside arts, and humanities, as tools for justice, for social change.

Summary of Key Insights

The following provides a summary of key insights gleaned from our cross-national conversation about four STEM discourses frequently mentioned in policy texts in Ireland and New Zealand. They become for us the starting point for future collaborative research and activism.

The concept of teaching and learning

- In Ireland and New Zealand, there is a big emphasis on "teaching and learning" in the STEM education policy and research literature.
- We show that the concept of learning connects to change and the development of the individual as a private good, rather than as an individual who has a responsibility for the greater good of society.
- The distinction between the individual nature of learning and the relational nature of education is made by Biesta (2020) and Sjöström (2018).
- Education has multiple and often contradictory purposes and therefore cannot be understood from the perspective of the primacy of the economy (Pederson et al., 2024).

The concept of problem solving

- The concept of problem-solving STEM education suggests that all young people need to learn are the skills of inquiry and justification while learning to become mini-scientists.
- This problem-solving framing of the task of the science/STEM educator presents a narrow and limited view of the purposes of STEM education and fails to acknowledge the necessary struggle between different types of knowledge and ways of knowing.
- By contrast, a problem-posing education—brought into the literature by critical pedagogy and feminist theorists, such as Freire (2018) and hooks (1994)—presents STEM education for emancipatory purposes and opens the possibility for (trans)formation.

The concept of civic engagement

- Here we examine relations between STEM education, democracy, and civic engagement, what it might mean to be educated to make good decisions in the complex scientific and technological world of today.
- We outlined the democratic responsibility of the STEM educator in relation to working with young people to induct them into the norms of society and at the very same time working with them to have affordances for something new to emerge.
- While democracy is deeper and more dynamic than simply electoral democracy, and can include argumentation and deliberative democracy, Young (1996 reminds us of the hidden danger inherent in using an elite approach to civic engagement and the importance of a de-centered deliberation that is inclusive of all voices.
- John Dewey, the 1930s American philosopher of education, reminded us that the education system is the midwife of democracy and that democracy is a dynamic system that needs reorienting by every new generation, connecting it to changing societal needs.

- The concept of de-centered deliberation can be used as a mechanism for communities to move forward in a way that protects the interests and agency of marginalized groups. This is a central tenet of democracy.

The concept of inclusion

- In STEM policies today we have a new emphasis on words such as inclusion, equality, and diversity. We need to scrutinize the framing of these concepts for STEM education and democracy. If framed within a commodified view of education for the primacy of the economy, it becomes unlikely that the greater good of society is considered.
- The idea of thinking like a social movement and continuing to build trust and solidarity is an important aspect of STEM learning and civic engagement. These are central public interest values for authentic inclusion in a pluralist democracy.
- Inclusion as a social transformation clearly requires the arts and a discursive ethics for interruption of the status quo and for humanizing what are traditionally known as the neutral and objective, moral and apolitical "hard sciences."
- Nancy Fraser's work on justice and on the importance of interrogating the "framing of problems" as the third wave of feminism, Donna Haraway's concept of "staying with the trouble," and Sara Ahmed's work on words/discourses as non-performatives offered valuable insights and helped advance our theorizing in relation to STEM learning and civic engagement.

About the Authors

Professor Geraldine Mooney Simmie is Professor of STEM Education and Director of EPI✦STEM National Research Centre for STEM Education at the School of Education, University of Limerick (Ireland). Geraldine's research interest is in emancipatory teachers' practices (e.g. teaching, upskilling in content knowledge, professional development), scientific literacies for all, epistemic justice for girls and minorities in the STEAM classroom, policy enactment and the linkages between STEAM Education, Discursive Ethics and a constantly changing Democracy.

In Ireland, Geraldine is convenor of the *Educational Studies Association of Ireland's* (ESAI) Critical & Feminist Research Policy Analysis *Special Interest Group (SIG).* Geraldine is a member of the *American Educational Research Association's (AERA)* Paulo Freire SIG. See link to her recent EPI✦STEM paper. In her role as Director of EPI✦STEM, Geraldine recently interviewed Professor Luke O'Neill, a biochemistry professor [Trinity College Dublin] on his new book. They spoke about the importance of nourishing joy as well as building scepticism, creativity, collaboration and cool thinking when teaching young people science in the lower secondary school classroom: "Real Science" in School Science? With Prof Luke O'Neill, Prof Geraldine Mooney Simmie and Dr Regina Kelly (epistem.ie)

Sara Tolbert is Associate Dean for Research and Professor of Science and Environmental Education in the Faculty of Education at University of Canterbury (UC), Aotearoa New Zealand, and SENCER Ambassador (2022-present). Her areas of scholarship include participatory science and environmental education, critical feminisms and critical pedagogies, teacher/youth empowerment, transdicsiplinary climate change education, grassroots education reform, and multilingual education. She is co-director of the UC Learning for Earth/Ako Futures (LEAF) research collaborative, and lead researcher in the UC Community and Urban Resilience Initiative. Some of her current projects are Postdigital Citizen Science, with Petar Jandric, Sarah Hayes, and Michael Jopling; Pāngarau Unleashed: A multiple case study of de-streaming secondary mathematics, with David Pomeroy and Kay-Lee Jones, and Reimagining Science Education in the Anthropocene with Jesse Bazzul, Marc Higgins, and Maria Wallace. Sara is Section Editor (Critical Perspectives) for *Science Education* (Wiley), Associate Editor for *Journal of Environmental Studies and Sciences* (Springer), and Lead Editor for *Cultural Studies of Science Education*. She is co-founder of Science Educators for Equity, Diversity, and Social Justice (SEEDS), which just held their first F2F biennial conference this year (January 2024) since 2019.

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Cultivating Sustainability Praxis on a Campus Farm

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Abstract

This mixed methods study investigates student learning outcomes from undergraduate STEM and non-STEM courses, employing farm-situated place-based experiential learning (PBEL) modules at a private liberal arts university in the Midwest. Given that these courses occurred during both COVID-19 and U.S. police brutality protests, this study critically interrogates the influence of this "dual pandemic" on student meaning-making. The study examines how student scores on environmental science literacy, civic-mindedness, sense of place, and scientific reasoning measures changed throughout the PBEL courses. With the exception of scientific reasoning, change in each measure was statistically significant ($p<0.001$). A stepwise linear regression determined whether any measures predicted civic-mindedness. Environmental science literacy and university place attachment were found to be predictive of civic-mindedness. Focus group data revealed how PBEL modules affected student learning outcomes and how the dual pandemic affected student civic-mindedness and place attachment.

Introduction

This paper examines how a series of STEM and non-STEM courses incorporating Place-Based Experiential Learning (PBEL) on a private Midwestern university's campus farm impacted students' situated sustainability meaning-making (Sorge et al., 2022), place attachment (Williams & Vaske, 2003), civic-mindedness (Hess et al., 2021; Steinberg et al., 2011), environmental science literacy (Liang et al., 2018), and scientific reasoning (Drummond & Fischhoff, 2017). The courses in this research study were enhanced with PBEL by their instructors, who had participated in a Faculty and Staff Learning Community (FSLC) on PBEL and sustainable food systems (Angstmann et al., 2022).

PBEL is a promising pedagogical framework for articulating situated learning with a meaningful interdisciplinary location. Place-based and experiential learning are gaining popularity in the earth and environmental sciences (Semken et al., 2017), as well as in a wide range of other disciplines (Hamer, 2000), because PBEL can increase instructor and student enthusiasm and enjoyment (Dabbour, 1997; Lawson, 1995), enhance perceived value of the learning experience to students (Graeff, 1997), and positively impact student performance in content knowledge, course engagement, critical thinking skills, and civic-mindedness (Ernst & Monroe, 2004; Gruenewald, 2003a; Lieberman & Hoody, 1998; Sobel, 2004). PBEL also has the potential to provide students with a sense of agency through a "pedagogy of responsibility" (Martusewicz & Edmundson, 2014) that encourages them to construct rather than consume knowledge (Smith, 2002). Real-world experiences enable them to actively consider their civic role and its impact on broader society (McInerney et al., 2011; Smith & Sobel, 2014).

According to Donaldson, et al. (2020), place-based education (e.g., fieldwork research experiences), particularly when implemented through a situated learning theory lens (Lave & Wenger, 1991), can create experiences of legitimate peripheral participation for students within a community of practice situated in authentic disciplinary contexts. Experiences of legitimate peripheral participation provide opportunities for students to embody scientific practices, develop scientific identity, and interact within a community of practice as they develop along a novice to expert continuum (Donaldson et al., 2020). By engaging in the thought and practices of the earth and environmental sciences in legitimate but developmentally-appropriate ways and in a relevant local place, learners have opportunities to use their knowledge and skills and, in doing so, to create connections between the values and identities of learners, the relational situatedness of places, and the applicability of scientific concepts in establishing coherent systems understanding of the environmental problems and conflicts that vex society (Brown et al., 2020; Galt et al., 2012; Williamson et al., 2023).

While many benefits of PBEL have been reported, its successful implementation can be challenging, because it requires an intentional and explicit linkage of local place-based phenomena to global economic, social, and environmental problems (Furman & Gruenewald, 2004; Gruenewald, 2003b; Gruenewald & Smith, 2014; Nespor, 2008; Spring, 1998). Further, development and implementation of a PBEL curriculum is often disincentivized by a lack of training, extensive time commitments, and the need to connect and collaborate with meaningful community partners; moreover, most efforts to implement PBEL are spearheaded by individual instructors with little to no formal pedagogical training or institutional support. This results in a lack of programmatic consistency, common learning framework, and cohesive best practices, which limits research on the impact of PBEL on students to a single course rather than demonstrating its applicability to a wide range of disciplines.

By cultivating students' capacity to construct and expand their own critical awareness of the present ills born from unsustainable modes of thought and practice, educators help to prepare their students to act and intervene in ongoing environmental and sustainability crises (Kahn, 2010). To support this learning, educators must reflect critically on their educational thought and practice. Educators and the learning experiences they facilitate create important opportunities for students to construct sustainability and environmental science knowledge and skills and to cultivate their commitments to sustainable food systems and civic life within the local places they inhabit. By providing educators with space to collaborate in cross-disciplinary communities of practice, where discourse, discussion, and critical reflection on teaching and learning are used to improve teaching practice, FSLCs can help educators expand their disciplinary perspectives, contextualize instruction within the institution and local and global communities, build confidence and knowledge to try new instructional approaches, and foster civic engagement and pride (Borrego & Henderson, 2014; Calkins & Light, 2008; Lynd-Balta et al., 2006; Schlager et al., 1998; Ward & Selvester, 2012).

This study is part of a three-year NSF Improving Undergraduate STEM Education project (Award #1915313) that aimed, using a PBEL approach, to integrate a campus farm across courses in nine different disciplines (both STEM and non-STEM departments) of a private, predominantly white, primarily undergraduate university in the midwestern United States. The PBEL FSLC was the primary engine of course transformation.

In the first year of the project (Fall 2019–Spring 2020), university faculty and staff participated in an FSLC beginning in Fall 2019 and ending in Spring 2020. Monthly meetings took place throughout the course of that year. The meetings started as in-person gatherings but were switched online during the spring due to the COVID-19 pandemic, which halted the university's in-person instruction. During the FSLC, participants explored their own scholarly identities (Price, 2018), interrogated their modes of inquiry, and were introduced to critical reflection (Ash & Clayton, 2009), as well as the PBEL approach. (For a complete view of the FSLC curriculum see Angstmann et al., 2022.) The FSLC was intentionally designed so that pre- and post-session work fostered an intentional, collaborative, and reflective meeting space that ultimately resulted in the development of a tangible portion of each faculty's farm-based PBEL course module.

By the end of the FSLC, participants were expected to have identified a course in which they could integrate the campus farm using the best practices of a PBEL approach. Farm-situated PBEL best practices (Angstmann et al., 2019) recommend

- providing a broad introduction to sustainable agriculture including sociopolitical and environmental aspects of agriculture and the role of a campus farm in the food system,
- defining an authentic, real-world problem or question for students to explore,
- facilitating attachment and meaning to place through a minimum of four hours of interaction with the campus farm space,
- using inquiry-based, place-situated, iterative experiential learning,
- utilizing reflective questioning to help students identify learnings and personal change.

A total of ten courses were enhanced to include PBEL activities on the campus farm. There were five STEM courses and five non-STEM courses. For the former, there were two introductory-level ecology courses and three upper-level courses across three disciplines: chemistry, biology, and pharmacy. For the latter, there was one introductory-level course in environmental studies and four upper-level courses across four disciplines: marketing, communications, education, and religious studies. Table 1 identifies the courses, which were first offered during the Fall 2020–Spring 2021 academic year, and offers a brief description of each.

In this study, we examine the extent to which, and how, student outcomes were affected by the incorporation of campus farm PBEL modules in the above courses. Our specific research questions are as follows:

> **RQ1**: How and, if so, to what extent does student civic-mindedness, situated sustainability meaning-making (SSMM), place attachment, environmental science literacy, and scientific reasoning increase due to participation in PBEL farm modules?
>
> **RQ2:** How and, if so, to what extent do any of the factors listed in RQ1 predict student civic-mindedness?
>
> **RQ3:** How, if at all, did the circumstances surrounding the COVID-19 pandemic, civil unrest, and protests against police brutality impact student outcomes?

Through these questions, we explore how PBEL on an urban campus farm (Angstmann et al., 2019) contributed to the development of student civic commitments, their environmental science literacy, their place attachment, and their ability to create place meanings within a sustainability framework. Specifically, we examine how PBEL learning that engages the three pillars and overlapping dimensions of sustainability (e.g., social impacts of environmental degradation) enabled new place meanings and connections.

TABLE 1. PBEL Farm Courses, Modules, Descriptions, and Students

Course	Module Title	Module Description	Students
Ecology	Soil Respiration, Biodiversity, and the Analysis of Variance	By combining biological concepts and socio-environmental impacts of local and global food systems with applied research, students explore 1) how sustainable urban farms contribute to a more balanced food system and 2) the importance of soil activity and biodiversity for food production through the experimental testing of hypotheses comparing soil respiration and arthropod diversity in a variety of macro- and micro-habitat types.	20/18
Environmental Studies	Exploring Urban Agriculture in Indianapolis	Students read, reflect, and discuss Michael Pollen's *The Omnivore's Dilemma* to become familiar with food system issues. They also examine the environmental impact of their food consumption via a carbon footprint exercise. Utilizing ethnographic methods at the campus farm and other local urban farms, students will localize readings and discussions to examine diverse urban farmer perspectives on food production and consumption. Qualitative data are interpreted using course concepts culminating in a paper/presentation.	18
Upper-Level Ecology	Bringing Microbes and Carbon Cycling Down to Earth	Students build upon what they learn in course lectures and from prior courses to design and conduct hypothesis-driven research at the campus farm and its adjacent prairie on soil carbon and controls of moisture and temperature. Students write a final report, present at the cross-disciplinary poster session, and contribute to a multiyear soil archive used in faculty research to quantify long-term soil ecosystem function in urban agriculture systems.	14
Chemistry	Urban Agriculture & Environmental Health: Characterizing Risks of Soil Contamination	Environmental health is discussed in the context of the types, prevalence, and levels of soil pollutants in an urban landscape, including urban sustainable agriculture in contrast to industrial farming. Students develop hypotheses for a suite of contaminants and design experiments requiring collection and analysis of soil and vegetation samples from the campus farm and other local urban farms. Students discuss challenges and solutions to urban contaminated soils, present at the cross-disciplinary poster session, share their data with farmers, and contribute to a long-term temporal dataset of urban contaminants.	13
Theology	Employing the "Loving Eye" in Nature Journals	Students learn about the complex ecological processes at play in an urban agriculture context, using ethnographic methods with the farm manager, interns, and patrons. These data are put in conversation with discourses in theology, particularly those that explore nature through two "eyes": the "arrogant" and the "loving" (McFague, 1997), via weekly journal prompts. The module provides a possible model for the ethical development of scientifically literate citizens capable of critically inquiring into ecological issues.	20
Education	Exploring Scientific & Historical Gardening Contributions with Young Learners	Pre-service education students, in collaboration with fourth graders at a public school and the campus farm, design and implement a curriculum guide that utilizes project-based inquiry and active experimentation based on learned content about scientists and their experimental contributions to botany and gardening. Pre-service students test lessons with fourth grade students at the campus farm and engage in reflective practice as they adapt their lessons. This project gives pre-service teachers a deep understanding of curricular design and pedagogical awareness, exposes young learners to environmental science concepts and botanical/agricultural history, and results in publicly available lessons for grades 3-5.	29

TABLE 1 CONTINUED. PBEL Farm Courses, Modules, Descriptions, and Students

Business/Management	Food as Space, Place, and Identity	Using industry and issues analyses combined with 1) visits to the campus farm, a local orchard, and an urban food production facility, 2) case studies of Gerber in Poland, Amazon, Whole Foods, and Second Helpings Food Rescue, and 3) a joint class with nutrition students from the Pharmacy program, students analyze the effects of globalization, sustainability, emerging technologies, politics, and ethics on consumer, investor, and citizen choices related to food. Students also use strategic and ecosystem thinking to better understand the shifting landscape of the food industry.	119
Communications	Using Digital Media To Empower Marginalized Populations	This inquiry-based, service-learning module centers upon a communication challenge presented by a farm organization to their assigned student group consultant. Students, with their urban farm, create a model of the farm-defined communication problem, conduct formal interviews to learn about how the community is impacted by the farm, and devise strategies to solve the communication challenge; these strategies may include developing media content to advertise a specific event, developing a campaign strategy or website, or live Tweeting a silent auction.	20
Pharmacy	Sustainable Healthy Nutrition	Students are led through an inquiry-based investigation into the nutritional and environmental characteristics of a local, seasonal diet and learn how those characteristics contribute to human and environmental health. Students journal experiences gathered through course readings and discussions, farm tours, cooking demonstrations, and personal reflections to create a knowledge base of diet, lifestyle, and nutrition and their relationship to disease.	37

With the third question, we examine how the "dual pandemic" of COVID-19 and the ongoing experience of systemic racism (Jones, 2021; Newman et al., 2023), especially as embodied in the highly visible social movements opposing systemic racism (e.g., Black Lives Matter), affected the aforementioned student learning outcomes in this farm-based PBEL context and brought out students' altruistic ideals and motivations. For this latter point, we are primarily interested in exploring whether "dual pandemic" events contributed to a greater awareness among students regarding environmental, social, and food-related issues and solutions. To be clear, by talking about a "dual pandemic," we are not arguing that systemic racism was some new "pandemic"; rather, the term is meant to refer to the notion that as the U.S. began sheltering in place, concerned about the uncertainty of what might lie ahead, we were also bombarded with images of racialized suffering "in a manner that was impossible to unsee or to look away" (Jones, 2021, p. 427). The horror before us was not just a virus; the horror was also comprised of the most despicable facets of our society, which could no longer be willfully ignored as we fretted in solitude over the future.

Methods

We used a mixed methods intervention research design (Creswell & Creswell, 2017) to answer our research questions. With this research design, quantitative and qualitative data were collected during the semesters in which the PBEL interventions were implemented. We analyzed both types of data for points of convergence and used the qualitative findings to interpret quantitative patterns. While our quantitative measures never aimed to examine how students were affected by COVID-19, protests, and civil unrest, our qualitative data helped to dissect how these significant events were impacting students during the 2020–2021 academic year and were, in turn, influencing how and why we saw statistically significant change across our quantitative measures.

Students were recruited from the 10 PBEL courses during their first course meeting. During the Fall 2020 semester, all recruitment took place online, while in the Spring 2021 semester it was conducted in person. A member of the research team visited each class, either via recorded video, Zoom, or in person, and spoke with students about the research project and provided study information sheets and consent forms. Students were then emailed an individual link via Qualtrics to a pre-survey.

Three additional reminder emails were sent to students who had not completed the survey over the next 10 days. Members of the research team then visited each course two weeks before the end of the semester to remind students about the study, recruit them to focus groups, and tell them to expect an email with a link to a post-survey. As with the pre-survey, emails were sent via Qualtrics to students over a two-week period with periodic reminders about the post-survey. Institutional Review Board approval was obtained at the institution where the research was conducted.

Quantitative Methods

Participants

One hundred and sixty-six students (43% of potential population) completed both the pre- and post-survey during the 2020–2021 academic year. The university's Office of Institutional Research and Assessment provided student demographic data, such as year in school, gender, race/ethnicity (white/non-white), major, and GPA. Demographic data by course and combined for the 166 students are provided in Table 2. One student was enrolled in two participating courses; that student's data were counted in each course but only once in the combined analysis.

Instruments

The pre-/post-Qualtrics surveys were composed of five different surveys. The Environmental Literacy Survey (Liang et al., 2018) was a national survey developed in Taiwan with a specific focus on environmental literacy in undergraduate students. Our version of this scale was composed of 42 questions with no sub-constructs. Altering the survey presented in Liang et al. (2018) was

TABLE 2. Student Demographic Data by Course and Overall.

	Bio	Pharm	Chem	Ed	Env St	Mgmt	Eco1	Eco2	Comm	RL	Total
GENDER											
Female	7	20	6	18	9	17	9	3	5	12	106
Male	3	10	1	0	4	21	4	10	1	5	59
Unidentified	0	2	0	0	0	0	0	0	0	0	2
RACE/ETHNICITY											
White	7	28	6	17	13	33	11	10	6	15	146
Non-White	3	4	1	1	0	5	1	3	0	2	20
Unidentified	0	0	0	0	0	0	1	0	0	0	1
LEVEL											
First-Year	0	0	0	0	5	0	5	8	0	1	19
Second-Year	0	1	0	1	5	0	2	4	0	2	15
Third-Year	3	7	3	12	1	0	4	1	2	1	34
Fourth-Year	7	20	4	5	2	38	2	0	4	13	95
Professional	0	4	0	0	0	0	0	0	0	0	4
TOTAL	**10**	**32**	**7**	**18**	**13**	**38**	**13**	**13**	**6**	**17**	**167**

necessary to make it fit our context. The Scientific Reasoning Scale (Drummond & Fischhoff, 2017) is a series of yes/no questions focused on an individual's scientific reasoning skills. Scores are represented as a percentage correct. The place attachment survey (Williams & Vaske, 2003) contains two sub-constructs: place identity and place dependence. It examines students' attachment towards the place they call home, their university, and the campus farm (or other urban farm in some classes). The Situated Sustainability Meaning-Making (SSMM) survey was created during the project's pilot to understand students' perceptions of a local farm (Sorge et al., 2022; Williamson et al., 2023). The survey was informed by conceptual and theoretical literature (Kudryavtsev et al., 2012; Stedman, 2002; Young, 1999), because there was no previous survey instrument for this purpose. The SSMM survey was designed with sub-constructs for sustainability's main themes: environmental, social, and economic. The Civic-Minded Graduate (CMG) survey (Steinberg et al., 2011) was used in this research in its unidimensional format. The survey has focus area constructs on students' knowledge, skills, disposition, and behavioral intentions towards civic participation.

Qualitative Methods

Near the end of the Spring 2021 semester, the first and third author, both experienced qualitative researchers, conducted three focus groups and one interview of 60–90 minutes each. The interview was conducted with one male student from the Spring ecology course (Eco2). One focus group was comprised of all 20 students in the Theology course (RL). The other two focus groups were comprised of two and three students, respectively. These focus groups included students from every course except the chemistry (Chem), environmental studies (Env St), and pharmacy (Pharm) courses. Specifically, one of these focus groups included a female student from the education course (Ed) and a female student from the communications course (Comm); the other focus group included a male student from the business capstone course (Mgmt), another female student from the education course, and a female student from both the education and ecology courses (Eco2). While we attempted to recruit students to focus groups at the end of the Fall 2020 semester, we were unsuccessful. We attribute our recruitment struggles during that semester to the stresses and disruptions caused to the lives of students, researchers, and instructors by the COVID-19 pandemic.

The focus group/interview protocol (see Appendix 1 for the full protocol) was designed to collect data that could help to explain the quantitative findings, particularly those related to civic-mindedness, sense of place, and environmental science literacy. To give one example, we asked students the following question: "Since beginning course work on the campus farm, have you experienced feelings of greater attachment to it—or feelings of greater attachment to the environment, more generally?" Given that the data collection occurred during the height of the "dual pandemic," our focus group/interview protocols also included questions about COVID-19, as well as questions about civil unrest and national protests against police brutality. To give an example of this line of questioning, we asked: (1) "Has your perspective on civic engagement changed in any way since the COVID pandemic? If so, how? (2) Has your perspective on civic engagement changed in any way since the recent national protests and civil unrest? If so, how?" Qualitative data were thematically analyzed to deepen our interpretations of the quantitative results.

Each of the Spring 2021 focus groups and the interview were recorded. The audio was later transcribed for analysis. During the focus groups/interview, the first and third author took notes, which helped to identify follow up questions, to document student responses that were surprising, and to support our subsequent thematic analysis. To begin the thematic analysis (Braun & Clarke, 2006; Creswell & Creswell, 2017; Guest et al., 2011), the first and third authors inductively developed themes by first reflecting on the focus groups/interview and then reviewing the written notes taken by both authors. These themes focused on growth in civic-mindedness and environmentalist attitudes, attachment to university and campus farm, environmental science literacy, and the impact of COVID-19, civil unrest, and national protests on their attachments and civic interests. The first author then reviewed the transcripts and began to organize and categorize the data into specific codes and descriptions. The third author provided a critical review of the first author's thematic coding structure and reported full agreement with the results of the analysis.

Results

Quantitative Findings

We do not report results for each individual course in this paper, as we are here concerned with the overall effects of our PBEL approach measured by the instruments. Additionally, sub-constructs for the survey instruments are not included in this study. Dummy questions were inserted into the online survey and students who answered them incorrectly had their data removed from the analysis. Independent sample t-tests of survey responses were run for all remaining students for each instrument using SPSS v27. Additionally, Cohen's d was calculated for each t-test (see Table 4) to determine effect size. No outliers were found in the data used in the analysis, and differences between the pre- and post-surveys were normally distributed. Assumptions for a paired-sample t-test were met by these data.

Finally, a stepwise regression model was run using student demographic information and other survey results to predict student post-civic-mindedness. The assumptions of a linear regression were met, such as the absence of multicollinearity and autocorrelation. The response rate was 62.8%.

Cronbach's alpha was quantified for each of the pre- and post-constructs to determine internal consistency. All constructs, except for Scientific Reasoning, had an $\alpha > .900$ on both the pre- and post-assessments. While the alpha for the pre-Scientific Reasoning was within an acceptable range, the post-assessment was not (Table 3).

TABLE 3. Cronbach's Alpha for Pre- and Post-Assessments

Assessment	Pre	Post
CMG	.904	.937
Environmental Scientific Literacy	.954	.971
Home Place Attachment	.909	.909
Butler Place Attachment	.932	.930
Farm Place Attachment	.973	.950
Scientific Reasoning	.881	.518
SSMM	.962	.974

TABLE 4. Pre- and Post-Assessment Means for All Courses Combined

	Mean	N	Std. Deviation	Std. Error Mean
CMG PRE	112.75	166	13.50	1.05
CMG Post	120.60	166	14.21	1.10
Env. Sci. Literacy Pre	168.26	166	20.64	1.60
Env. Sci. Literacy Post	173.55	166	23.83	1.85
Home Place Attachment Pre	41.83	166	9.10	0.71
Home Place Attachment	45.30	166	8.58	0.67
Butler Place Attachment Pre	41.11	166	9.85	0.76
Butler Place Attachment	44.41	166	9.53	0.74
Farm Place Attachment Pre	29.31	166	10.10	0.78
Farm Place Attachment Post	32.81	166	8.97	0.70
Scientific Reasoning Pre	.6703	166	.227	.018
Scientific Reasoning Post	.6616	166	.225	.018
SSMM Pre	81.59	166	11.55	0.90
SSMM Post	87.57	166	11.35	0.88

Paired-sample t-tests were run on pre- and post-survey constructs to determine change over the course of the semester. Table 4 provides the pre- and post-assessment means for Civic-Mindedness, Environmental Scientific Literacy, Place Attachment for Home, University, and the Farm, Scientific Reasoning, and Farm Place Meaning. For all instruments, except Scientific Reasoning, the mean increased from pre- to post-assessment.

Table 5 provides the results of the paired sample t-tests. All constructs showed statistically significant increases ($p < .001$) except for Scientific Reasoning. Additionally, the Cohen's d scores reveal that, of those constructs that had statistically significant increases, three had medium effect sizes (CMG overall, Home Attachment, and SSMM), while the rest were nestled between the small to medium effect size range (Lakens, 2013).

Stepwise Linear Regression: Predicting Civic-Mindedness Scores

This research also examined the factors that impact/predict an individual's civic-mindedness as measured

TABLE 5. Paired Sample t-Test Results for All Courses Combined.

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval Difference: Lower	Upper	t	df	Sig (2-tailed)	Cohen's d
CMG Pre-Post	7.85	11.87	14.21	9.70	6.03	-8.516	165	0.000	.661
Env. Sci. Literacy Pre-Post	5.29	16.06	1.25	7.75	2.83	-4.242	165	0.000	. 329
Home Attachment Pre-Post	3.46	16.06	23.83	4.96	1.96	-4.562	165	0.000	.654
Univ. Attachment Pre-Post	3.30	8.25	0.64	4.56	2.03	-5.143	165	0.000	.3999
Farm Attachment Pre-Post	3.51	9.49	0.74	4.96	2.05	-4.760	165	0.000	.369
Sci. Reasoning Pre-Post	0.01	0.23	0.02	-0.02	0.04	0.555	165	0.580	.043
SSMM Pre-Post	5.87	10.80	0.84	0.63	4.32	-7.123	165	0.000	.553

by the CMG survey. A stepwise linear regression was performed using SPSS v27 with post-CMG score as the dependent variable, all other post-assessment scores were used as potential independent variables as well as the student's race/ethnicity, level, sex/gender, course, and post-course GPA.

With these data, a student's Environmental Science Literacy score and their post-Attachment score to the university were the only statistically significant predictors of their Civic-Mindedness as represented by their CMG score (see Table 6). This regression model has a R2=.620, $F(2,163)=133.252$, $p<.001$ and a regression equation of: CMG=31.786 + (.429) (Post-Env Scientific Literacy Score) + (.325) (Post-University Place Attachment)

TABLE 6. Final Model Linear Regression Coefficients

	Unstandardized Coefficients: B	Unstandardized Coefficients: Std. Error	Standardized Coefficients: Beta	t	Sig.
Constant	31.786	5.555		5.722	.000
Env. Sci. Lit.	.429	.029	.719	14.658	.000
Univ. Attach.	.325	.073	.218	4.446	.000

Qualitative Insights: Explaining Statistical Change

Using focus group/interview data, we now focus on explaining how and why we see statistically significant changes in student Civic-Mindedness, Environmental Science Literacy, and Sense of Place and also explain why Environmental Science Literacy scores and University Place Attachment were predictive of student Civic-Mindedness scores. We also examine the effect that the COVID-19 pandemic and national protests against police brutality had on students as they engaged in PBEL courses. All student names given below are pseudonyms.

Civic-Mindedness and Environmental Science Literacy

When students spoke about civic engagement during the focus groups, it was often discussed relative to two different codes: 1) care for the environment (i.e., environmentalism) and 2) U.S. civil unrest and national protests against police brutality. For the first code, students often expressed concerns around anthropogenic climate change and unsustainable food systems and were interested in personally addressing their own role in those problems. Several students attributed these concerns and interests to their PBEL courses and spoke about how, in these courses, they constructed a deeper understanding of the environmental and ecological sciences. For example, Johanna, a theology student, reported that having a scientific understanding of "the ecological system ... and how humans fit in" can be the foundation for "a new perspective" for how to "interact with the environment ... and care for it." Other students also articulated how the knowledge constructed in their PBEL courses created a desire to interact carefully with the environment. For example, Mary, a student from the communications course, stated, "I've just seen from this course ... how important the environment is, how important it is to protect it, and [the importance of understanding] different environmental injustices." Similarly, Sally, a student from the education course, added that her experiences on the campus farm helped develop her environmental consciousness: "[the farm] just reminds me that, like, I need to be very conscious of the impact that I'm making on the environment."

Students also identified several specific ways to protect or provide care for the environment. Generally, several students across the qualitative data set reported that they could provide such care by recycling, by volunteering on the campus farm, by purchasing locally and sustainably grown produce, and by voting for politicians who will support sustainability efforts. Students' intentions to care for the environment, however, were also often attached directly to their programs of study. For example, Sally discussed how she could introduce sustainability, sustainable food systems, and the idea that "you can actually make a difference based off of your actions" in her future elementary school classroom. She explained that she wanted to help her future students understand that they "have an impact on the environment" and that—echoing her course's carbon footprint activity—they need to strive to "leave as little of a footprint" as possible, to "take the time to really appreciate everything the environment has to offer," to take "note of how quickly it's starting to deteriorate," and to ensure that her young students can identify ways that they "can have a positive impact on the environment."

The students in the Theology course also brought up a deeper problematization when they discussed the relationship between worldviews (e.g., subject-object vs subject-subject; arrogant eye vs loving eye, see McFague, 1997) and human interaction with the environment. Johanna described how she likes to frequent a state park that is close to her home. She explained that when she does so, she likes to take a trash bag with her to pick up garbage carelessly discarded along the trails. She reported that this practice stems from her belief that the park should "be respected and, like, should be celebrated." She elaborated by articulating that she has a "mutual respect" for the environment: "I'm looking at, like, a place like a subject and not like an object." Morgan added that through her experience in the theology course and its PBEL farm module, she has "changed." She reported that in the past, she saw plants "more as objects than I ever did as like their own beings," and that in shifting this worldview she had become "more acutely aware that my surroundings are alive." Finally, to build upon this a little further, Miranda stated: "the perspective that we use, and the way that we view things determines ... how we act and what we think; what we prioritize and act upon." Here, we find students acknowledging the important role dominant mental models, such as subject-object worldviews, play in how humans go about addressing sustainability and how different modes of thought, such as subject-subject worldviews, might affect human interaction with the environment.

Given the timing of the focus groups/interview during the height of the COVID-19 pandemic, civil unrest, and widespread protests in the U.S., we decided to explore how, in the context of this PBEL farm modules project, environmental concerns might intersect with sociopolitical concerns around current events. This is represented by the second code introduced in the beginning of this section. In our data set, students articulated connections between sustainability concerns, current social justice issues, and their own thoughts on, and intended actions within, civil society during discussions on civic-mindedness. For theology students, subject-subject worldviews again came into perspective; for example, Sarah stated: "Every human, like, deserves to be valued as a subject. ... I think we've struggled to do that, like, just in basic human rights ... water, food, and shelter and then race and then ... sexuality. ... We objectify a lot of things for a lot of reasons that aren't, you know, necessarily correct." Here, we witness a student acknowledging an entanglement between objectification, sustainable and just food systems, and systemic racism. Johanna elaborated that the pandemic and civil unrest have "made it easier to, like, recognize these problems" and that civil unrest has brought people together as "collaborators" working to address "social justice issues" and "environmental issues," which, according to her, were all "tied up together." A desire and passion to address social and environmental issues throughout one's career was articulated by multiple other students across the focus groups.

Sense of Place

During focus groups, discussions around sense of place—place attachment, place dependence, and place meaning (i.e., Situated Sustainability Meaning-Making)—introduced new articulations of place attachment and what contributes to the constitution of that attachment. These discussions provided greater insight into why we saw statistically significant increases in place attachment scores relative to home, university, and campus farm (see Table 5). To explain these changes that occurred throughout PBEL experiences during the "dual pandemic," we identified four key codes: 1) attachment to home through sheltering in place or absence/longing, 2) attachment to university through meaningful social relationships, 3) attachment to campus farm and the natural world through alleviation of isolation, and 4) attachment to farm and university through feelings of reciprocity.

First, we identified that student home attachment was most often attributed to students who had to isolate in their homes with family members or, when home could not be accessed due to COVID-19 precautions, who had a longing for their home and family. For the former, Steve, a theology student, reported that he and his two older brothers sheltered in place at their parents' home for several months during the pandemic and completed their respective schoolwork online. He reported that this arrangement was "a blessing in disguise," because it provided him the opportunity "to reconnect with them." As a result, the COVID-19 pandemic increased his attachment to home. The latter group included multiple students who lamented that they were unable to go home because of the need to protect family members, mainly grandparents, who were at high risk for COVID-19 complications. While attachment to home may have increased for a variety of reasons, many students also reported the desire to get out of their homes during the pandemic.

Second, Spring 2021 students elaborated extensively on the important role social relations play in the formation of our place attachments. This was most evident when students discussed their university attachment, which was most often articulated as being developed through their social relationships with peers during COVID-19. John, a student from one of the ecology courses, portrayed place as the physical environment in which relationships are nurtured and values shared. Attachment to the university, for him, then flowed from these relationships, which he needed to rely on more during the "dual pandemic." He stated, "it's not necessarily the buildings, the things that I'm involved with, the classes I've taken. It's the fact that I've met people here that I would not have met anywhere else. So, I think that definitely contributes to maybe not the physical place, but the fact that without that, without this physical place ... I would never have been with some of the people that I care about most." As he explored place attachment and social relationships further, he described going to local protests with his fraternity brothers. He stated that "it has made me more attached to the friends and the people that I've gone with to these protests, because I know that these people ... are of similar values, of similar thought to me. And, I guess I value them more knowing that they would be willing to go to things like that with me." Sally also acknowledged that at the university, she could be around people who share similar viewpoints, concerns, and values. This attached her more to the university and her peers than to home, because her hometown, she reported, was "very white and very conservative."

Third, many students, including over half the theology students, reported that their attachment to the farm, and the environment more broadly, was influenced by the opportunity such places offered for them to safely escape from COVID isolation. Johanna reported that it was "so nice" to be able to take walks in parks on her own or with friends and feel safe from the risks of COVID. Such walks provided her with opportunities to "reflect" on "everything that was happening." When visiting the farm during her PBEL course, she reported that "the farm did that for me, as well." Morgan agreed with Johanna and added, "As for like the farm and everything, it kind of almost feels like a little escape, because it's like I can be out in nature and be like enjoying this [farm] that's on campus." For Johanna and Morgan, as well as other PBEL students, the farm and the broader environment provided a safe reprieve from the stress of COVID isolation.

Interestingly, several students seemingly saw the benefits offered by such places almost as gifts, which created a sense of responsibility to give in return. For the final code, students articulated the role of reciprocity in their formation of place attachment. This means that students were grappling with complex ideas around their responsibilities and their indebtedness to what they receive from the places with which they interact. PBEL students described how the campus farm, the broader environment, the university, and even the surrounding city have given them so much and that they must reciprocate. Here, we see the ways that reciprocal relationships can knit one to specific places. Sally, the education student mentioned above, stated: "if [the campus farm was] looking for help, I feel like I would feel comfortable signing up to do whatever it is. Even though I may not have all the knowledge, I feel like I could give back because they welcomed me in and taught me a little bit about the farm and how it works." Similarly, John described his feelings about the farm in this way: "The farm produces food that's healthy, that goes to our table, that the friends that I have in the fraternity, and the people—my brother's coming to Butler—the food that he will eat here, is maybe produced by the campus farm. So, I guess it gives me an investment [in the farm] knowing that it has given something back." In other words, some students expressed that they wanted to "give back" to places that have impacted their lives and that their attachment to such places, like the campus farm, inspired them to provide the same care that was provided to them in that place.

Stepwise Linear Regression and Qualitative Support of Findings

With the COVID-19 pandemic beginning in the first year of this project, the student body was affected by significant disruptions to their overall educational experiences, including not only how they engaged with the university community and their courses but also how they interacted with the campus farm in the PBEL modules. As reported above, for Fall 2020–Spring 2021 students, we found that both Environmental Science Literacy scores and post-University Attachment scores were strongly predictive of CMG scores. In other words, the higher PBEL students scored on environmental science literacy and university attachment measures, the more likely they were to have high civic-mindedness scores. In this section, we aim to examine the intersection of these three concepts in the qualitative data.

The codes presented in the first two subsections of the qualitative results section illustrated the complex ways in which PBEL students developed university attachment, civic-mindedness, and environmental science literacy. The data reported above point to the ways that PBEL students, during the "dual pandemic," began to experience entanglements between their attachment to the university, their attachment to the campus farm, their social relationships, and their desire to make a difference in the areas of environmental and social justice. Many students characterized the importance of their university peers—and, for education students, the importance of their professors—in how attached they were to a particular place. Oftentimes, these relationships were nurtured outdoors in natural spaces (e.g., parks, the campus farm) that were relatively safe from COVID infection. At other times, these social relationships led them to places on and off campus where they discussed/expressed their feelings, worries, or concerns. Melissa, a student from the university's education program, was especially vocal in describing how some education professors were willing to spend a lot of time supporting their students. For example, Melissa stated that her professors were very accommodating and that she could talk to them if she was "having a bad day" and even "get a cup of coffee" with them if she had concerns about an assignment. This reportedly helped instill in her "the sense that I am almost at home." John reported joining his university peers in an off-campus protest against police brutality. The university provided a place where students could connect with others and the natural world during a time of great uncertainty and upheaval.

In sum, our focus group data revealed the increased importance of the university, its students, and its undergraduate programs, particularly in the context of the "dual pandemic." The university was often named as one of the only consistent means of both environmental (e.g., the campus farm) and social (e.g., peer relationships) connectedness for students throughout the COVID-19 pandemic. The solitary experience of pandemic life was partially mitigated by student relationships with their peers, opportunities for outdoor excursions, and also relationships within their departmental programs—the education program was a standout in this regard. It was also in the context of these social relationships that students processed the societal concerns and stressors (e.g., civil unrest) that were ubiquitous throughout the "dual pandemic." So, if students were attaching to the university via the social and environmental relationships that university life had made possible, and if within these relationships there were opportunities for discussion and, at times, action in response to environmental and social injustice, then it is evident that there is clearly some connection between university place attachment scores, environmental science literacy, and CMG scores.

Discussion and Conclusion

The purpose of this study was to examine the outcomes of implementing sustainability-themed PBEL on a campus farm. We found quantitative and qualitative evidence that PBEL farm modules, specifically when situated in relation to the complexities of the COVID-19 pandemic, civil unrest, and protests against police brutality, produced a learning environment that was particularly effective at increasing pro-environmental and civic thought and action, as well as student willingness to engage in social justice issues, such as food (in)security and how it is asymmetrically experienced by systemically oppressed communities. These findings build upon existing literature that demonstrates that embedding social and ecological issues into disciplinary learning experiences enables students to expand their views of their identities, agency, and roles in contributing to change (Garibay, 2015; McGee & Bentley, 2017; Williamson et al., 2023).

Our findings point to the power that generation-defining events can play on how people perceive their relationships to places, as well as how and what they learn through their place-based interactions or lack thereof. Our PBEL approach corresponds well with the literature that testifies to the value of place-based education, as well as the argument put forth by Carter et al. (2021) that students are drawn to the earth and environmental sciences—particularly topics related to environmental, ecological, or sustainability concerns—out of a sense of altruism. Student participants in this study, both STEM and non-STEM majors, increased their civic-mindedness, their place attachments, their sustainability meaning-making, and their environmental science literacy by engaging in PBEL modules. In doing so, they also encountered experiences that engaged their altruistic values and fostered their development of pro-environmental thought and action toward social and environmental justice. Altruistic outcomes were further evident in how students described the reciprocal obligations they have to the places that socially and emotionally nurture them.

The "dual pandemic"—and the multitude of crises arising from or revealed in its wake—appeared to create an educational milieu in which place attachment, civic responsibility, and knowledge of the environment could be cultivated and enhanced using PBEL farm modules. Students, like all of us, were isolated and experiencing a great deal of stress and uncertainty during the Fall 2020 and Spring 2021 semesters. Engaging on their campus, in their programs, with their peers, and on the campus farm in their courses seemed to at least partially, although perhaps only briefly, mitigate the loneliness and fear associated with life under COVID-19 and the societal injustices and repressive and ideological violence that it laid bare.

That said, there are limitations to this study. This study was conducted at a private, predominantly white university during the global COVID-19 pandemic, and our findings reflect that context. Future studies examining the impact of PBEL in urban and campus-situated agricultural contexts could expand upon our findings here by analyzing a more diverse sample of students and universities collected in a post-COVID environment. Our findings speak to a very complex moment, and we acknowledge that our specific results were shaped by many powerful, generation-defining forces that restricted access to particular places. The timeframe for our data collection could also be characterized as a time of great civil unrest, considering the social protests against police brutality, which affected students in a variety of complex ways and influenced how they made meaning of course materials. The COVID-19 pandemic also limited opportunities for classroom observations and discussions and affected whether students self-selected to participate in focus groups/interviews.

With the COVID-19 pandemic subsiding and with the issues igniting civil unrest and protest receding from mainstream visibility, a future study may find different results. In fact, in this study, we found substantially different results than our previous studies on PBEL farm modules (Sorge et al., 2022; Williamson et al., 2023). In what remains of this paper, we will first discuss how this study compares to our previous studies. We will then close by considering future directions for research that explores in greater detail how a mixture of PBEL and course content that challenges student mental models might impact sustainability thought and praxis.

Comparison to Past Findings

The results of the current study were much different from one of our earlier studies (Sorge, et al., 2022), which surveyed students participating in PBEL activities on the same campus farm in Fall 2017 and Fall 2018. According to Sorge, et al. (2022), 2017–2018 student CMG scores were predicted by post-place attachment to the campus farm scores, the course in which the students had had the PBEL experience, and student SSMM scores. Notably, between the present study and the Sorge et al. (2022) study, civic-mindedness remained a scale upon which students reported increased development; however, what predicted these CMG scores was different between 2017–2018 and the 2020–2021 academic year, when CMG scores were predicted by university attachment and environmental science literacy scores.

We postulate that this shift is due to some extent to student experiences of life during the "dual pandemic." For example, given that students were attaching to the university campus due in part to the opportunities it provided for social relationships—which were, as a consequence of the "dual pandemic," often experienced outdoors in natural environments and, at times, in contexts (e.g., the university) where important values were shared and discussed (e.g., protests, conversations)—it is unsurprising that, with this current study, student civic-mindedness is connected with environmental science literacy and university attachment.

Additionally, in another one of our studies with PBEL students from the 2017–2018 and 2018–2019 academic years (Williamson et al., 2023), the development of farm place attachment was influenced by students' academic/career goal interests, as well as their background. According to Williamson et al. (2023), the campus farm provided students with opportunities to gain insight and hands-on experiences influenced by their recent and distant experiences. This was especially true for one student's recent academic experiences, which had contributed to increased anxiety and stress. The farm-based PBEL experience provided opportunities for that student to reportedly feel greater control over their life. Time on the farm, then, was capable of providing "emotional relief" (Williamson et al., 2023, p. 11). This is interesting because, in this current study, instead of the campus farm being the primary place where students might find alleviation of anxiety and stress from their university programs, students found such alleviation within the broader university, which contains the campus farm, because it provided an escape from the solitude and anxiety of the "dual pandemic." During the 2020–2021 academic year, the source of the anxieties and stress students faced was different. This does not necessarily mean that students were not concerned about their assignments and grades during this time; rather, perhaps it was simply that the stress and fear associated with the "dual pandemic" were much stronger.

Future Directions: Mental Models and Systems Thinking

Some of our qualitative data from the theology focus group suggests that by coupling critical frameworks (i.e., subject-subject worldviews, "the loving eye") with PBEL experiences on the campus farm, students began to develop alternative mental models and worldviews. These mental models articulated novel forms of relational subjecthood that refused simplistic human/non-human distinctions, as well as the modes of valuation that so often accompany the ideological systems that express a hierarchy of being, with humanity at the apex and all other entities, living or otherwise, beneath (see Blaser, 2010; Escobar, 2018; Fore, 2022; Latour, 2012).

When considered within a "systems thinking" framework (Kim, 1999; Meadows, 2008) mental models play a fundamental role in the realities we have constructed and uncritically reproduce. Mental models are the source of systemic structures from which repeated events or patterns occur, yet they are often hidden from decision makers, limiting the ability to create sustainable and effective change to wicked problems (Monat & Gannon, 2015). By understanding the often subconscious mental models that shape their worldviews, students can begin to intentionally interrogate and reshape their perspectives to foster a paradigm shift in how nature and humans are valued and perceived. Future work in PBEL education and research should examine how students' PBEL experiences can help them to develop critical reflective frameworks and construct knowledge of novel modes of sustainability thought and praxis.

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APPENDIX:
NSF IUSE PBEL Farm Focus Group Protocols
Modified for COVID, National Protests, and Civil Unrest, October 2020

Student Focus Group

Hello, my name is _________.

This focus group will be recorded and then transcribed. The transcription will not include any personal information, so as to keep your personal information confidential. If anyone does not wish to be recorded, we will reschedule a time to get your input without the use of a recorder. Is everyone fine with being recorded today?

I am part of a research team from the ______. The objective of this focus group is to understand your experiences engaging with the campus farm in your courses. Your participation in this focus group is completely voluntary, and if you wish to decline responding to any question you may do so. You may leave this focus group at any time.

1. What aspects of the curriculum have you enjoyed the most? Least?
2. What are your academic and career goals?
   a. What specifically do you think draws you to this trajectory?
   b. Have these changed in any way since you engaged with the campus farm? If so, how?
   c. Have these changed in any way since the COVID pandemic? If so, how?
   d. Have your goals changed since the recent national protests and civil unrest? If so, how?
3. How has your feeling toward your academic career goals changed over time?
   a. What aspects of the curriculum have influenced these changes? How?
4. Since beginning course work on the campus farm, have you experienced feelings of greater attachment to it—or feelings of greater attachment to the environment, more generally?
5. In your experience, do you interact with a place differently when you feel some sort of attachment to that place?
6. How, if at all, has the COVID pandemic influenced or impacted your feelings of attachment to home?
   a. The university?
   b. The campus farm?
7. How, if at all, have the recent national protests and civil unrest influenced or impacted your feelings of attachment to home?
   a. The university?
   b. The campus farm?
8. What does civic engagement mean to you?
   a. How has civic engagement been portrayed in your courses?
   b. [If applicable] How has civic engagement been portrayed in your experiences with the campus farm?
   c. Has your perspective on civic engagement changed in any way since the COVID pandemic? If so, how?
   d. Has your perspective on civic engagement changed in any way since the recent national protests and civil unrest? If so, how?
9. In your experience, how does civic engagement occur or what does it look like?
   a. Where do you think these views come from?
10. In what ways do you think civic engagement is important to your own work?
    a. Do you have any examples of being civically engaged, in general?
    b. Do you have any examples of being civically engaged during your courses?
    c. Do you have any examples of being civically engaged during your work experiences?
11. What does it take to be a civic-minded professional?
    a. Do you have any examples?
12. Has your interaction with the campus farm affected the ways in which you want to interact with the community in the future (either personally or professionally)?

PROJECT REPORT

Chemistry in the Museum: Elucidation of 1920s Medical Kits

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Abstract

This project report describes the process of a team of undergraduate researchers (Chemistry and Nursing majors), who analyzed 20th-century medical kits housed at The Columbus Museum (Columbus, GA, USA). Curators and museum personnel were unfamiliar with the contents and needed assistance in identifying the various chemical contents. Items were identified by the Taylor Lab, which was followed by fully elucidating the chemical information in a chemical report and student-curated exhibit. The intent of this project was to help the museum be aware of how to properly curate and store the medical collections for an extended period. Laboratory analyses were executed to determine the composition of the aged items in the collections. The historical context of these kits and their contents provided knowledge of medicine to the community of Columbus, Georgia, in addition to explaining the use of medically related items in the 20th century.

Introduction

Can chemists, nurses, and historians work together? At the request of The Columbus Museum (Columbus, GA), Chemistry professor Kerri Shelton Taylor and students Shyrisse Ramos (Chemistry) and Jordan Spires (Nursing) of Columbus State University (CSU) were asked to investigate two collections consisting of three 20th-century medical kits for the purpose of identifying the various chemical contents. One of the kits was composed primarily of medicines, which were contained in the form of ampoules and hypodermic needles, alongside a select few hypodermic tablets. The other kits contained instruments for the use of administering medicines and assisting patients in the 20th century. It was assumed that these kits were used to assist with house calls for patients of all ages.

Three medical kits from the early 20th century are housed in The Columbus Museum. Collection 89.23.2 is characterized as a nurse's kit with related contents, belonging to Mrs. Sarah Yarbrough Allen. Collections 89.23.1 and 95.19.0 are characterized as physicians' kits. The contents of 95.19.0, acquired in 1995, were owned by Dr. John L. Hilt. The contents of 89.23.1 belonged to Dr. Clarence C. Allen. Upon review of the contents in the nurse's and physicians' bags, it seemed likely that these medical professionals completed house calls. These three individuals, Dr. John L. Hilt, Dr. Clarence C. Allen and Mrs. Sarah Yarbrough Allen, were probably general practitioners in the Columbus, Georgia area.

These kits contained the typical medicines used during the 20th century to cure/treat the most common ailments, such as colds, syphilis, and cardiac arrest. The hypodermic needles and the ampoules were kept in a pocket-size case, and the kits also contained medicines that could cure a range of different ailments. There were also tools we found in these kits, such as examples of early blood transfusion apparatus and speculum.

Methods

The purpose of this project was to chemically analyze the medicines used by these medical professionals during the early 20th century. A secondary goal of this project was to aid the museum specialists and the collections manager in the determination of the stability and safety of the chemical contents. The Columbus Museum aimed to preserve the integrity of these collections and maintain them for years to come. The chemical analysis of these contents intended to show the conditions for proper storage and preservation of the items over extended periods of time.

When executing this project and understanding the real-world problem of chemical analysis outside a classroom setting, the CSU scientists viewed the issue as subject matter experts. In retrospect, it would have been helpful to consider the methods used by medically related museums. Expert agencies like the National Park Service (NPS) would have provided great guidance on this topic. NPS requires:

- Safe and secure storage of museum collections in a dedicated space with minimal penetration and optimum thermal performance.
- Museum storage space adequate to accommodate the particular characteristics and quantity of objects, specimens, and archival items in the collection. It must also provide adequate space to accommodate reasonable growth of the collection over the next ten years.
- Organization of the space to allow for the efficient use of curatorial equipment and techniques and to provide for effective access and optimum preservation of the museum collection.
- Containerizing collections to the extent possible to minimize the negative effects of relative humidity and temperature fluctuations.
- Insulating the space so it will maintain a stable environment that protects the objects from adverse temperature and relative humidity conditions and damage from biological infestations (National Park Service, 2000).

According to the Building Design and Construction Network, museums, archives, and art storage facilities generally have strict requirements for interior temperature and relative humidity (RH) control. The unofficial museum standard for temperature and RH is 70°F and 50% (O'Brien, 2010).

The process of investigating this "real-world" problem was fully designed and executed by the CSU team and occurred in four phases (Table 1). Phases 1–3 were typical for Chemistry and Nursing research students. In Phase 1, the students itemized the collection and deduced which chemicals needed to be regenerated (Figure 1). The authors chemically regenerated the aged compounds to minimize destructive analysis of the museum components (Figures 2–3). The method for assessing the hazards was chosen by the research students, under the mentorship of the professor, museum curator, and collections manager.

TABLE 1. Four-Phase Process Associated with Cataloging and Curating the 20th-Century Medical Kits with Timeline of Executed Dates

July 2019	August-December 2019	March 2020	June 2020-January 2021
PHASE 1	**PHASE 2**	**PHASE 3**	**PHASE 4**
•Review museum collections • Record aged items through photography •Deduce items needed for regeneration in lab • Order necessary reagents	• Regenerate aged compounds collections in order to understand concerns of hazards • Determine hazards of aged compounds • Compile data into report	• Continue to arrange chemical information in scientific report • Continue analysis	• Present chemical information in scientific report • Collaborate with Columbus Museum to curate and install exhibition based on the project analysis • Write explanatory text for general audiences in a museum setting

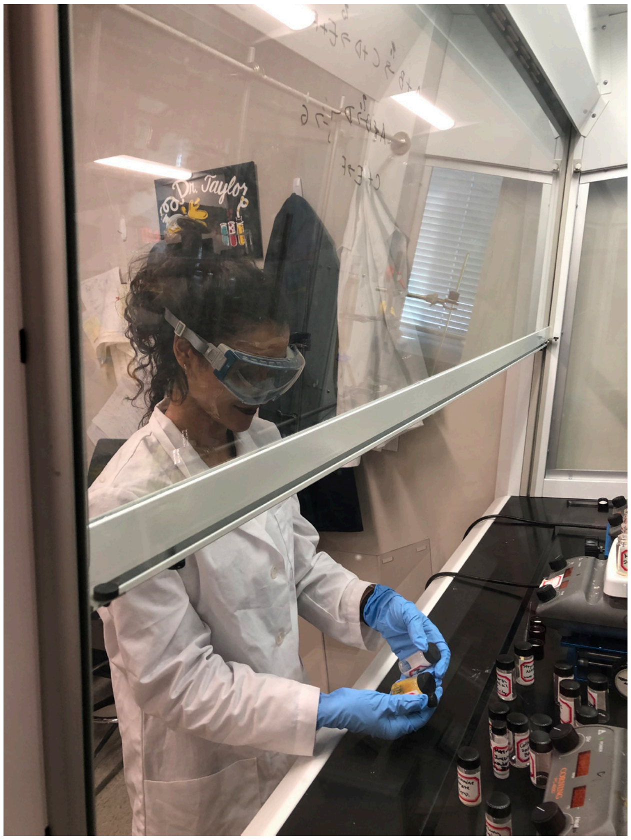
FIGURE 1. Shyrisse Ramos catalogs the age and identification of the aged items in the 20th-century medical kits, housed at The Columbus Museum.

FIGURE 2. Jordan Spires replicates the chemical compounds that would serve as a representation of aged items in the 20th-century medical kits housed at The Columbus Museum.

TABLE 2. Samples Exposed to Distilled Water

ITEM	OBSERVATIONS				
	DAY 1 (10/04/19)	DAY 5 (10/08/19)	DAY 6 (10/09/19)	DAY 7 (10/10/19)	DAY 60 (12/02/19)
Ferrous sulfate	Slight bluish, clear liquid	No change	Slight change in color	Yellow liquid	No change

FIGURE 3. Shyrisse Ramos catalogs the age and identification of the aged items in the 20th-century medical kits, housed at The Columbus Museum.



In Phase 2, four variables were tested: (1) temperature, (2) ambient air/moisture, (3) water sensitivity, and (4) light. Four vials of each chemical were prepared and labeled according to the variable being tested. The ambient temperature of the lab was routinely monitored at 67 °F. However, the change in temperature of the regenerated contents was studied from 32–158 °F. This range of temperature was chosen to represent the exposure of the contents to extreme cold (A/C overload) or heat (loss of A/C). Table 2 shows examples of compounds tested for water solubility. An interesting finding of Phase 2 was related to ferrous sulfate, which displayed an extreme color change from bluish solution to yellowish solution when exposed to moisture and ambient air during the two-month period (Figure 4).

Phase 4 was an opportunity for the students to develop their roles as scientific specialists. The curation and installation involved strong collaborations among the Taylor Lab, museum curator, and collections manager.

Chemical Findings

A chemical report (which can be found in the appendix) was provided to the museum to demonstrate the context and comparison of how medicines were used in the 20th century compared to the present day (21st century).

FIGURE 4. Water sensitivity of ferrous sulfate is measured. Distilled water (0.5 mL) was added to ferrous sulfate (0.1 g).

FIGURE 5. Chemical structures of medicines in the medical kits housed at The Columbus Museum

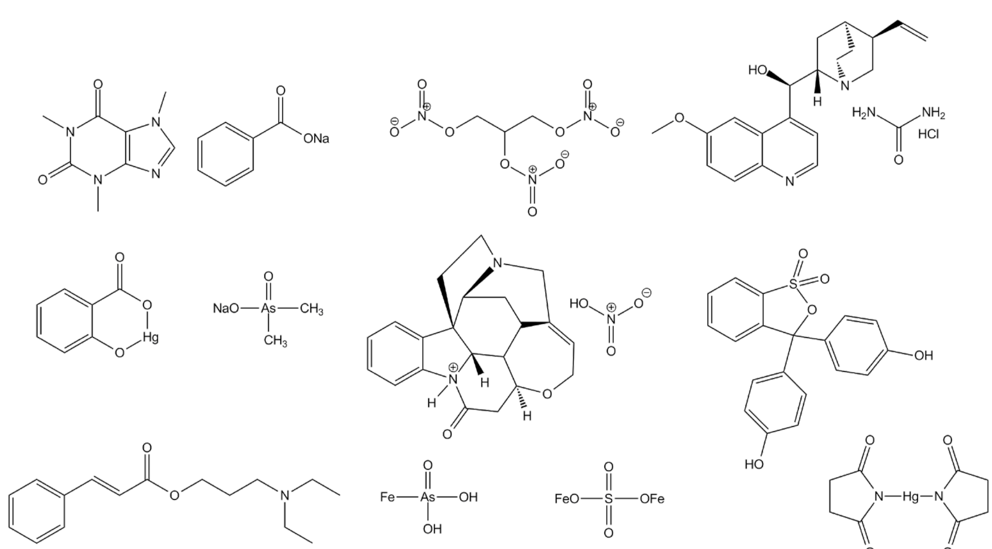


TABLE 3. Chemical Contents Characterized by Their Use in the 20th and 21st Centuries

Chemical	20th-Century Use	Present-Day Use
Mercury Succinimide (Hypodermic Tablets)	Treatment of gonorrhea; pulmonary tuberculosis	No longer used because of its toxicity
Quinine & Urea Hydrochloride	Local anesthesia, used to numb a specific part of the body. Quinine was also used to treat malaria.	Often used for abdominal surgeries; it is still used today for the treatment of some painful
Mercuric Salicylate (with Quinine and Urea Hydrochloride)	Mercury was used as a laxative and dewormer; also used as a syphilitic remedy	N/A Highly toxic
Quinine Dihydrochloride	Treatment of malaria	To treat malaria
Sodium Cacodylate	Treatment of syphilis	Highly toxic, since it is an arsenical compound; today considered a human carcinogen and used as a herbicide.
Strychnine Nitrate	As an analeptic, a central nervous system stimulant; also used in treatment of non-ketotic hyperglycinemia*	Often used as a rat poison; pesticide
Iron Arsenite & Strychnine	Arsenic was used as a synthetic chemotherapeutic agent and as a syphilis treatment, specifically in a compound	Used today in the manufacturing of insecticides
Phenolsulphthalein (Phenol Red)	Laxative, also used as a renal test to test for kidney failure; injected intravenously	Today used as a pH indicator; may cause cancer in humans
Mulford Hypo-Unit (Hypodermatic Injections)	Used to store hypodermic needles, made of nickel	N/A
Atropine Sulfate	To inhibit salivary and bronchial secretions, for cardiopulmonary resuscitation, management of acute myocardial infarctions (heart attacks)	Used to treat low heart rate; antimuscarinic agent; reduce salivation and bronchial secretions before surgery; antidote for
Digitol Aqueous	For cardiac disease	Unknown
Strychnine	Increases reflexes. When heated, emits highly toxic fumes. Remedy for heart and respiratory complaints, acts as a stimulant	Rat poison
Nitroglycerin	To prevent chest pain (agina) in patients with heart conditions, hypertension	To prevent chest pain (angina)
Camphor in Oil	Relieves pain, irritation, itching (natural oil)	Creams, ointments, and lotions
Caffeine Benzoate (Caffeine Sodium Benzoate)	Stimulates heart and breathing, wanted to counteract diminished blood pressure/respiration during anesthesia (for low blood pressure)	Treatment for respiratory depression (hypoventilation), but is not approved by the FDA
Cardiac ((R)-(-)-Phenylephrine Hydrochloride)	Anti-inflammatory, cold medicine, decongestant	Anti-inflammatory, cold medicine, decongestant
Aposthesine	Anesthesia	Not used because of its toxicity
Ribothiron, made of ferrous sulfate with vitamin B2, thiamine hydrochloride, and riboflavin	Iron deficiency anemia	N/A

Additionally, the report described the results of the laboratory analysis when the contents were tested against the variables of temperature, ambient air, water sensitivity, and light. Example compounds studied are shown in Figure 5. At the museum's request, necessary reagents were ordered and mimicked to replicate the compounds of the aged medical collections in order to determine hazards.

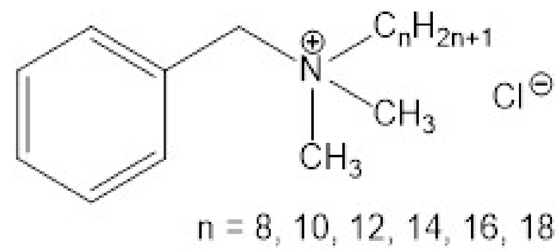
Table 3 displays the chemicals itemized by the CSU team. Interesting findings included the use of several medicines containing mercury, which is no longer used in the 21st century. Similarly, strychnine was used as a stimulant for the cardiac and nervous systems, while in the present day it is used as a rat poison. Thirdly, arsenic was noted in iron arsenite, in medicines used as a synthetic chemotherapeutic agent and as a syphilis treatment; arsphenamine is now used as an insecticide. However, it was exciting to realize that some medicines have been consistently used across both centuries. The chemicals camphor, caffeine benzoate, and (R)-(-)-phenylephrine hydrochloride have been used for the relief of pain, respiratory/cardiac, and inflammatory issues, respectively.

Lygel Tube and Bloody Gauze

The major goal of this study and the subsequent student exhibit was to understand two unique and interesting contents: a rusting Lygel ointment (95.19.47 D) and brittle gauze with dried blood spots (95.19.56 O-P). Samples from these contents were taken and submitted for external analysis to the Mass Spectrometry Lab at Auburn University. Multiple samples were collected by generic q-tips to analyze and compare a native (non-rust) sample to a rusted sample of the Lygel tube.

The swabbed ends of 95.19.56 D (rust and native samples), along with a blank q-tip, were submitted for analysis. All q-tip samples were cut off with a clean scalpel, and 300 μL of hexanes and 300 μL 50% water 50% methanol were added. Samples were vortexed and sonicated well. The liquid was centrifuged to separate the layers and the hexanes was analyzed by GC-MS, while aqueous was analyzed by LC-MS in positive and negative modes after separation on a Waters BEH C18 column. Select organic compounds were identified in the non-rust and rust samples. In the rust sample, decamethylcyclopentasiloxane, dodecamethylcyclohexasiloxane, and tetradecamethylcycloheptasiloxane were noted while in the non-rust sample, diethyl phthalate and undecane were detected. All structures can be viewed in the appendix.

FIGURE 6. Schematic representation of benzalkonium chloride



Lysol was used as an antiseptic jelly meant to prevent the growth of disease-causing microorganisms. The directions were still visible on the rusted tube and state that this jelly was used with a douche to help clean the reproductive area of female patients. In the directions, there is mention of Lysol. The benzene ring in the Lysol was also present in the diethyl phthalate in the non-rusted lygel sample. The main active ingredient in Lysol was benzalkonium chloride (Figure 6).

According to a HuffPost article, Lysol was used in the 1920s for feminine hygiene issues and odors. This product was used as an aid to spice up a couple's "love life behind closed doors." An example of these 20th-century ads, which were meant to encourage women to wash routinely (Bologna, 2018), can be found on the HuffPost website. In the 21st century, however, Lysol is known to be used as a disinfectant to protect from harmful germs on a variety of surfaces.

Samples of the brittle gauze and the dried blood spots (95.19.56 O-P) were taken and submitted for external analysis at the Auburn University Mass Spectrometry Lab. Chromatograms were provided in a supplementary document to the Columbus Museum as pdf files. Excel files (csv) from the Auburn University Mass Spectrometry Lab contained both positive and negative ions. This data provided the peak height and area for the ions at the different retention times to help the Taylor Group probe the human metabolome database (hmdb.ca) to find tentative identities. Upon review, more than 3,900 items were quantified and identified by the human metabolome database (hmdb.ca).

Limitations with the blood analysis include further analysis to determine the background and potential recipient(s) of the blood samples located on the soiled gauze. Initial discussions were completed with a forensic chemist at the Georgia Bureau of Investigations (GBI), Mrs. Victoria Oehrlein, to distinguish a method and company for testing the blood sample. However, the experts noted some possible complications with DNA analysis: (1) separation of extraneous DNA and (2) financial cost.

Factor 1: Extraneous DNA

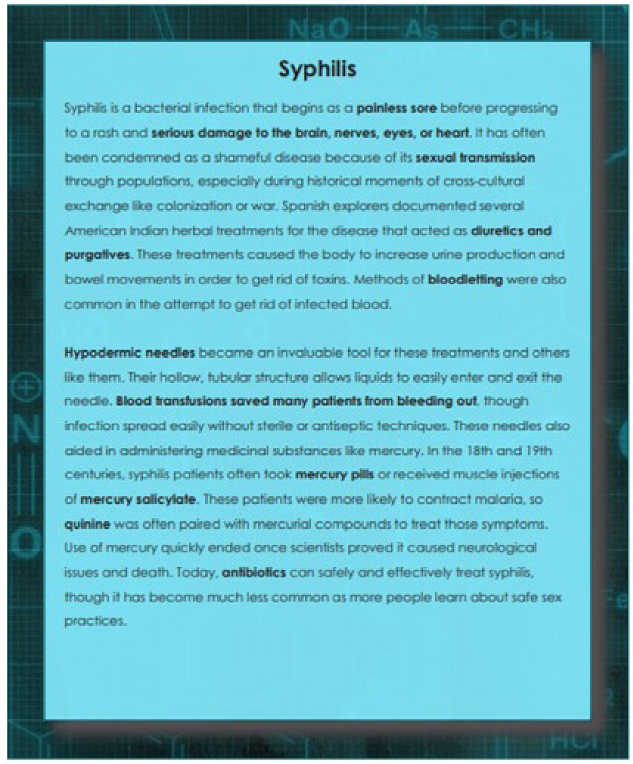
The blood samples, item 95.19.56 O-P, are from the 20th century (1920s–1940s) and likely have encountered a number of clinical professionals, patients, family descendants, museum personnel, scientists….to name only a few. This complicates analysis, as we would not know whose DNA truly belongs to the blood stain. Throughout the investigative process, the museum personnel and Taylor Group always wore gloves and made sure to maintain the composition of the items. In a forensic lab setting, DNA samples are compared against a known roster of individuals to decipher the true candidate. In this case, there are too many "knowns" to account for in this 100-year gap between the gauze being soiled and the present analysis.

The interest in the blood samples was piqued by the desire to understand the details associated with the dried blood. Blood can have many descriptors, such as gender, age, type, etc. These three kits were used by three different clinicians with the intention of serving the community of Columbus, Georgia as general practitioners. This means that the blood samples could be from patients of any age (i.e., baby, child, or adult) or gender (female or male). Furthermore, these blood samples could have easily been contributed by more than one source and could in fact be from multiple patients or the clinicians themselves. The commercial labs mentioned that the samples were, to date, considered ancient, which meant that they likely would not withstand the analysis. The Taylor Group would not be confident in reporting our findings to the museum.

Factor 2: Financial Cost

During multiple discussions with commercial labs, it became clear that the analysis would cost $2,000–3,000 at a minimum. Our budget did not allow for such an expenditure. The associated cost was not something that the Taylor Group or The Columbus Museum considered essential, which led to the end of the inquiry.

FIGURE 7. *Mystery Science* panel on syphilis, written collaboratively by Ramos and Spires with the collections manager and museum curator



Results and Reflection

Data was presented in a poster presentation at a regional chemistry conference, the Southeastern Regional Meeting of American Chemical Society (SERMACS), in October 2019. The chemical report was submitted to Columbus Museum staff Rebecca Bush and Aimee Brooks in December 2019. In addition to the report and poster, the students contributed a final reflection on this project. The exhibition installation began in April 2020; however, the original dates were shifted due to COVID. The team worked remotely and safely amidst the pandemic to generate *the Mystery Science Museum 3000*. The exhibition was open to the public from July 2020 until January 2021. Ramos and Spires collaborated with the museum collections manager and history curator on the writing of explanatory text for general audiences in a museum setting. The major topics that were spotlighted in the exhibition included tuberculosis, anesthesia, and syphilis (Figure 7).

This museum exhibition elicited strong civic engagement, as it was created by CSU students and demonstrated the connection of the 20th-century kits of previous Columbus residents and clinicians who served the Columbus community. The team of Ramos and Spires was awarded the Georgia Association of Museums Student Project Award (Figure 8).

FIGURE 8. Spires and Ramos received the Georgia Association of Museums Student Project Award for their work on the exhibition Mystery Science Museum 3000. Rebecca Bush (left) was the primary staff liaison for the project and Holly Beasley Wait (right) is a GAM Awards committee member and executive director of the National Civil War Naval Museum in Columbus.

Reflections

Mentor

I was amazed at how the medical uses of the various items evolved from the 20th century to the present day. It was eye-opening to learn that caustic materials can be used/viewed as beneficial for the body (i.e., quinine and strychnine). One of the most interesting medicines was a rusting tube that was called Lygel. In the 20th century, it was used for female hygiene to help intimacy in the bedroom. However, the components of Lygel are used in the present day as Lysol. It is unsettling to know that such a material that today is used for cleaning counters was perceived as useful according to the field of gynecology.

As a mentor, I am thrilled for the opportunity to learn alongside my students and further understand the historians' creed: everything has a history. As a scientist, I appreciate the value of medicine's evolution. Medical care and curative materials are necessary and adapted according to the needs of society. This project has truly been an illuminating experience. Lastly, this research opportunity has helped me to reflect on my experiences as a patron in the museum setting. I have become aware of the sense of pride, and at times even humor, that curators can have in their job. More specifically, I have gained an appreciation of the elements needed to generate a well-established exhibit (Midden, 2018).

When creating an exhibit, an interpretive master plan needs established, which includes a four-step process: (1) concept design, (2) schematic design, (3) design development, and (4) final design (Smithsonian Museums, 2018). Within this arrangement, the curator must present a big idea using key messages and critical questions. The students did a phenomenal job helping to arrange the exhibit. Both the students collaboratively wrote the panels of text for the exhibit, alongside the curators at The Columbus Museum. I was especially impressed by the subtleties in the exhibit. The major color that spanned the exhibition was the blue color traditionally found on operating gloves and the structures of the chemical components in the three medical kits were spread along the walls of the exhibition.

Students' responses

This project was very informative. We have learned about the various medicines that were used in the 20th century, in comparison to medicines that are used today. It was truly an honor to be able to analyze the components of these chemicals and observe the evolution of medicine since the 1920s. Many of the medicines used have adverse effects and are no longer used in practice. The impact of the doctor/nurse on the patient is demonstrated through the instruments and cases (Jarman, 2015; National Research Council, 2011).

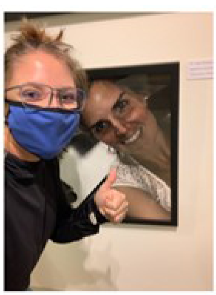
Through the process of working with The Columbus Museum, we have been able to witness the extensive process of museum curation and exhibition. It is no easy task, but it is a service to the community (Bachofer & Cass, 2022). This project not only incorporates history and art, but also shows the role of science in historical contexts.

Some medicines that were used during the 20th century are not used today because of potential hazards. During that time period, the hazards were not known; however, they have been documented in recent years through scientific advancements. Because of the age of the chemicals and medicines that are currently possessed by The Columbus Museum, special care must be taken so that these pieces of history can be maintained for years to come. Our research chronicles all observed changes as a result of each chemical modification.

Civic Engagement

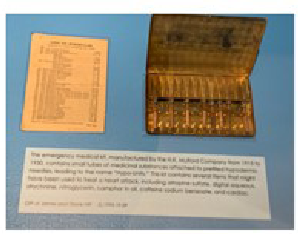
The collaborative project of the CSU team and The Columbus Museum strongly supports the goal of civic engagement. The Association of American Colleges & Universities defines the concept of civic engagement as "working to make a difference in the civic life of our communities and developing the combination of knowledge, skills, values, and motivation to make that difference. It means promoting the quality of life in a community, through both political and non-political processes." (Ehrlich, 2000) The students were provided opportunities outside the classroom to engage with the museum staff and university faculty in the regional area of southwest Georgia and parts of Auburn, Alabama. The goal of civic engagement was achieved. CSU students participated in unique curatorial and science activities of personal and public concern that were both individually life enriching and socially beneficial to the Columbus community. In short, the students supported The Columbus Museum in its ultimate mission to preserve history for future generations.

FIGURE 9. Response from a CHEM 1152 student



I have lived in the Columbus area for the last 3 years and never have been to the Columbus museum. I found it quiet fun to see the history of how Columbus was discovered and how it has grown over time. It was also a great distraction from studying for exams. I think that the most interesting part for me throughout the Nursing exhibit was how medical physicians used to carry around small medical kit full which contained prefilled hypodermic needles which contained the medicine helpful to decrease and treat a heart attack. I was actually shocked how many common molecules that I have learned in class are actually used in the medical field. I would have never really thought of how aspirin is actually created, just how it is used to help pain, inflammation and fever reducer. My overall experience of the exhibit showed a better understanding of how important science, especially chemistry is for everyday life.

The exhibit showed the connection between medicine and chemistry during the 1920-40s. While also showing how much chemistry has changed over time to improve medicine for problems related to current everyday life. Advanced studying of medicine has determined the good and the bad of early used medicine and has only generated a greater opportunity for better modern-day medicine and will continue to construct new and improved medicine in the medical field. It has also showed that some chemicals that were used back in the early 1900's could also cause later consequences. An example would be Apothesine which was used for tuberculosis treatment and anesthesia, however today it is not used because it is considered to be toxic.



This interdisciplinary project and student-focused exhibit served as a great example of civic engagement. This student exhibition very effectively supported the medical theme rooted in subsequent exhibitions and museum programming. *Mystery Science Museum 3000* followed an exhibition, "The Doctor Is In," which spotlighted the history of healthcare in Columbus, Georgia (Columbus Museum, 2020). The unique feature of the *Mystery Science Museum 3000* exhibit specifically spotlighted Columbus natives as successful servant leaders in the field of medicine. Furthermore, the exhibition was pivotal in publicly demonstrating the items used by Sarah Yarbrough Allen, Columbus's first African American registered nurse.

This project was an opportunity for CSU undergraduate students and local professionals to collaborate on an impactful creative endeavor for the city of Columbus, Georgia. CSU students served as servant leaders by honoring the community. In addition, the students' research provided context on how certain chemicals were used to treat medical conditions in the previous century. As such, the research team provided museum staff with knowledge on the precautions associated with safely maintaining the chemical items and handling historic medical kits.

Even though the exhibition was presented during the pandemic, efforts were made to publicize the content. Allied health majors from a CHEM 1152 course were provided bonus points for attendance at the exhibition. In Figure 9, a student comments about how the course impacted her educational focus. The general comments show that attendees found satisfaction in seeing chemistry in practice rather than in theory. Some mentioned that the exhibit was a good reminder to keep pushing through the rough parts of school, due to the satisfaction and value of being a practicing clinician. Students also commented that the researchers did a great job designing the exhibit, as the content was put in terms simple enough for the general audience to understand while also being able to enjoy the experience.

This project impacted the research students in unique ways as it related to their future vocations. It further enforced Shyrisse's desire to be a medical examiner and Jordan's plan to become a nurse anesthetist. This project has continually fascinated the students, due to their eclectic interests in chemistry, medicine, and art. They contributed their work and knowledge through the historical view of the items in these collections.

On a grander scale, this exhibition impacted the community and medicine. These students' collaboration displayed how medicine has evolved since the 20th century, as well as within the context of Columbus, Georgia. It demonstrated how intertwined the disciplines of science, art, and history can truly become. Furthermore, the community of Columbus, Georgia witnessed the influence and contribution of two passionate and hardworking students from Columbus State University.

Final Thoughts

Ultimately, the purpose of this project was twofold: to provide students from two very different disciplines with the experience of showing the importance and value of the other discipline, while also serving the practical purpose of helping The Columbus Museum further understand the materials in their collection and how they should continue to preserve these materials.

Following the exhibition, the Collections Manager commented that museums do have tight standards regarding environmental requirements. However, some in the field (including conservators) believe that those requirements could be safely "loosened" in certain situations, locations and collections. For example, it can be really hard for southeastern museums to maintain a 50% RH during the humid summer. It can be really hard for southwestern museums to reach it in their dry summers. If it can be proven that materials can be safely cared for at relative humidity levels besides the standard 50%, that could give museums an economic benefit by redirecting resources into other things like educational programming. It's also a greener choice, which is good for everyone. Furthermore, this loosening of requirements could allow the smaller museums more opportunities to borrow art and artifacts from larger museums, expanding audiences that might not normally get a chance to see those objects. Overall, the museum industry still needs to be convinced that this is a safe thing to do, and any project adding to that knowledge base, for or against, is beneficial.

In this process, the research team in the Taylor Group learned from the expertise of the curatorial team at The Columbus Museum. The research team provided insight about the handling and preserving of chemical materials in the collection, which was previously limited. These findings have allowed the museum to provide more detail for their in-house content management system, and it also provided an opportunity to display this material as a part of a medical exhibit.

About the Author

Kerri Taylor is an associate professor at Columbus State University (Columbus, GA, USA), and her academic and research focus is on organic chemistry, specifically the field of synthetic medicinal chemistry and material science. Taylor holds a Bachelor of Arts degree in chemistry from Miami (Ohio) University, a master of science degree in chemistry from the University of Kentucky, and a Ph.D. in chemistry from the University of Akron.

Acknowledgements

I would like to thank and acknowledge Columbus State University for allowing me to mentor and guide the students on this project. The Columbus Museum (Columbus, GA) should also be acknowledged and thanked for their permission to review the contents of the 20th-century kits. Funding was provided by CSU's Department of Chemistry, the CSU Interdisciplinary Initiative Grant (provided by the CSU Faculty Center), and the CSU Student Research and Creative Endeavors Grants Committee.

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APPENDIX:
Chemistry in the Museum Elucidation of 1920s Medical Kits

Chemical Report

This section of the report contains chemical analysis, examination results, and suggested recommendations for short-term and long-term use.

List of Tables

List of Figures

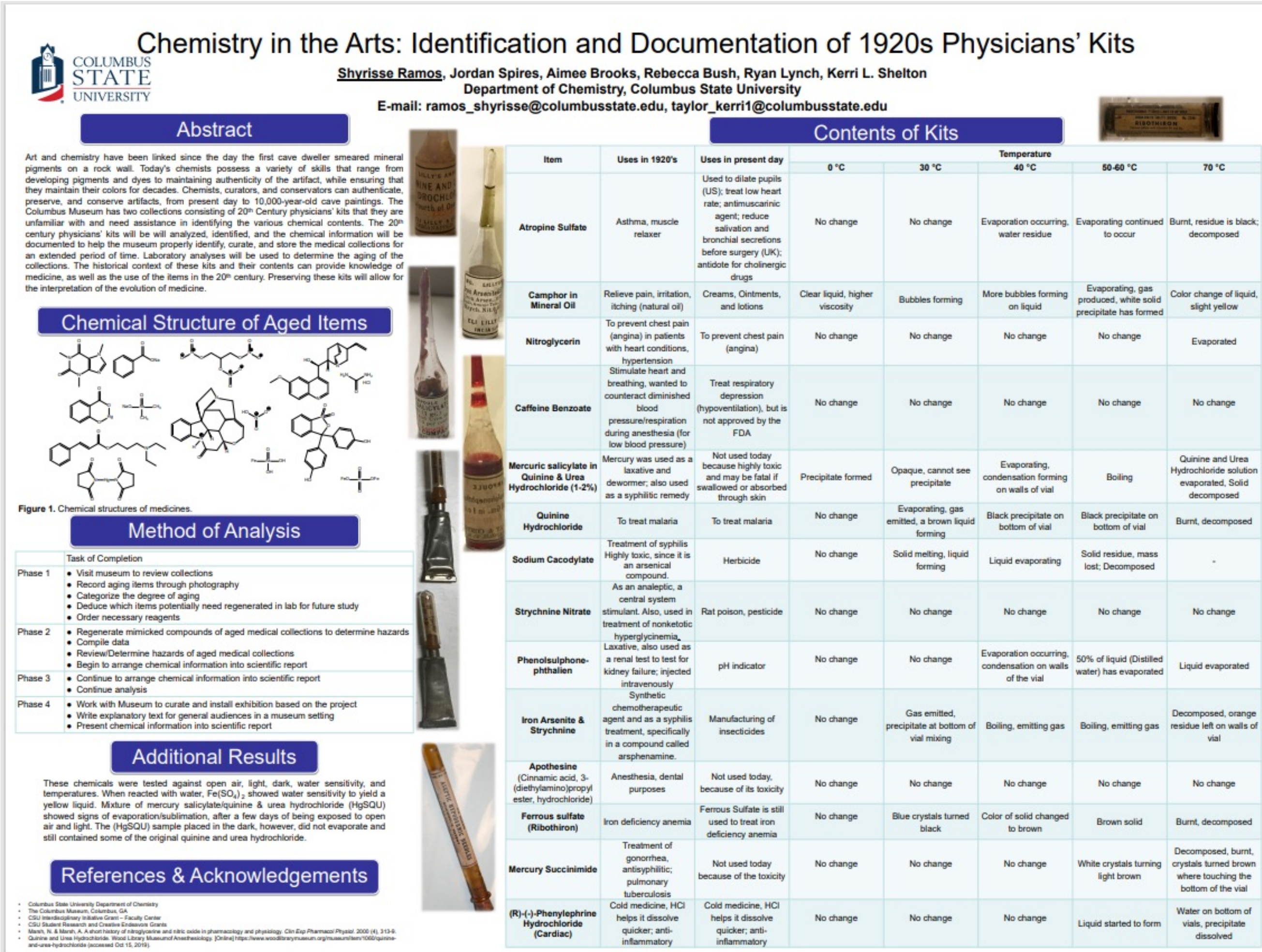
Background

Three medical kits from the early 20th century are housed at The Columbus Museum. Collection 89.23.2 is characterized as a nurse's kit and related contents, belonging to Mrs. Sarah Yarbrough Allen. Collections 89.23.1 and 95.19.0 are characterized as physicians' kits. The contents of 95.19.0, acquired in 1995, were owned by Dr. John L. Hilt. The contents of 89.23.1 belonged to Dr. Clarence C. Allen. Due to the contents within the nurse's and physicians' bags, it seemed likely that these medical professionals completed house calls. These three individuals, Dr. John L. Hilt, Dr. Clarence C. Allen, and Mrs. Sarah Yarbrough Allen, were probably general practitioners.

These kits contained the typical medicines used during the 20th century to cure/treat the most common ailments, such as colds, syphilis, and cardiac arrest. The hypodermic needles and the ampoules were kept in a pocket-size case, and the kits also contained medicines that could cure a range of different ailments. There were also tools in these kits, such as an early blood transfusion apparatus and a speculum, which suggests that these doctors made house calls and carried the necessary items for various situations that could arise.

The purpose of this project was to chemically analyze the medicines used by these medical professionals during the early 20th century. A secondary goal of this project was to aid the museum specialists and the collections manager in the determination of the stability and safety of the chemical contents. The Columbus Museum aims to preserve the integrity of these collections and maintain them for years to come. The chemical analysis of these contents intended to show the conditions for proper storage and preservation of the items over extended periods of time. Table 1 demonstrates the context and comparison of how medicines were used in the 20th century compared to the present day (21st century). Tables 2–5 describe the results of the laboratory analysis, when the contents were tested against the variables of temperature, ambient air, water sensitivity, and light.

FIGURE 10. Poster presented at SERMACs conference



Chemistry in the Arts: Identification and Documentation of 1920s Physicians' Kits

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Abstract

Art and chemistry have been linked since the day the first cave dweller smeared mineral pigments on a rock wall. Today's chemists possess a variety of skills that range from developing pigments and dyes to maintaining authenticity of the artifact, while ensuring that they maintain their colors for decades. Chemists, curators, and conservators can authenticate, preserve, and conserve artifacts, from present day to 10,000-year-old cave paintings. The Columbus Museum has two collections consisting of 20th Century physicians' kits that they are unfamiliar with and need assistance in identifying the various chemical contents. The 20th century physicians' kits will be will analyzed, identified, and the chemical information will be documented to help the museum properly identify, curate, and store the medical collections for an extended period of time. Laboratory analyses will be used to determine the aging of the collections. The historical context of these kits and their contents can provide knowledge of medicine, as well as the use of the items in the 20th century. Preserving these kits will allow for the interpretation of the evolution of medicine.

Chemical Structure of Aged Items

Figure 1. Chemical structures of medicines.

Method of Analysis

	Task of Completion
Phase 1	• Visit museum to review collections • Record aging items through photography • Categorize the degree of aging • Deduce which items potentially need regenerated in lab for future study • Order necessary reagents
Phase 2	• Regenerate mimicked compounds of aged medical collections to determine hazards • Compile data • Review/Determine hazards of aged medical collections • Begin to arrange chemical information into scientific report
Phase 3	• Continue to arrange chemical information into scientific report • Continue analysis
Phase 4	• Work with Museum to curate and install exhibition based on the project • Write explanatory text for general audiences in a museum setting • Present chemical information into scientific report

Additional Results

These chemicals were tested against open air, light, dark, water sensitivity, and temperatures. When reacted with water, $Fe(SO_4)_2$ showed water sensitivity to yield a yellow liquid. Mixture of mercury salicylate/quinine & urea hydrochloride (HgSQU) showed signs of evaporation/sublimation, after a few days of being exposed to open air and light. The (HgSQU) sample placed in the dark, however, did not evaporate and still contained some of the original quinine and urea hydrochloride.

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- CSU Interdisciplinary Initiative Grant – Faculty Center
- CSU Student Research and Creative Endeavors Grants
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Contents of Kits

Item	Uses in 1920's	Uses in present day	Temperature 0 °C	30 °C	40 °C	50-60 °C	70 °C
Atropine Sulfate	Asthma, muscle relaxer	Used to dilate pupils (US); treat low heart rate; antimuscarinic agent; reduce salivation and bronchial secretions before surgery (UK); antidote for cholinergic drugs	No change	No change	Evaporation occurring, water residue	Evaporating continued to occur	Burnt, residue is black; decomposed
Camphor in Mineral Oil	Relieve pain, irritation, itching (natural oil)	Creams, Ointments, and lotions	Clear liquid, higher viscosity	Bubbles forming	More bubbles forming on liquid	Evaporating, gas produced, white solid precipitate has formed	Color change of liquid, slight yellow
Nitroglycerin	To prevent chest pain (angina) in patients with heart conditions, hypertension	To prevent chest pain (angina)	No change	No change	No change	No change	Evaporated
Caffeine Benzoate	Stimulate heart and breathing, wanted to counteract diminished blood pressure/respiration during anesthesia (for low blood pressure)	Treat respiratory depression (hypoventilation), but is not approved by the FDA	No change	No change	No change	No change	No change
Mercuric salicylate in Quinine & Urea Hydrochloride (1-2%)	Mercury was used as a laxative and dewormer; also used as a syphilitic remedy	Not used today because highly toxic and may be fatal if swallowed or absorbed through skin	Precipitate formed	Opaque, cannot see precipitate	Evaporating, condensation forming on walls of vial	Boiling	Quinine and Urea Hydrochloride solution evaporated, Solid decomposed
Quinine Hydrochloride	To treat malaria	To treat malaria	No change	Evaporating, gas emitted, a brown liquid forming	Black precipitate on bottom of vial	Black precipitate on bottom of vial	Burnt, decomposed
Sodium Cacodylate	Treatment of syphilis Highly toxic, since it is an arsenical compound.	Herbicide	No change	Solid melting, liquid forming	Liquid evaporating	Solid residue, mass lost; Decomposed	-
Strychnine Nitrate	As an analeptic, a central system stimulant. Also, used in treatment of nonketotic hyperglycinemia.	Rat poison, pesticide	No change	No change	No change	No change	No change
Phenolsulphone-phthalien	Laxative, also used as a renal test to test for kidney failure; injected intravenously	pH indicator	No change	No change	Evaporation occurring, condensation on walls of the vial	50% of liquid (Distilled water) has evaporated	Liquid evaporated
Iron Arsenite & Strychnine	Synthetic chemotherapeutic agent and as a syphilis treatment, specifically in a compound called arsphenamine.	Manufacturing of insecticides	No change	Gas emitted, precipitate at bottom of vial mixing	Boiling, emitting gas	Boiling, emitting gas	Decomposed, orange residue left on walls of vial
Apothesine (Cinnamic acid, 3-(diethylamino)propyl ester, hydrochloride)	Anesthesia, dental purposes	Not used today, because of its toxicity	No change	No change	No change	No change	No change
Ferrous sulfate (Ribothiron)	Iron deficiency anemia	Ferrous Sulfate is still used to treat iron deficiency anemia	No change	Blue crystals turned black	Color of solid changed to brown	Brown solid	Burnt, decomposed
Mercury Succinimide	Treatment of gonorrhea, antisyphilitic; pulmonary tuberculosis	Not used today because of the toxicity	No change	No change	No change	White crystals turning light brown	Decomposed, burnt, crystals turned brown where touching the bottom of the vial
(R)-(-)-Phenylephrine Hydrochloride (Cardiac)	Cold medicine, HCl helps it dissolve quicker; anti-inflammatory	Cold medicine, HCl helps it dissolve quicker; anti-inflammatory	No change	No change	No change	Liquid started to form	Water on bottom of vials, precipitate dissolved

TABLE 4: Museum Contents Characterized by Their Use in the 20th and 21st Centuries, Recommended Dosage and Side Effects (Any words that appear unique will be denoted with an asterisk (*) and described in the "Key Words & Definitions" section.)

Contents

Table 1 categorizes the chemicals in the collections of 89.23.1, 95.19.0, and 95.19.1. The contents are ordered in numerical order. Each compound is characterized by its use in the 20th and 21st centuries, recommended dosage, and side effects (safety concerns).

Museum Coding	Item	20th-Century Use	Present-Day Use	Dosage	Safety Concerns/
1995.19.27 C	Mercury Succinimide (Hypodermic Tablets)	Treatment of gonorrhea; pulmonary tuberculosis	Not used because of its toxicity		Side Effects
1995.19.56 A-B	Transfusion apparatus; the metal ends are where the interchangeable needles are connected. The orange tube without the metal on its ends is the tourniquet.	Used for blood transfusions	Modified transfusion apparatus; intravenous lines are inserted into the blood vessel. Blood type is matched with patient's blood type	N/A	Poisonous; stable in air, literature says it can be affected by light
1995.19.57 B	Quinine & Urea Hydrochloride	Local anesthesia, used to numb a specific part of the body; Quinine was also used to treat malaria.	Often used for abdominal surgeries; it is still used today for the treatment of some painful conditions.	Administered through an intravenous injection.	N/A
1995.19.57 C (also coded as 1995.19.57 E)	Mercuric Salicylate (with Quinine and Urea Hydrochloride)	Mercury was used as a laxative and dewormer; also used as a syphilitic remedy.	N/A Highly toxic	Was mixed with water for internal use, mixed with olive oil for hypodermic use (injection), and mixed with Quinine and Urea Hydrochloride (ampoules)	N/A
1995.19.57 D	Quinine Dihydrochloride	Treatment of malaria	Treatment of malaria	Intravenous injection	Toxic by inhalation and ingestion
1995.19.57 F	Sodium Cacodylate	Treatment of syphilis;highly toxic, since it is an arsenical compound	Today considered a human carcinogen and used as a herbicide	Unknown	N/A
1995.19.57 G	Strychnine Nitrate	As an analeptic, a central nervous system stimulant; also used in treatment of non-ketotic hyperglycinemia*	Often used as a rat poison; pesticide	Unknown	Carcinogenic; toxic by ingestion, inhalation, or skin absorption, hygroscopic
1995.19.57 I	Iron Arsenite & Strychnine	Arsenic was used as a synthetic chemotherapeutic agent and as a syphilis treatment, specifically in a compound called arsphenamine.	Today used in the manufacturing of insecticides	1 g	Toxic by inhalation and ingestion; light sensitive; causes damage to central nervous system
1995.19.57 H/J	Phenolsulphthalein (Phenol Red)	Laxative, also used as a renal test to test for kidney failure; injected intravenously	Today used as a pH indicator; may cause cancer in humans	30-200 mg daily to act as a laxative	Toxic by ingestion and inhalation; a strong irritant; only 0.25 mg of arsenic is needed to cause fatality; possible carcinogen, suspected of causing infertility
1995.19.59 A	Mulford Hypo-Unit	Used to store hypodermic needles, made of nickel	N/A	N/A	Flammable, may cause cancer, may cause damage to fertility and/or unborn child

TABLE 4, continued

Museum Coding	Item	20th-Century Use	Present-Day Use	Dosage	Safety Concerns/
1995.19.59 B	Atropine Sulfate	To inhibit salivary and bronchial secretions, for cardiopulmonary resuscitation, management of acute myocardial infarctions (heart attacks)	Used to treat low heart rate; antimuscarinic agent; used to reduce salivation and bronchial secretions before surgery; antidote for cholinergic drugs	Unknown	
1995.19.59 C/F	Digitol Aqueous	For cardiac disease	Unknown	Unknown	Atropine is toxic if inhaled or ingested. It is fatal if swallowed; hygroscopic
1995.19.59 D	Strychnine	Increases reflexes. When heated, emits highly toxic fumes. Remedy for heart and respiratory complaints, acts as a stimulant	Rat poison	Unknown	Unknown
1995.19.59 E/H	Nitroglycerin	To prevent chest pain (agina) in patients with heart conditions, hypertension	To prevent chest pain (angina)	Unknown	Toxic if ingested; poison.
1995.19.59 G	Camphor in Oil	Relieve pain, irritation, itching (natural oil)	Creams, ointments, and lotions	N/A	High doses can cause headaches, dizziness, lightheadedness, tremors, convulsions, mental confusion, and even death
1995.19.59 I	Caffeine Benzoate (Caffeine Sodium Benzoate)	Stimulate heart and breathing, wanted to counteract diminished blood pressure/respiration during anesthesia (for low blood pressure)	Treat respiratory depression (hypoventilation), but is not approved by the FDA	500 mg; total dose should not exceed 2.5 g in 24 hours.	No known hazards
1995.19.59 J	Cardiac ((R)-(-)-Phenylephrine Hydrochloride)	Anti-inflammatory, cold medicine, decongestant	Anti-inflammatory, cold medicine, decongestant	Unknown	Large doses may cause headaches, agitation, a condition resembling anxiety; neurosis, muscle twitches, etc; targets the central nervous system and the heart
1995.19.63 B	Catgut, non-boilable	Serve as sutures. Made of dried and twisted intestines of cattle, i.e., sheep, horses, cows, goats; packaged in an alcohol solution (ethanol and isopropanol), in order to retain flexibility	Still used today	N/A	No known hazards
1995.19.63 C	Bauer & Black Sterile Chromic Catgut (Boilable)	Serve as sutures. Preserved in xylol, toulene-99.75%, phenyl mercuric acetate-0.025%	Still used today	N/A	No known hazards
1995.19.62 C	Aposthesine	Anesthesia	Not used because of its toxicity	For injection,	No known hazards
1995.19.7	Ribothiron, made of Ferrous Sulfate with Vitamin B2, Thiamine Hydrochloride, and Riboflavin	Iron deficiency anemia	N/A	1-2%, typically with epinephrine	Toxic; today, lidocaine is commonly used

Examination and Testing

In the laboratory setting, four variables were tested: (1) temperature, (2) ambient air/moisture, (3) water sensitivity, and (4) light. Four vials of each chemical were prepared and labeled according to the variable being tested. As the variables were monitored and altered, the composition of the select chemicals (the regenerated contents) appeared to experience a chemical change. Some of the variables, such as water sensitivity, appeared to have no sign or evidence of a chemical change. The variables of temperature, light, and ambient air were shown to strongly influence the stability of the regenerated contents.

Hypothesis

In the present state, the contents of the collections 89.23.1, 95.19.0, and 95.19.1, if stored in a dry, dark place, will be stable and can be maintained for an extended period of time. These contents are suitable for display for exhibition purposes. Hazards may only occur if placed in direct sunlight. It is suggested that with extreme heat the components are likely to be destroyed and degraded. Based on the safety concerns associated with the contents (listed in Table 1), we recommend that they are safe to handle and display, as long as they are not broken or unsealed.

Evidence

Temperature

The ambient temperature of the lab was 67 °F. However, the change in temperature of the regenerated contents was studied from 32–158 °F. This range of temperature was chosen to represent exposure of the contents to extreme cold (A/C overload) or heat (loss of A/C). Table 2 shows an overview of the chemical changes recorded when the regenerated contents were exposed to a change in temperature. The variable of temperature did not influence caffeine benzoate, strychnine nitrate, and Apothesine. Dramatic changes were noted when the regenerated contents were exposed to high temperatures (Table 2).

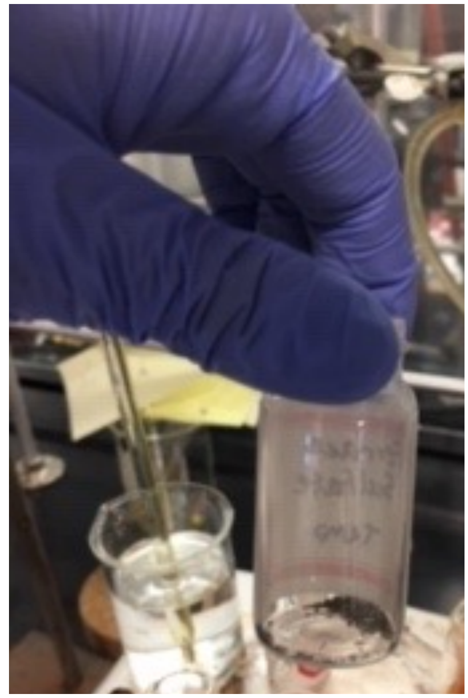
TABLE 5: Museum Contents upon Exposure of Temperature Changes from 0 °C (32 °F) to 70 °C (158 °F)

Item	Temperature (10/09/19)				
	0 °C (32 °F)	30 °C (86 °F)	40 °C (104 °F)	50-60 °C (122-40 °F)	70 °C (158 °F)
Atropine Sulfate	No change	No change	Evaporation occurring, water residue	Evaporating continued to occur	Burnt, residue is black; decomposed
Camphor in Mineral Oil	Clear liquid, higher viscosity	Bubbles forming	More bubbles forming on liquid	Evaporating, gas produced, white solid precipitate has formed	Color change of liquid, slight yellow
Nitroglycerin	No change	No change	No change	No change	Evaporated
Caffeine Benzoate	No change	No change	No change	No change	No change
Mercuric Salicylate in Quinine & Urea Hydrochloride (1-2%)	Precipitate formed	Opaque, cannot see precipitate	Evaporating, condensation forming on walls of vial	Boiling	Quinine and Urea Hydrochloride solution evaporated, solid decomposed
Quinine Hydrochloride	No change	Evaporating, gas emitted, a brown liquid forming	Black precipitate on bottom of vial	Black precipitate on bottom of vial	Burnt, decomposed
Sodium Cacodylate	No change	Solid melting, liquid forming	Liquid evaporating	Solid residue, mass lost; decomposed	---
Strychnine Nitrate	No change	No change	No change	No change	No change
Phenolsulphone-phthalien	No change	No change	Evaporation occurring, condensation on walls of the vial	50% of liquid (distilled water) has evaporated	Liquid evaporated
Iron Arsenite & Strychnine	No change	Gas emitted, precipitate at bottom of vial mixing	Boiling, emitting gas	Boiling, emitting gas	Decomposed, orange residue left on walls of vial
Apothesine (Cinnamic acid, 3-(Diethylamino) propyl Ester, Hydrochloride)	No change	No change	No change	No change	No change
Ferrous Sulfate (Ribothiron)	No change	Blue crystals turned black	Color of solid changed to brown	Brown solid	Burnt, decomposed
Mercury Succinimide	No change	No change	No change	White crystals turning light brown	Decomposed, burnt, crystals turned brown where touching the bottom of the vial
Cardiac (R)-(-)-Phenylephrine Hydrochloride	No change	No change	No change	Liquid started to form	Water on bottom of vials, precipitate dissolved

Light and Ambient Air

A set of the chemicals was studied to provide information about the stability of the regenerated contents when opened to determine the effect of ambient air. All samples were observed over a two-month period. The variable of light was first observed over a period of four consecutive days to determine short-term effects. The samples were then reviewed about two months later to determine any long-term effects of the light variable. This variable was studied to provide the museum with an idea of the stability of the compounds should the containers break while in use/storage/handling. The experimental procedure was designed with both exhibition and storage in mind.

FIGURE 11: Ferrous Sulfate decomposing at approximately 86 °F



Ms. Ramos measured approximately 0.025 g of each solid component into the vial. Select samples contained 0.05 g of the solid, as some of the chemicals were more brittle and clumped together. Simultaneously, two sets of samples were created to observe the effect of light exposure. One set was placed on a window ledge that experienced direct amounts of sunlight on a daily basis. A second set was placed in a cabinet in the dark. The lids of all vials were removed to allow proper exposure to the ambient air. Table 3 outlines the results when the samples were exposed to direct sunlight and open air. Table 4 details the results when the samples were kept in complete darkness.

Initially, ferrous sulfate was present as blue crystals. When exposed to water and air, the ferrous sulfate changed into an orange liquid, most likely due to the iron in the ferrous sulfate reacting with water and moisture in the air. Another chemical mixture, mercuric salicylate in a quinine and urea hydrochloride solution, reacted when exposed to the same conditions. Over time when exposed to the light and air, the sample composition evaporated and led to a small amount of solid in the vial. We have not identified the chemical composition of the solid. Upon further request by the museum, we can conduct additional studies. Similar observations were noted when the phenol red solution was exposed to the light and air.

Due to financial expense and governmental regulations, we studied the effects of nitroglycerin for select variables: ambient air, temperature, and light. A 1.0 mL sample of nitroglycerin was split into two samples. When the nitroglycerin sample (0.5 mL) was left in light and ambient air, the contents evaporated after four days.

Dark and Ambient Air

In addition to the light study, the samples were monitored over a two-month period when left in ambient air in the dark. The phenol red evaporated completely and a red powder residue remained. After two weeks, the mercury salicylate and phenol red in the open air and the light condition evaporated completely, and a slight solid residue remained in the vials.

The ferrous sulfate underwent a major change. On day one, the ferrous sulfate was present as blue crystals. After four days, the ferrous sulfate was present as a yellow liquid. This was most likely due to the iron reacting with the oxygen atoms in the distilled water.

Moisture

Ms. Ramos measured approximately 0.025 g of each solid component into the vial. Select samples contained 0.05 g of the solid, as some of the chemicals were more brittle and clumped together. Table 5 outlines the results when the samples were exposed to moisture. These samples were left in the sunlight, with the caps on. The effect of moisture was first observed over a period of seven days to determine short-term effects. The samples were then observed about two months later to determine any long-term effects of the water variable.

Some of the chemicals dissolved completely with the water; however, others were insoluble in water. Strychnine nitrate formed a cloudy liquid when mixed with 0.5 mL of distilled water. When mixed with 0.5 mL of distilled water, mercury succinimide formed an opaque white liquid.

TABLE 6: Samples Exposed to Direct Sunlight and Open Air, with the Caps Off

ITEM	Observations				
	Day 1 09/24/19	Day 2 09/25/19	Day 3 09/26/19	Day 4 09/27/19	Day 72 12/02/19
Ferrous sulfate	Blue Crystals	Blue Crystals	Blue Crystals	Blue Crystals	Decomposed
Mercuric Salicylate in Quinine & Urea Hydrochloride (1-2%)	Cloudy, liquid	Cloudy, liquid	Solid settled to the bottom	Solid settled to the bottom	Decomposed
Phenol Red (1 mL of water)	Red liquid	Red liquid	Red liquid	Dark liquid settled at bottom, lighter layer on top	Decomposed
Atropine Sulfate	White solid	White solid	White solid	White solid	Decomposed
Caffeine Sodium Benzoate	White, clumpy solid	White, clumpy solid	White, clumpy solid	White, clumpy solid	Decomposed
Camphor in Mineral Oil	Clear liquid	Clear liquid	Clear liquid	Clear liquid	Clear liquid
Sodium Cacodylic	White, clumpy solid	Clear liquid	Clear liquid	Clear liquid; solid completely disappeared	Decomposed
Strychnine Nitrate	White, grainy solid	White, grainy solid	White, grainy solid	White, grainy solid	Decomposed
Aposthesine	White solid, powder	Liquid formed, still some solid remaining	Liquid formed, most of solid dissolved	Liquid formed, some solid remaining	Decomposed
Cardiac	White solid chunks	White solid chunks	White solid chunks	White solid chunks	Decomposed
Quinine Hydrochloride	White solid	White solid	White solid	White solid	Decomposed
Mercury Succinimide	White crystals	No change	No change	No change	Decomposed
Iron Arsenite	Yellow liquid	Solid settled to the bottom, with relatively clear liquid remaining on top	No change	No change	Decomposed

TABLE 7: Samples Exposed to No Sunlight and Open Air, with the Caps Off

ITEM	Observations				
	Day 1 09/24/19	Day 2 09/25/19	Day 3 09/26/19	Day 4 09/27/19	Day 72 12/02/19
Ferrous sulfate	Blue Crystals	Blue Crystals	Blue Crystals	Blue Crystals	Decomposed
Mercuric Salicylate in Quinine & Urea Hydrochloride (1-2%)	Cloudy, liquid	Precipitate settled to the bottom of vial	Precipitate settled to the bottom of vial	Precipitate settled to the bottom of vial	Decomposed
Phenol Red (1 mL of water)	Red liquid	Red liquid	Red liquid	Red liquid	Decomposed
Atropine Sulfate	White solid	White solid	White solid	White solid	Decomposed
Caffeine Sodium Benzoate	White, clumpy solid	White, clumpy solid	White, clumpy solid	White, clumpy solid	Decomposed
Camphor in Mineral Oil	Clear liquid	Clear liquid	Clear liquid	Clear liquid	Clear liquid
Sodium Cacodylic	White, clumpy solid	Clear liquid, still some solid remaining	Clear liquid, most of solid dissolved	Clear liquid	Decomposed
Strychnine Nitrate	White, grainy solid	White, grainy solid	White, grainy solid	White, grainy solid	Decomposed
Aposthesine	White solid, powder	Liquid formed, still some solid remaining	Clear liquid, most of solid dissolved	Clear liquid	Decomposed
Cardiac	White solid chunks	White solid chunks	White solid chunks	White solid chunks	Decomposed
Quinine Hydrochloride	White solid	White solid	White solid	White solid	Decomposed
Mercury Succinimide	White crystals	No change	No change	No change	Decomposed
Iron Arsenite	Yellow liquid	No change	No change	No change	Decomposed

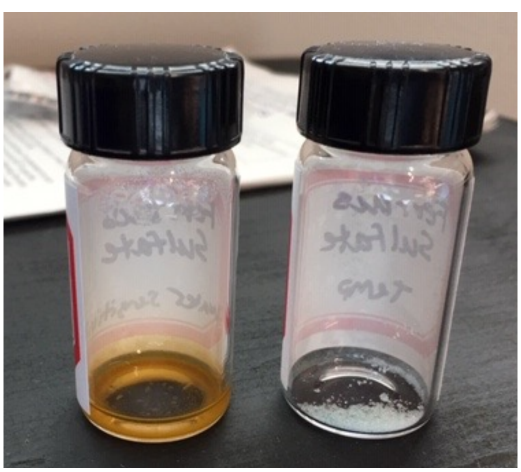
FIGURE 12: Mercuric Salicylate in the Open Dark Condition (Left) and Open Light Condition (Right)

Water Sensitivity

TABLE 8: Samples Exposed to Distilled Water (Variables of sunlight and no exposure to air were maintained as constants. The caps of the vials were left on.)

ITEM	Observations				
	Day 1 (10/04/19)	Day 5 (10/08/19)	Day 6 (10/09/19)	Day 7 (10/10/19)	Day 60 (12/02/19)
Ferrous Sulfate	Slight bluish, clear liquid	No change	No change	Slight change in color	Yellow liquid
Mercuric Salicylate in Quinine &Urea Hydrochloride (1-2%)	Cloudy liquid, solid resting at top	No change	No change	No change	No change
Phenol Red (1 mL of water)	Red liquid	No change	No change	No change	No change
Atropine Sulfate	Clear liquid	No change	No change	No change	No change
Caffeine Sodium Benzoate	Clear liquid	No change	No change	No change	No change
Camphor in Mineral Oil	Clear liquid	No change	No change	No change	No change
Sodium Cacodylic	Clear liquid	No change	No change	No change	No change
Strychnine Nitrate	Cloudy, white, opaque liquid	No change	No change	No change	No change
Aposthesine	Clear liquid	No change	No change	No change	No change
Cardiac	Clear liquid	No change	No change	No change	Changed color, brown tint
Quinine Hydrochloride	Clear liquid	No change	No change	No change	No change
Mercury Succinimide	Cloudy, white, opaque liquid	No change	No change	No change	No change
Iron Arsenite	Yellow liquid	No change	No change	No change	No change

FIGURE 13: Ferrous Sulfate in the Condition of Water Sensitivity (Distilled water (0.5 mL) added to ferrous sulfate (0.1 g).)



External Analysis of Lygel and Blood Samples

In these kits, there were two very unique and interesting contents: a rusting Lygel ointment (95.19.47 D) and brittle gauze with dried blood spots (95.19.56 O–P). Samples from these contents were taken and submitted for external analysis.

Lygel – 95.19.47 D

This was used as an antiseptic jelly meant to prevent the growth of disease-causing microorganisms. This tube has visible evidence of rust and exposure to air. The curator at The Columbus Museum indicated an interest of identifying the contents and determining whether the corrosion was a concern for an exhibition and storage. In image DSC_3044.JPEG, the directions state that this jelly was used with a douche to help clean the reproductive area of female patients. In the directions, there is mention of Lysol. The benzene ring in the Lysol was also present in the diethyl phthalate in the non-rusted Lygel sample. The main active ingredient in Lysol was benzalkonium chloride. Lysol was used in the 1920s for feminine hygiene issues.

To identify the chemical components of the aging tube, samples were sent to the Mass Spectrometry Lab at Auburn University for analysis and comparison of a native (non-rust) sample with a rusted sample. Samples were collected by a generic q-tip and messengered to the Auburn labs.

The ends of 95.19.56 D, rust, and blank q-tip were cut off with a clean scalpel, and 300 μL of hexanes and 300 μL 50% water 50% methanol were added. Samples were vortexed and sonicated well. The liquid was centrifuged to separate the layers; the hexanes were analyzed by GC-MS, while aqueous was analyzed by LC-MS in positive and negative modes after separation on a Waters BEH C18 column.

Visible differences in the LC-MS total ion chromatograms are faint, so extracted ion chromatograms were generated to show the ions that appeared different in the samples. Possible chemical formulas have been generated and/or isotope models given for the compounds found in higher abundance in the samples than in the q-tip blank. There is some evidence for the weak inorganic elements, and ICP-MS or atomic absorption would be better suited to identify the inorganic compounds. Select organic compounds were identified in the non-rust and rust samples. In the rust sample, decamethylcyclopentasiloxane, dodecamethylcyclohexasiloxane, and tetradecamethylcycloheptasiloxane were noted, while in the non-rust sample, diethyl phthalate and undecane were detected.

FIGURE 14: Schematic representation of Benzalkonium Chloride

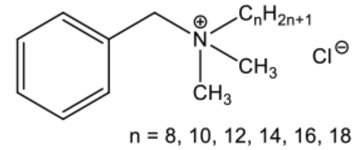


FIGURE 15: Schematic representation of Decamethylcyclopentasiloxane

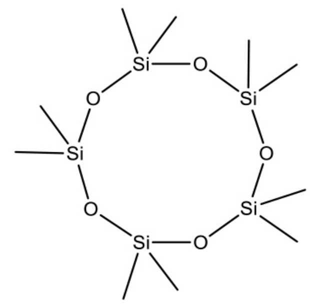


FIGURE 16: Schematic representation of Dodecamethylcyclohexasiloxane

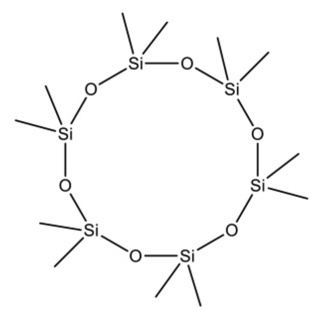


FIGURE 17: Schematic representation of Dodecamethylcyclohexasiloxane

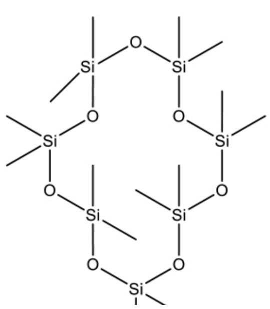


FIGURE 18: Schematic representation of Diethyl Phthalate

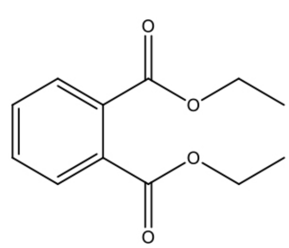
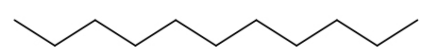


FIGURE 19: Schematic representation of Diethyl Phthalate



Lygel in the 1920s

The use of the antiseptic ointment Lygel can be considered odd but suprising. According to a HuffPost article, women in the 1920's used Lygel for feminine hygiene issue and odors. This product was used as an aid to spice up a couple's "love life behind closed doors." An example of these ads from that time period, which were meant to encourage women to wash routinely, appear below. The article further states that "Lysol brand antiseptic disinfectant first appeared on the scene in 1889 as a way to help end a cholera epidemic in Germany. In 1918, ads touted it as an effective means to fight the flu virus during the influenza pandemic" (Bologna, 2018).

However, in the present day (21st century), we know that Lysol is used as a disinfectant to protect against harmful germs on a variety of surfaces.

FIGURE 20: Lysol ads from the 1920s (Source: Bologna, 2018)

Blood Samples – 95.19.56 O-P

Samples of the brittle gauze and the dried blood spots were taken and submitted for external analysis at the Mass Spectrometry Lab at Auburn University. Chromatograms were provided in a supplementary document as pdf files. Excel files (csv) were acquired and contained both positive and negative ions. These provide the peak height and area for the ions at the different retention times to help the Taylor Group query the human metabolome database (hmdb.ca) in order to find tentative identities.

Upon review, over 3900 items were quantified and identified by the human metabolome database (hmdb.ca). The prevalence and validity of such metabolites is being reviewed further by the Taylor Group. If there is sufficient interest, the samples can be further reviewed for other genetic information. However, this analysis may have an associated expense.

Limitations with the Blood Analysis

The Taylor Group hoped to conduct further analysis to determine the background and potential recipient(s) of the blood samples located on the soiled gauze. Initial discussions were completed with forensic chemist and CSU alumna, Mrs. Victoria Oehrlein, to distinguish a method and company for testing the blood sample. She submitted a number of commercial labs that were capable of executing DNA testing. However, the experts who were contacted noted some possible complications with DNA analysis. Since January 2020, a number of commercial labs were contacted to determine the possibility and method of analysis. However, two factors, separation of extraneous DNA and financial cost, ultimately ended our inquiry.

Factor 1: Extraneous DNA

The blood samples, item 95.19.56 O–P, is from the 20th century (1920–1940's) and likely has come into contact with a number of clinical professionals, patients, family descendants, museum personnel, scientists....to name only a few. This complicates analysis as we would not know whose DNA is truly belonging to the blood stain. Like the museum personnel, the Taylor Group wore gloves at all times and made sure to maintain the composition of the items. In a forensic lab setting, DNA samples are compared against a known roster of individuals to decipher the true candidate. In this case, there are too many "knowns" to account for in this 100-year gap between the gauze being soiled and the present analysis.

Our interest in the blood samples was to understand the details associated with the dried blood. Blood can have many descriptors—gender, age, type, etc. These three kits were used by three different clinicians with the intention of serving the community of Columbus, Georgia as general practitioners. This means that the blood samples could be from patients of any age (i.e., baby, child, or adult) or gender (female or male). Furthermore, these blood samples could have been contributed by more than one source. In fact, these samples could be from multiple patients or the clinicians themselves. The commercial labs mentioned that the samples were to be considered ancient, which likely meant that they would not withstand the analysis. The Taylor Group would not be confident in reporting our findings to the museum.

Factor 2: Financial Cost

Multiple discussions with commercial labs revealed that the analysis would cost a minimum of $2,000–3,000. Our budget did not allow for such an expenditure. The associated cost was not something that the Taylor Group or The Columbus Museum considered essential, which ended our inquiry.

Recommendations

We recommend that for exhibition purposes the contents be displayed in indirect sunlight or under ambient light. This would allow for the contents to continue to "live" among the collection's contents and maintain their integrity. The museum maintains a temperature that should preserve the medicines.

Short-Term Maintenance

Short-term maintenance would include keeping all of the chemicals and medicines in a consistent temperature between 32–86 °F. When in exhibition, the optimal temperature can maintain the integrity of the chemical components and provide a favorable experience for the patrons. It may be best for these medicines to be positioned in an enclosed environment and away from water, in order to protect them from any damaging conditions, such as potential water damage in the case of a leak or a flood.

Long-Term Maintenance

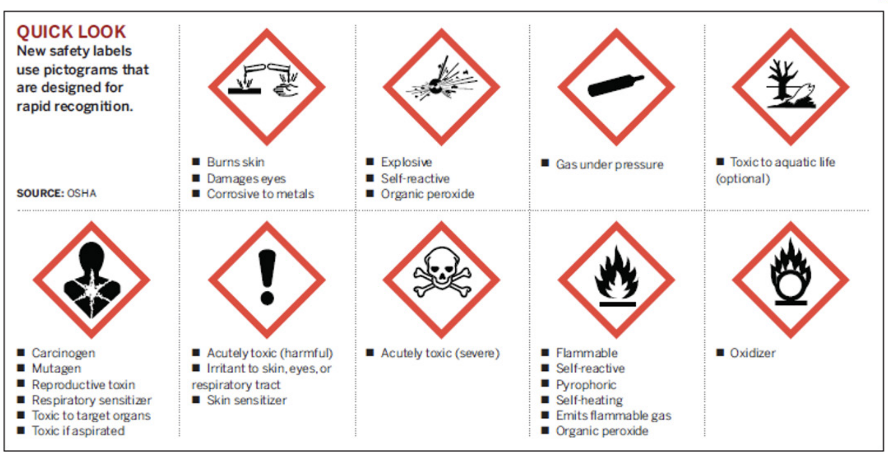
Long-term maintenance would include keeping all of the chemicals and medicines in storage where the temperature remained above 32 °F and under 86 °F. The museum keeps the temperature at about 70 °F, which is an optimal temperature for maintaining the integrity of the chemical components. When in storage, it may be best for these medicines to be packaged in plastic bags to protect them from any damaging conditions, such as potential water damage in the case of a leak or a flood.

Key Words & Definitions

Non-Ketonic Hyperglycemia

A rare genetic disorder that results in the accumulation of glycine within the body's tissues and fluids, due to a compromised enzyme system that fails to break down glycine. Glycine is an amino acid, used to make protein in the body. It is also a neurotransmitter. Glycine is sometimes used to treat schizophrenia and other disorders involving the brain.

FIGURE 21: Symbols of chemical hazards (Source: Kemsley, 2012)



The STEM Gender Gap:
Outreach Activities from Two Higher Education Institutions in Oklahoma

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Tulsa Community College

Abstract

Studies have shown that one of the best ways to include a greater number of girls in STEM (Science, Technology, Engineering, and Mathematics) is to influence them from an early age, starting at the elementary or middle school level. In the past 15 years, the Department of Chemistry, Physics, and Engineering at Cameron University (CU) has been involved in several outreach activities, including the hosting of a one-week summer academy for middle school girls, Women in Leadership and STEM conferences, and several workshops involving middle and high school girls. Tulsa Community College (TCC) recently inaugurated its high school summer academy to encourage more girls to gravitate toward STEM and to provide positive reinforcement. We believe our outreach programs have been very helpful to female students, particularly to students who are in underserved rural and metropolitan schools throughout the state of Oklahoma.

Introduction

Even in the 21st century the number of women in science and engineering, especially in the upper level of those professions, is very low. In the area of physics and engineering, only 20% of bachelor's degree holders are women. This trend continues to graduate-level degrees and the transition into the workplace. Various research findings show that social and environmental factors contribute most to the underrepresentation of women in STEM, particularly in physics and engineering. While the gender gap in those areas is shrinking in cities and urban areas, it is still very prevalent in rural areas. A role model for a career in STEM—a teacher, parent, or family member—can encourage a girl's interests in math and science, and, especially at the middle school level, can inspire her desire to explore a STEM career. Creating an environment to influence girls at this age will increase their likelihood of having an interest in science and math. In recent years, girls across the world have shown their excellence in mathematics skills, proving that the classical assumptions of men's excellence in mathematics and women's excellence in language skills are wrong. As a society, we need to pay careful attention to the creation of a STEM-encouraging environment for girls in classrooms and in the workplace. From a young age, school children are familiarized with several well-known male scientists like Einstein, Newton, Galileo, Faraday, Gauss, and Darwin, but usually with only one female scientist, Marie Curie. Even the famous discovery of the composition of stars by Cecilia Payne is still not known among young girls.

The stereotypical belief that math and science are male-dominated career choices affects young minds and leads to future career choices. A study conducted by Cheryan et al. (2013) showed that stereotypes of academic fields influence who chooses to participate in these fields. For example, the depiction of women in computer science in the media can influence the recruiting of more women in this field. Nosek et al. (2009) suggested that widespread, implicit stereotyping is correlated with gender inequality in science and math. They further suggested that changing implicit stereotyping requires the consideration of social realities that unintentionally shape minds. To understand the factors affecting the gender gap, we need to know the difference in performance of boys and girls in math from the elementary to the high school level. The data on standard math tests like the National Assessment of Educational Progress (NAEP) in the United States or the Trends in International Mathematics and Science Study (TIMSS) do not show trends of better performance by boys than by girls (Kahn & Ginther, 2017). A recent global education monitoring report by UNESCO covering data from 120 countries shows that in some countries like Malaysia, Cambodia, Congo, and the Philippines, the gender gap for math performance is reversed by a few points (Batel et al., 2022). Breda et al. (2023) studied PISA (Program for International Student Assessment) 2012 data on 251,120 15-year-old boys and girls in 61 countries to analyzed math-related career studies as a function of math performance. They found that boys have a stronger positive correlation between a math-related career and math performance than girls. Having a community and peer mentoring can contribute significantly to women's success in STEM fields. These could be in the form of tutor groups, club activities, and other research-focused mentoring (Atkins et al., 2020; Whitten et al., 2003; Winterer et al., 2020). Colbert and Hill (2015) suggested that the lack of computing education in K–12 schools can contribute to a gender gap in those areas at the professional level. Research found that during the adolescent years (middle school), students are more likely to gravitate toward in-group activities in order to have influence in peer groups. Goodwin (2013) stated that most girls lose interest in STEM-related topics between the ages of nine and twelve. Introducing more STEM-related activities to this group of girls can provide a sense of belonging and motivation. Reinking and Martin (2018) also stated that one of the theories about the STEM gender gap is "Gender Socialization." A report published in Harvard Business Review mentioned that 40% of women who earn engineering degrees either quit or never enter the profession (Sibley, 2016). The author also suggested that to prevent higher numbers of women from leaving the engineering profession, engineering programs need to avoid gender-based tasking and expectations in class work and at internship sites. A recent review published in the *Magazine of the Society of Women Engineers* (Meiksins, 2023) suggested that work/family conflict and lack of personal development are among the various causes of female engineers leaving the profession. They suggested that a program like NSF-ADVANCE, which emphasized research-based institutional transformation, could be created, focusing on industry's need to improve women's employment experiences.

FIGURE 1A: PhD Degrees Received in the US by Men and Women, 2014–2019

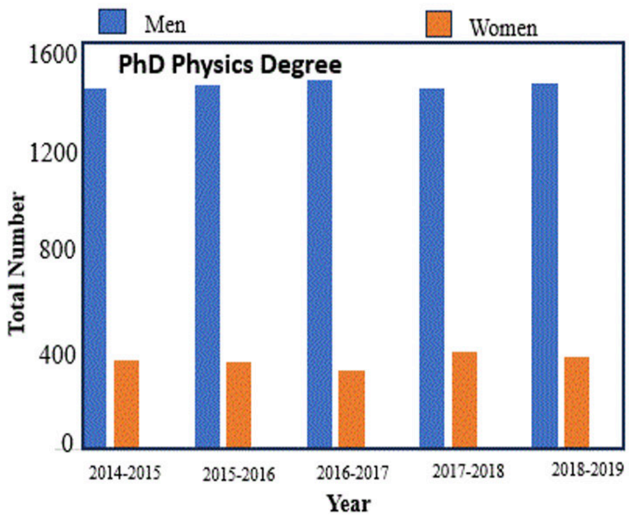
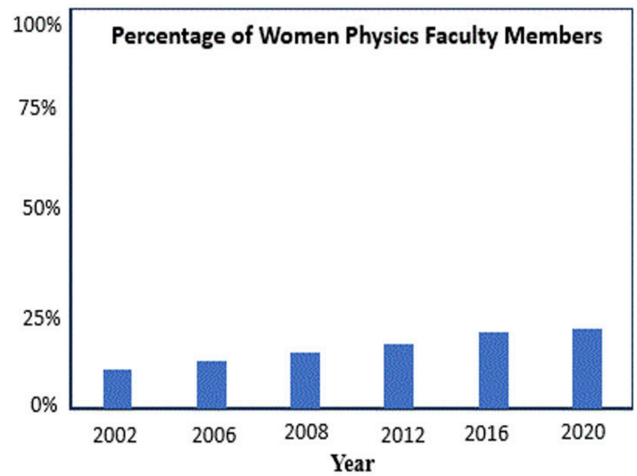


FIGURE 1B: Percentage of Women Faculty Members in Physics, 2002–2020



Data from American Institute of Physics Statistical Research Center

The Engineering and Physics Career Gender Gap

Within STEM fields like the biological sciences, women are no longer underrepresented. It is time to focus more on math-intensive STEM areas like physical science, engineering, and computer science. A report published in *Scientific American* in 2022 mentions that only 22% of computer science undergraduate degrees are awarded to women. Data published by the National Girls Collaborative Project show that fewer than 20% of professionals in computer and mathematical science are women. The field of engineering also has fewer than 20% women professionals. Figure 1 plots the data from the American Institute of Physics Statistical Research Center, which shows that fewer than 30% of physics doctorates were earned by women in the years 2015–2019. Data show that during past 20 years, only 20% of university physics faculty are women. There is, however, a slow increase of about 10% over the last 20 years. In the period from 1980 to 2019, the percentage of women earning a Ph.D. degree increased less than 15%.

STEM Education in Oklahoma

The National Science Foundation (NSF) and other nonprofit organizations fund programs to encourage young people to prepare for a STEM profession. Some of these are Girls Who Code, Letters to a Pre-Scientist, and programs offered by the Society of Women Engineers, the Association for Women in Science, the Special Section in the APS (American Physical Society) and ACS (American Chemical Society) for Women in STEM, National Girls Collaborative Project, and various outreach programs from NASA. Even though there are a number of programs at the national level to encourage more girls to study physics and engineering, in rural area schools girls are still not aware of those initiatives. States like Oklahoma, which ranked 45th in education in 2022, need more initiatives to promote STEM education for young students. At the eighth-grade level, 84% of Oklahoma students are not proficient in math, and the National Assessment of Educational Progress (NAEP) shows that Oklahoma's eighth grade students are 10% below the national level. This score is lower than in our neighboring states, Kansas, Missouri, and Arkansas. Data from the NSF on science and engineering show that Oklahoma has had a consistently lower percentage of bachelor's degrees in STEM in the past 20 years. Figures 2a and b display those data. There is a great need in Oklahoma for STEM education and for more people with STEM degrees. K–12-level STEM outreach programs from universities or community colleges could be extremely helpful.

FIGURE 2A: Percentage of STEM Degrees in Oklahoma

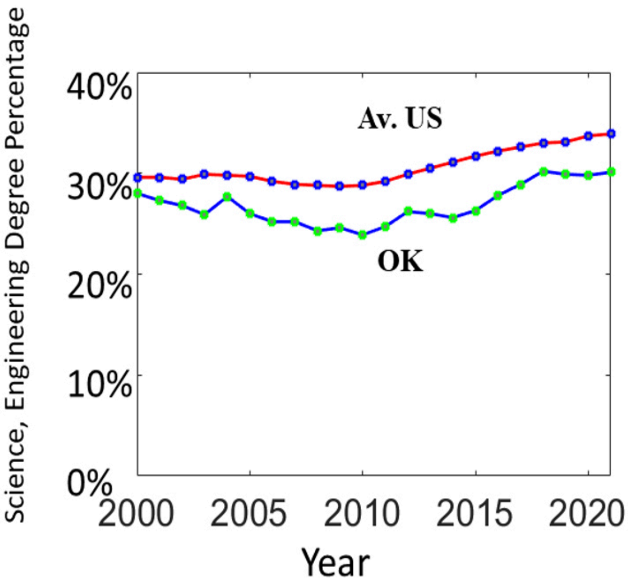
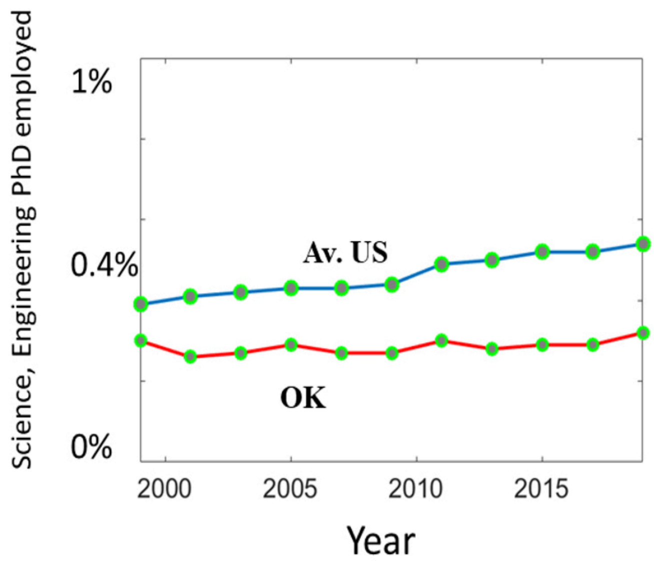


FIGURE 2B: STEM PhDs Employed, Compared to US National



Initiative from Cameron University:

Aerospace Engineering and Applied Mathematics for Middle School Girls

Cameron University is located in the southwestern region of the State of Oklahoma. It is a regional university with about 3500 students. The Department of Chemistry, Physics, and Engineering has been actively involved in promoting STEM activities in the community. It has been hosting a free summer camp, Aerospace Engineering and Applied Mathematics for Middle School Girls, for the past 10 years. Every year 10–12 middle school girls (grades 6–8) participate in this summer academy. It has been a one-week residential camp except when there were COVID restrictions. This academy has been very popular in southwestern Oklahoma. Various factors like school district, race, GPA, and a recommendation letter from the teacher are included in the selection process so that there is diversity among the participants. Every year we have two or three undergraduate students from the department serve as camp councilors to help the students along with the university faculty. We also include two or three local middle/high school science teachers to assist with the setup and management of the camp. We include a wide range of physics and engineering topics related to aerospace. Students are provided with breakfast, two snack breaks, and a lunch break during day camp. All materials, food, and drinks are provided free of charge for the participants. The main objective of this academy is to encourage the students in applied mathematics and to demonstrate how it is used in the areas of science and technology.

We include the following learning objectives for the students participating in the camp:

1. Demonstrate basic physics experiments related to kinematics.
2. Communicate effectively about the broader application of physics of motion.
3. Show teamwork by participating in group activities.
4. Earn an Aerospace Academy Camp badge.

FIGURE 3: Middle School Summer Academy Team in Summer 2021

TABLE 1. Brief Schedule of Activities for the Five-Day Camp, Summer 2021

DAY 1	· Keynote speaker (a women scientist) · Q& A session for the girls with keynote speaker · Lesson in physics of motion utilizing cart, motion sensor, photogate sensors, PhET simulation, and tracker simulation
DAY 2	· Physics of motion and gravity · Incline plane · Learn plotting motion data using LoggerPro software
DAY 3	· G force · Bernoulli's equation · Foil simulation · Build model F-15 plane from cardboard paper following NASA instructions
DAY 4	· Hands-on activity on hot air balloon · Foam rocket launch. Analyze data from foam rocket activity in terms of distance, angle, and time · Construct water bottle rocket
DAY 5	· Quiz bowl · Build a rocket using a standard kit · Closing ceremony with families

leadership panel continues to bridge the gap between CU students who are about to begin their careers and local women who have found success in theirs. In addition to the panel sharing their personal experiences, students are encouraged to submit questions before the panel discussion that address their specific concerns. An impromptu question and answer session ends the panel. The evening culminates with a mixer to encourage participants to network and build further connections with local women in leadership and with one another.

This project also includes the selection of students to attend the Annual Oklahoma Women in Leadership Conference. Although its high registration cost may prevent a typical CU student from attending, this conference provides a useful experience for students and can help prepare our students to be successful business leaders by showing them how important trust and impactful leadership are for the success of a business. A *Forbes* article (Graham, 2020) surveyed 2200 chief financial officers and found that the most common mistakes people make when networking are "not asking for help, failing to keep in touch or reaching out only when they need something, failing to connect with the right people, not thanking contacts when they provide help, and not helping others." By learning about these strategies to establish trust and fulfillment in their relationships, Cameron students will be empowered to act as leaders within their community.

Cameron University (CU) Women in Leadership and STEM Conference

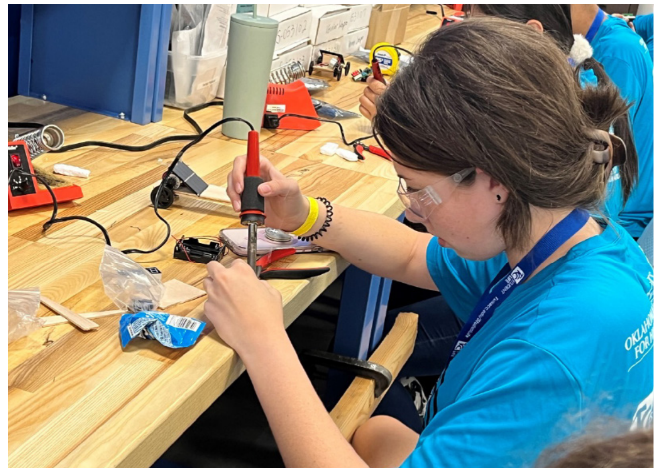
For the past seven years, the Department of Chemistry, Physics, and Engineering has been hosting a CU Empowering Women in Leadership and STEM Conference. The primary purpose for this project is to empower Cameron University undergraduate/graduate women, community members, and area high school women to seek their full potential in leadership roles within their chosen fields. This conference is geared toward giving students access to professional development, industry insight, and current research in the field of organizational leadership. The seminar is designed to be a one-day opportunity for students and local women in leadership positions to explore the skills that create a successful executive/leader. The

Tulsa Community College Summer STEM Academy for High School Students

TCC's residential Summer STEM Academy provides STEM career exploration in a stimulating, engaging, and fun learning environment via hands-on instruction and experimentation. Students actively engage in project-based learning activities in math, engineering, and physics related to the design and building of a roller coaster, going into detail beyond lessons learned in everyday secondary STEM courses. The program served a total of 30 students, 28 first-time participants and two junior counselors who were interested in STEM in grades 9–12. Over 50% of the student participants recruited were female and approximately 40% were from other underrepresented groups.

FIGURE 4A: Junior Counselor Atriya Nourbakhsh Interviewed by Local News Media

FIGURE 4B: Southwest Oklahoma High School Student at a Summer Academy at Tulsa Community College



The focus of recruitment was building a diverse population of students, recruited with the assistance of tribal nations, local secondary schools, churches, community organizations, and outreach programs, meeting Board of Regents target populations. This academy serves as a supporting or reinforcing initiative to the introductory initiatives listed above with the middle school girls. We believe providing follow-up opportunities throughout that state will solidify STEM confidence and interest in female students. Figure 4a shows a student who attended the CU Summer Academy in Lawton, Oklahoma and then later was able to serve as a junior counselor at the HS TCC STEM Academy. Figure 4b depicts a southwest Oklahoma student who traveled to Tulsa to participate in the summer academy. As with the middle school girls academy, all costs are covered by external and internal grants and industry sponsorships. This allows the academy to be accessible for all students across the state.

Women in Science Conference, Science Sessions for Local Schools, Girl Scouts

Faculty from Chemistry, Physics, and Engineering have been participating with groups of female students at a Women in Science conference in Oklahoma for the past several years. We have been demonstrating physics, chemistry, and engineering activities to about 1500 middle school and high school girls from all over Oklahoma each year. We do electromagnetics, optics, and mechanics

FIGURE 5: Faculty and Students from Cameron University

demonstrations in physics, and chemistry demonstrations like chromatography and making slime. Engineering demonstrations such as making a bounce cart are also offered. Our students and faculty enjoy this rewarding experience. In addition, our faculty host science sessions every semester for local schools and Girl Scout groups. These sessions are in high demand from our local community. Figure 5 shows Cameron University's diverse group of faculty and students who participated in a recent Women in Science conference.

Conclusion

Aerospace Summer Camp offered many fun-filled activities for the students. Parents and guardians also enjoyed the students' rocket launching and were very happy to see their enthusiasm. We encourage the students to keep in touch with us for future mentoring and to share their progress. Participating in a wide range of activities in this camp emphasizes teamwork among students, opportunities for active participation, and effective communication. This prepares students for professional success and helps to develop a desire for lifelong learning in science. This camp also gives undergraduate students from our department opportunities to get involved in STEM outreach activities with young girls, for example by helping them do lab setup and record data and by responding to their questions. This type of learning engagement gives students confidence to move forward in their careers and prepares the students to become professionals in their selected fields of study. In the future, we are planning to include camps with other topics like observational astronomy, space weather, and applied optics. We are also planning to include a mentorship program in physics, engineering, and astronomy, where our faculty could give high school girls the opportunity to do job shadowing and demonstrate frequent activities in science and math. By participating in these high-impact learning experiences like CU Women in STEM and Leadership conferences, our students come to understand the different leadership opportunities they can create, in a set discipline or for a specific company, once they complete their degree. This experience will motivate students to stay steadfast in their program and by doing so, will enhance their academic experience and their ability to become leaders in their field. These students will also use what they experience during this seminar along with their academic courses to actively engage in leadership experiences on campus. After students have actively participated during the one-day leadership and business seminar in Oklahoma City, they are encouraged to participate in an online evaluation and are prompted to provide details about the most beneficial aspects of this seminar. Ultimately, this project enhances student learning by facilitating their development of a long-term professional vision. The event provides students with a game plan to better navigate the networking process and highlights strategies for tapping into the network they already have, building connections within the university and with the community.

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