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IN MEMORY OF

Dr. Kit Martin

FEBRUARY 9, 1984-MARCH 24, 2023

Kit was an entomologist, humanitarian, author, programmer, author, educator, and friend. His paper can be found in this volume.

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MAINTAINING PROGRAM SUSTAINABILITY AND LONGEVITY AFTER FUNDING EXPIRES

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Abstract: The challenge in developing sustainability plans for programs after funding expires is ubiquitous in Broader Impacts. Established programs can be used as infrastructure for future research impacts. Recently, our Pennsylvania KidWind Challenge lost its long-term funding. Due to growing interest to continue the competition, we created fundraising infrastructure, developed partnerships, and raised industry funds to sustain the challenge. This poster will describe lessons learned from planning and implementing a program sustainability plan.

Introduction

Program sustainability for federally-funded educational outreach programs is always a challenge given the short duration of funding cycles. However, well-established programs can be used as infrastructure for future research impacts. There are multiple options to pursue when looking to sustain a program including: 1) pursuing additional grant funding, 2) pursuing foundation funding, 3) pursuing industry funding, and 4) promoting in-house fundraising event opportunities. Every option requires a plan, personnel, and strategic partnerships to implement successfully. All options have their pros and cons that need to be considered to find the right option for a particular program. This paper will focus on pursuing industry funding using a specific program led by the Center for Science and the Schools (CSATS) at Pennsylvania State University that recently lost funding in order to describe lessons learned for implementing a program sustainability plan. This program is offered in collaboration with Dr. Susan Stewart in the Aerospace Engineering Department at the Pennsylvania State University.

Our PA Wind for Schools program recently lost its long-term funding from the National Renewable Energy Laboratory (NREL) after ten years. The PA Wind for Schools program lead was given about a year notice before the loss of funding as NREL indicated it was time for the renewable energy industry to fund this particular endeavor. As a result, we decided to pursue industry funding to continue the PA Wind for Schools Program.

PA Wind for Schools

The PA Wind for Schools program engages precollege students from grades 4 through 12 to participate in an energy engineering challenge event focused on wind energy. To support the team coaches involved in the program, CSATS along with Dr. Stewart have offered a yearly workshop to both informal and formal educators to prepare them in supporting teams of students at the statewide KidWind Challenge. CSATS faculty and staff also organize and host the state level competition at the Penn State University Park campus. The competition requires teams of students to design, build, and test their own wind turbine system that includes a generator, hub, and possibly a gearbox. At the competition, teams test their turbines in a wind tunnel to determine which team can generate the most power and communicate their turbine design to a panel of judges. The winning teams are then invited to go on to the national-level KidWind Challenge.

Drawing teams from across the state of Pennsylvania, the PA KidWind Competition started with 7 student teams in 2012 and in recent years has grown to over 30 student teams (approximately 165 students). Participants in this competition come from both rural (47.1%) and urban (45.7%) communities with 60% coming from schools with a high percentage of families qualifying for free/reduced lunch.

In 2021, both teachers and researchers at the university expressed interest in continuing and expanding the competition to include additional renewable energy challenges, such as a solar energy challenge. With the announcement of the expiration of NREL funding, we then had to put together a sustainability plan to fund both PA KidWind and the additional energy engineering challenges.

Fundraising at an R1 Institution

Once we were notified of the expiration of funding, we initiated the development of a sustainability plan for the program. After a year of planning, we started implementing the sustainability plan in the Fall of 2022 with a focus on pursuing industry funding. Working at a large research university, we quickly discovered that many rules and guidelines exist with regard to raising money from industry. It was not as simple as approaching industry with a description of the program and an "ask" for funding. In order to address this challenge, we met with development officer within the College of Education. The development officer assisted us in navigating university politics and rules regarding industry funding and provided support in exploring additional funding options available to us, such as the PA Educational Improvement Tax Credit (EITC) Program.

Fundraising for a particular program at a large research institution can be challenging to navigate. For this reason, we recommend that you identify and work with university staff who work in the area of development (fundraising for the university). Development can help you to develop a sustainability plan for your program and to navigate the rules and guidelines surrounding fundraising at your University.

Strategic Partnerships

The PA KidWind program is part of a larger network of state and national organizations working to advance renewable energy education in K-12 schools. We strategically partnered with REpowering Schools, the fundraising arm of the National KidWind organization. REpowering schools helped us brainstorm industry partners with a presence or interest in Pennsylvania, sometimes even making the contact connection for us. Given that we had little experience in fundraising with industry, REpowering Schools assisted us in drafting an initial letter to industries with a request for support that offered multiple options in levels of funding. Once we had the initial letter, the leads of PA Wind for School then drew on both personal and professional contacts to reach out to industry partners.

After sending out our initial funding request, we followed up with inquiries about the program and funding needs. Industry partners who expressed interest in supporting the program requested a short (2-page) proposal describing the program and specific program costs. We developed the proposals for the industries to review. In addition, we met with the industry representative to discuss the proposal either in person or via Zoom. Each business had their own chain of command for how the request would be processed. Over time, funding from industry partners slowly started arriving to the College of Education in support of the program.

Timing

We experienced wide variation in the timing of funding based upon the industry partner. Once they made the decision to support PA Wind for Schools program, some companies were able to rapidly process the funding request. These companies were usually local small businesses. On the other hand, larger corporations had more formal processes that took a longer amount of time. *As a result, it is critical to start early and have alternative plans if the funding does not arrive on time.*

Results

We were able to raise enough funds to support our PA Wind for Schools Program this year. However, we are still waiting on funds to come in from two companies that pledged a considerable amount of money. As a result, we had to start work on the program without 100% of the funds being in place. Raising the funds required a considerable amount of time from the leads of the program. However, now that we have infrastructure in place and relationships with several industries, we are hoping for a smoother fundraising campaign next year. One change that we will make is starting our fundraising campaign much earlier to ensure adequate support for the program.

INTRODUCING THE APEAL PROJECT: ADVANCING PUBLIC ENGAGEMENT ACROSS LONG TERM ECOLOGICAL RESEARCH SITES

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Abstract: Here we share the theory and design of a new collaborative research project focused on understanding and advancing the development of public engagement strategies within scientific research organizations such as field stations and laboratories, using the Long-Term Ecological Research (LTER) network as our model. The project is being funded by NSF's Advancing Informal STEM Learning program.

Overview

Recent advancements in public engagement with science (PES) have largely focused on individual scientists, including research to understand scientists' attitudes and beliefs about engaging with public audiences (Besley et al. 2018) and the development of training programs (Selvakumar and Storksdieck, 2013; Nadkarni et al., 2019) and frameworks (Canfield et al., 2020) to support inclusive and evidence-based practices. We see an urgent need to expand these efforts to the organizational level of scientific research institutions, where the importance of PES is increasingly recognized, yet institutional systems to support effective PES are typically lacking. In late 2022, our group of PES researchers and practitioners launched the Advancing Public Engagement Across LTERs (APEAL) project, a three-year initiative funded by the National Science Foundation to understand and support the development of PES strategies within STEM research organizations, using the Long Term Ecological Research (LTER) Network as our model. The LTER Network is a group of 28 research sites distributed across the diverse biomes of North America, where scientists and NSF have invested in long-term research programs about environmental change. Two "big ideas" drive the APEAL project: The first is to investigate the development of PES strategies within STEM research organizations as a possible lever of change for improving PES nationwide. The second is to better understand how public engagement might serve as a tool for connecting major research institutions with the local communities they are part of. These ideas are important to the value and viability of long-term research programs. We will use conferences like the ARIS Summit to share what we learn along the way, and open new conversations with scholars and practitioners about how we collectively support effective PES within the nation's institutions of STEM research.

Background

1. Two key ideas from the science communication and informal science learning fields define the APEAL project:

2. Decades of research in science communication and informal science learning have shown that deficit-oriented activities are ineffective and can perpetuate inequities in society (NASEM, 2016;

Canfield et al., 2020). Deficit-oriented activities include those that prioritize filling knowledge gaps over fostering multi-directional exchanges of ideas and views and finding common ground. Deficit-oriented activities also commonly position community members as passive audiences with problems that need to be solved. This approach belies the unique perspectives, assets, and agency of communities, all of which are needed to effect positive societal change. A key antidote is the adoption of reflexive approaches that focus instead on reciprocal exchange and building ongoing relationships across the boundaries of science and society (Canfield et al., 2020).

3. Recent work shows that lack of shared strategy to guide the prioritization of PES efforts is a major barrier to effective PES in scientific research organizations (Besley et al., 2021). Rather than shared, intentional strategies, scientific organizations commonly have ad hoc portfolios of "outreach and education" programs that are loosely tied to the goals that scientists and stakeholders have for the societal impacts of current research, and the roles that research organizations might play within communities. This challenge can lead to inefficient use of time and resources, including reinvention of established ideas and practices, and also missed opportunities for collective impact across activities.

4. The APEAL project builds on these ideas by investigating the development of evidence-based, community-informed PES strategies within the LTER Network. The project is addressing three research questions: (RQ1) How do scientists, institutional leaders, and staff view and make decisions about the design and implementation of PES? (RQ2) To what degree do PES activities and PES strategies consider the interests and assets of local communities, including those underrepresented in STEM? (RQ3) How, and to what degree, can scientists, institutional leaders, and staff develop shared PES strategies aimed at enhancing reciprocal exchanges and ongoing relationships with communities?

Project Design

The APEAL project integrates a set of activities that work across different community levels to advance PES research and practice:

1. **LTER Network surveys and interviews, co-designed with a PES Working Group:** To build a better understanding of the role of PES within the 28 sites of the LTER Network, we are collecting survey and interview data from LTER scientists, leaders, and staff about how they consider PES, including views about PES strategy, reciprocal exchanges, and community relationships. We will co-design our survey with a PES Working Group of LTER scientists, site leaders, and staff, building from prior research.

2. **LTER site case studies and strategic engagement planning:** We are conducting multiple case studies coupled with strategic engagement planning at three LTER sites to investigate the community contexts of PES. This work is focusing on understanding community perspectives related to local LTER sites, enhancing existing relationships within these communities, and understanding how scientists might incorporate community interests and assets within PES strategies via participatory planning. Our case study sites are the Hubbard Brook LTER in New Hampshire, the Luquillo LTER in Puerto Rico, and the Virginia Coast Reserve LTER in Virginia.

3. **PES monitoring system, co-designed with the PES Working Group:** In an effort to obtain fine-grained, site-level information about PES activities, we are working with the PES Working Group to design and pilot a PES monitoring system to track activities at LTER sites over time. The system will accommodate locally collected data about site-level PES activities, for example: date, location, type of event, number of participants, scientists involved, and whether and how activities were developed with local communities.

4. **External advisory board:** To promote accountability of the work and broaden its impact beyond the LTER Network, we are convening an external advisory board of PES experts

and representatives of other STEM research networks and organizations.

Together, these activities will inform a new model of integrative science engagement that sees scientific institutions in partnership and as part of local communities, and that values individual science engagement activities as strategic choices for reciprocal learning for the long-term benefit of all stake- and rightsholders.

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BROADER IMPACTS ODYSSEY: A JOURNEY TRANSFORMING RANDOM ACTS OF BROADER IMPACTS TOWARDS A MORE SUSTAINABLE INFRASTRUCTURE

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Abstract: Despite layers of bureaucratic barriers, many professionals are striving to improve the coordination and organization of broader impacts (BI) from the ground up and without a BI champion. With little centralized infrastructure at our research-intensive land-grant institution, we are individual professionals passionate about BI, authoring white papers, forming committees, and launching surveys. We share our journey of fostering connections across a network of practitioners, sharing best practices, and spearheading a grass-roots effort.

With increasing emphasis on Broader Impacts (BI) and Broadening Participation (BP) of underrepresented groups in STEM fields by the National Science Foundation (NSF) and other federal funding agencies, Penn State is poised to make significant contributions in this arena while simultaneously increasing faculty's competitiveness in receiving grant funding for their technical research. To be deemed highly competitive, submitted proposals need to include BI/BP plans that are well-formulated, strongly integrated with the proposed research activities, realistic and sustainable based upon evidence of support from the institution and collaborating partners. "Impact expertise is vital, but impact cannot be the responsibility of one person; it's only achievable through teamwork, partnerships and connected actions" (Bayley and Phipps, 2017).

A Slow and Winding Road

The scope of Penn State's STEM education and outreach programs dedicated to making an impact has been disconnected and project specific. Incremental steps have been taken over time to bring these resources together. In 2018, the Strategic Interdisciplinary Research Office (SIRO) held a Broader Impacts Showcase in which over 40 Penn State groups promoted their work and ways that they support BI activities to faculty who attended the event. Even with knowledge of these various groups, faculty continue to face multiple challenges in BI. In the fall of 2020, 16 research faculty completed a brief survey about BI at Penn State, indicating that they and/or their colleagues regularly need assistance with BI in terms of proposal preparation and implementation of outreach activities. In the fall of 2020, ten (10) individuals who engage in BI activities completed a brief survey about BI at Penn State. All respondents indicated their units/facilities are included on federal grant proposals as part of the BI plans, though only two indicated they are involved in over 15 federal grant proposals annually. Several respondents expressed that they have reached maximum capacity for assisting faculty with BI plans of proposals while others voiced the need for increased exposure to research faculty.

In January 2022, the Office of the Senior Vice President for Research (OSVPR) convened a *Broader Impacts Committee* assembling BI and Diversity, Equity, and Inclusion (DEI) practitioners from across the institution. The committee was charged with characterizing the current BI resources and making recommendations for how the University could enhance the impact of research activities and competitiveness of proposals to federal agencies. In its efforts to describe the BI landscape at the institution the Committee BI activities. With their first survey deployed to over 100 units, the committee initiated a self-study to better understand which units support BI activities across the University, programs, expertise and capacity of each unit.

In Summer 2022, the Committee launched a new website with resources and a PI-directed survey to gather information from faculty on their BI activities and suggestions of ways the University might support planning and implementing BI activities. PIs can play an active role in conceptualizing BI infrastructure that will (1) support research faculty and (2) deliver BI programs that operate at the highest levels of excellence.

Are We There Yet?

The Broader Impacts Committee reconvenes in Spring 2023 to review findings and make recommendations that include specific transformative actions in terms of resources required to deliver high-quality, innovative broader impacts activities: human, computing, instrumentation, fiscal and social capital. Additionally, a subcommittee will examine financial models for BI infrastructure. Return on investment will consider:

- **Financial return –** provide needed support to meet the BI requirements of federal funding agencies leading to increased grant funding for research.
- **Multiplier effect for scaling research and impact –** collaborate with interdisciplinary teams to increase the scale of research and impact activities through formal networks and research centers.
- **Enhanced BI community –** generate impact that better connects Penn State research with institutional outreach programs, stakeholders, and community partners. "Impact requires institutions to identify meaningful ways to connect research to the real world, and support the knowledge, skills, resources, and structures needed to deliver it." (Bayley, J. & Phipps, D., 2019)
- **Connected culture of impact –** support faculty to develop their impact identity, expanding and cascading impact over their careers. "Widespread adoption of the concept of impact identity may also have implications for the recruitment and retention of a more diverse range of [faculty]. (Risen and Storksdieck, 2018)

The Committee will conduct follow-up interviews with BI providers and PIs. Data analysis and social network analysis will model the complex and interconnected network of practitioners across the institution. Guiding questions include:

- How do we develop a connected network and infrastructure to support researchers and their impact identities, rather than one-off programs?
- How does the institution hold itself accountable for conducting strong, high-quality BI that can be communicated to funders?
- As we assess our BI landscape, how do we leverage and/or transform the existing networks and financial models to conceptualize robust and sustainable BI infrastructure?

Reflections and Conclusions

Practitioners across the institution are assessing our BI landscape, analyzing existing networks and financial models to conceptualize sustainable BI infrastructure. Making a case for institutional and external funding dedicated to support BI helps secure future funding for and expand the reach of critical, socially relevant research, demonstrating the commitment and capabilities of the institution to internal and external stakeholders. The Broader Impacts Committee can be a vehicle for creating a culture of BI, inviting guest speakers, hosting networking events, providing training and professional development for BI professionals and PIs. While these activities infuse deeper knowledge and understanding of BI, they also bring attention to BI and the importance of centrally supported efforts that can help to move the organization forward.

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EFFECTS OF A DESIGN WORKSHOP ON EDUCATIONAL OUTREACH PRODUCTS AND CLEAN ENERGY FELLOWS' KNOWLEDGEABILITY OF THE BI OF THEIR RESEARCH

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Abstract: A concurrent mixed methods action research study was designed to evaluate the impact of a design workshop on clean energy fellow' knowledgeability of the broader impacts (BI) of their research and their design of educational outreach products. Results demonstrated significant, positive correlations between workshop attendance and the quality of educational products. While gains were also made in knowledgeability of BI, they are not necessarily correlated with workshop attendance.

Introduction

Each year, the Clean Energy Institute (CEI) at the University of Washington (UW) awards 30 to 40 clean energy fellowships to UW doctoral students. The purpose of this fellowship is to provide financial support for these students to conduct novel research on clean energy topics and to support the ability of "the next generation of clean energy leaders and innovators to have broader impacts on society" (CEI, 2020). Fellows have access to shared facilities and resources such as an Entrepreneur-In-Residence and Investor-In-Residence. They are also required to participate in a yearlong CEI Interdisciplinary Seminar Series, at least 2 outreach events, and develop a Product of Lasting Value (PLV) – an educational product that communicates some aspect of their clean energy research to a broader audience. The PLV requirement affords doctoral students the opportunity to reflect upon and to engage with the broader impacts of their research. It also disseminates cutting-edge, clean energy research to the broader public.

While many PLVs have been developed and disseminated over the years, little was known about the impact this requirement had on clean energy fellows. As part of my own doctoral studies, I employed action research to better understand the PLV requirement and its impact on clean energy fellows (Hendrickson, 2022). Action research is the systematic inquiry into one's practice that leads to solution-oriented action (Mertler, 2020; Creswell & Guetterman, 2019; Ivankova, 2015). Practitioners use multiple cycles of research to more deeply understand and respond to a problem of practice. Through two initial cycles of research, I gained a better understanding of existing PLVs. I also learned that some fellows appreciated the growth opportunity this requirement provides but needed more support throughout the PLV design process (Hendrickson, 2022). To provide more structured support for this project, I designed a three-part, semi-structured PLV Design Workshop and evaluated its impact on the professional development of clean energy fellows and the quality of their PLVs. Specifically, my last cycle of action research was guided by the following research questions (RQ):

RQ1: How does the PLV Design Workshop increase the quality of PLVs?

RQ2: How and to what extent does participation in the PLV Design Workshop increase clean energy fellows' knowledgeability of the broader impacts of their research?

RQ3: How and to what extent does participation in the PLV Design Workshop strengthen clean energy fellows' identification with the clean energy field?

Theoretical and Conceptual Frameworks

The research questions and design of the study were informed by a sociocultural view of learning. More specifically, the study was rooted in the situated learning (Lave and Wenger, 1991) and communities of practice (Wenger, 1998) frameworks. I view the PLVs that clean energy fellows develop as boundary objects that may be able to communicate one's science beyond their own community of practice (Hendrickson, 2022). Further, I interpret graduate students' engagement in the broader impacts of their research through Wenger-Trayner and Wenger-Trayner's (2015) landscapes of practice metaphor and conceptions of knowledgeability.

Methods

This study was designed to evaluate the ability of a three-part, semi-structured design workshop to increase the quality of PLVs and positively influence the professional development of clean energy fellows. I served dual roles as researcher and practitioner; I designed, facilitated, and evaluated the PLV Design Workshop. Participants in this study were UW doctoral students who had received clean energy fellowships for the 2021 – 2022 academic year. Workshop attendance ranged from 10 to 15 participants. All 26 clean energy fellows were invited to participate in all three sessions of the workshop which took place on Thursday afternoons during spring quarter and were spaced approximately 2 weeks apart:

- **Session 1:** Building Teams, Generating Ideas
- **Session 2:** Peer Feedback
- **Session 3:** Community Engagement

Both qualitative and quantitative methods were employed to gather data for this study. A PLV Rubric was developed to evaluate PLV quality (RQ1) and a recurring survey, a PLV Check In was administered to track fellows' progress on their PLV (RQ1). A pre- and post-survey were developed to assess fellows' knowledgeability of the broader impacts of their research and their identification with the clean energy field (RQ2 AND RQ3). However, there were no post-surveys completed most likely because I did not ask fellows to stay and complete it at our final workshop and fellows likely confused their final PLV Check In with the post-survey. Finally, a focus group interview was conducted to allow me to elaborate on pre-survey results (RQ2 AND RQ3).

Results

Overall, results from the PLV Rubric and Check Ins for RQ1 show a significant, strong, and positive relationship between workshop attendance and

PLV quality (Hendrickson, 2022). However, a lack of variation in one rubric criterion (PLV Purpose) suggests that this instrument should be further reviewed and tested. Quantitative and qualitative results from the PLV Workshop Pre-Survey (n=15) and focus group interview (RQ2) are inconclusive due to a lack of post-survey responses. However, an interesting trend that pre-survey and interview data show is that many fellows seem to be "interested in broader impact activities and understand that engaging in such activities have personal benefits such as making them "more well-rounded" (PLV Workshop Survey, 2022) researchers," but they do not feel knowledgeable about the same activities or feel that they relate to their research (Hendrickson, 2022). Results for RQ3 are also inconclusive due to lack of post-survey responses. While pre-survey data suggest that most fellows do identify with the clean energy field, data from the focus group interview suggest that increases in identification with clean energy may result from other aspects of the clean energy fellowship rather than the PLV workshop such as connecting with the Entrepreneur-In-Residence or participating in the CEI Interdisciplinary Seminar. Table 1 shows a summary of these results.

Two of the main limitations of this study included time constraints for the development and implementation of the workshop and data collection methods as well as the lack of post-surveys. Despite these limitations, the results from both qualitative and quantitative data have informed updates to this year's PLV requirement and Design Workshop.

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Table 1

Summary of Study Results

Research Question	Method of Data Collection	Summary of Findings
RQ1: PLV Quality	QUAN: PLV Rubric QUAL: PLV Check Ins	Significant, strong, positive correlation between workshop attendance and PLV quality
RQ2: BI Knowledgeability	QUAN & QUAL: PLV Pre-Survey QUAL: Focus Group Interview	Inconclusive due to lack of post-surveys
RQ3: Identification with Clean Energy	QUAN & QUAL: PLV Pre-Survey QUAL: Focus Group Interview	Inconclusive due to lack of post-surveys

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REVOLUTIONIZING STEM EDUCATION WITH BROADER IMPACTS

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Abstract: Broader impacts programs associated with technical research projects have the potential to fundamentally change the quality of education in science and technology classes. This paper describes how programs designed to help teachers learn about and engage their students in the practices of scientists and engineering to help them learn disciplinary content will benefit the students, the teachers, and society – the goal of broader impacts.

Broader Impacts of Research

All grant proposals reviewed by National Science Foundation are evaluated on two primary criterion: Intellectual Merit (the potential to advance knowledge in the field) and Broader Impacts (the potential to benefit society or advance desirable societal outcomes) (NSF, 2023). These outcomes may be integral to the research or from programs developed in corollary with the technical research. Among the goals for the broader impacts of technical grants are: full participation of women, persons with disabilities, and underrepresented minorities in science, technology, engineering, and mathematics (STEM); improved STEM education and educator development at any level; increased public scientific literacy and public engagement with science and technology; improved well-being of individuals in society; development of a diverse, globally competitive STEM workforce; increased partnerships between academia, industry, and others; improved national security; increased economic competitiveness of the U.S.; use of science and technology to inform public policy; and enhanced infrastructure for research and education. (NSF, 2023; pg II-11). For this reason, researchers proposing grants to NSF must consider the impacts of their work or work to develop programs that promote these benefits from their research.

STEM Education

Recent documents that guide the reforms being made in STEM education list the goals being "to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology." (NRC, 2012). To achieve these goals, K-12 education systems are encouraged to focus on three aspects of scientific work: the disciplinary core ideas ("content"), the crosscutting concepts (that cut across disciplines), and the science and engineering *practices* that professionals use to create knowledge and/or solve problems (NRC, 2012).

Previous reforms have been unsuccessful in achieving these goals for several reasons. Some efforts focused only on wealthy, white, and gifted students. Attempts at creating a heuristic for scientific work like "The Scientific Method" has ultimately led to portraying science as linear, static, objective, and sterile (Windschitl, 2004). It also suggests that all scientific work is driven by a hypothesis and/or can be achieved through a controlled experiment. Further, traditional science teaching overemphasizes "hands-on" work (Furtak & Penuel, 2019) where laboratory asks are conflated with "experiments" (Gyllenpalm & Wickman, 2011).

K-12 teachers are now asked to engage their students in the practices of both scientists and engineers to create knowledge or solve problems themselves. This is a challenging paradigm shift, particularly for those teachers who have little or no experience in engaging in those practices themselves. However, we argue that these practices, which researchers use daily, can be made visible and useful to teachers through Broader Impacts programs developed as collaborations between STEM educators and researchers and this approach has the potential to revolutionize STEM education.

Practices of Science and Engineering

STEM education is not alone in the desire to engage younger learners in these disciplinary ways of knowing. Computer science and Mathematics have also outlined practices within their field. However, for the purposes of this paper, we will focus on science and engineering.

The *Next Generation Science Standards* identifies ten individual practices (NGSS Lead States, 2013) (Table 1). Two are unique to engineering, the rest are shared, although applied in different ways depending on the context of the work.

Table 1 – The science and engineering practices (NRC, 2012; NGSS Lead States, 2013)

Science	Engineering
Asking questions	Defining problems (engineering)
Using mathematics and computational thinking	Using mathematics and computational thinking
Engaging in argument from evidence	Engaging in argument from evidence
Analyzing and interpreting data	Analyzing and interpreting data
Developing and using models	Developing and using models
Constructing explanations	Designing solutions
Planning and carrying out investigations	Planning and carrying out investigations
Obtaining, evaluating, and communicating information	Obtaining, evaluating, and communicating information

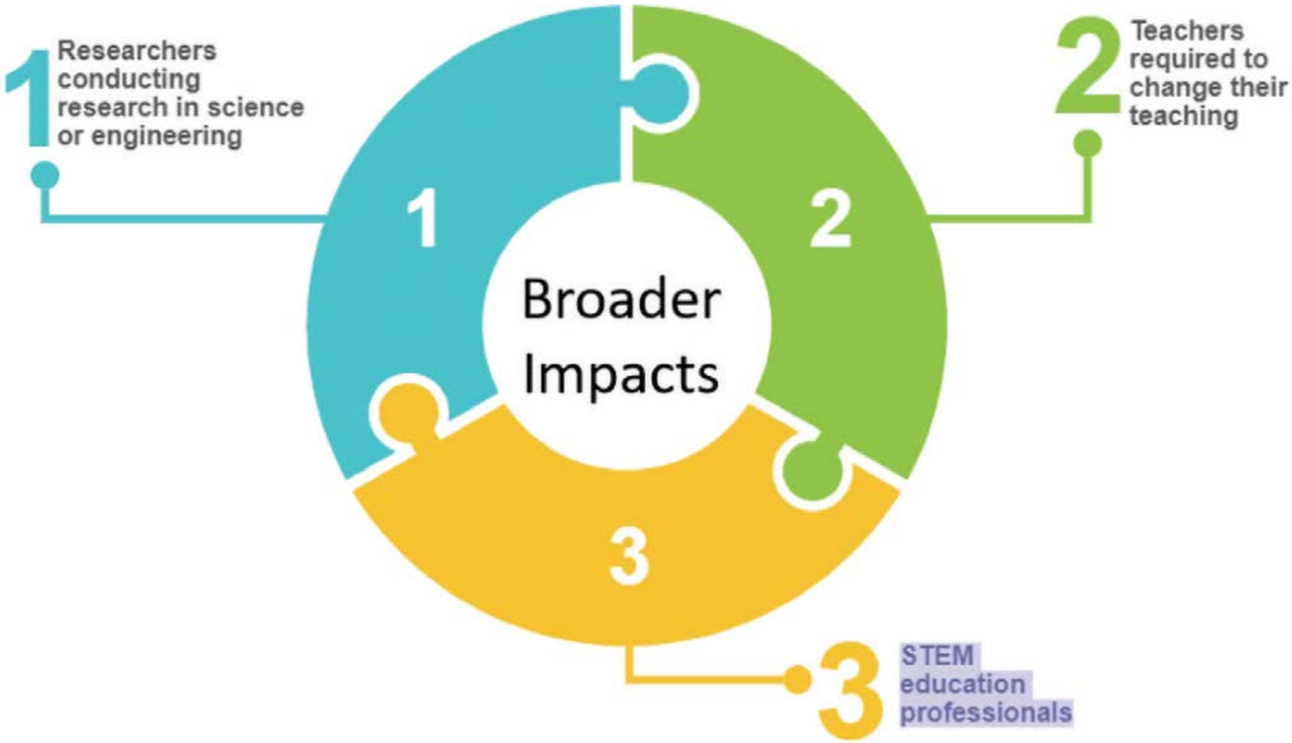

Figure 1-A model of the interconnected relationships with researchers, teachers, and STEM education professionals that can collaborate effectively in BI programs

Center for Science and the Schools (CSATS) at Penn State University

CSATS is in the College of Education and run by faculty with experience in science and in classroom teaching. We use this knowledge to collaborate with scientists and engineers to develop, propose, and (when funded) teach workshops to precollege teachers from across the country. We emphasize on the practices these researchers use in their work and develop ways to develop complementary or parallel projects that help teachers engage their students in these practices as a way to teach the disciplinary content they are mandated to teach. By intentionally promoting to and selecting teachers from rural and urban school districts with high percentages of students from groups typically underrepresented in STEM fields, we focus our efforts on two of the goals of Broader Impacts, full participation in STEM, and improved STEM education and educator developments.

Implications

Collaborations between researchers and STEM educators are mutually beneficial. Researchers need to ensure their work has positive societal impact, but few are unable to remain current on best practices in education, particularly in K-12 settings. Teachers need support in making the transition from traditional or inquiry-based instruction to one that engages students in the practices of scientists and engineers. STEM educators need examples of these practices being used authentically in order to provide high-quality professional development for pre- and in-service teachers.

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PLANTING AGRICULTURAL SCIENCE IN THE ELEMENTARY CLASSROOM, AG-SEEDLINGS

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Abstract: In collaboration with Penn state University's Center for Pollinator Research (CPR) and the Center for Science and the Schools (CSATS) has established together an educational program based on the agricultural sciences of pollinators. This program was developed to increase elementary educators' awareness of pollinator research, that will be taught within rural and urban communities of Pennsylvania. The AG-SEEDLINGS program will give educators the opportunity to learn the strategies used by researchers to investigate the challenges in agriculture production.

Introduction

The AG-SEEDLINGS agriculture educational program was developed to engage elementary (K-5) teachers that work in underserved populations within the state of Pennsylvania. In 2018, the United States Department of Agriculture published the, USDA (United States Department of Agriculture) Strategic Plan FY (Fiscal Year) 2018-2022. The USDA's FY 2018-2022 was compiled of 7 strategic goals to be implemented for the upcoming time frame. The AG-SEEDLINGS program was established to address the #7 strategic goal of "Food Security". The Center for Science and the Schools at Pennsylvania State University created the AG-SEEDLINGS program with the focus of supporting and encouraging elementary educators to teach students the importance of healthy dietary choices driven by reflected scientific data. The production of crops is dependable on the health and population of pollinators. Pollination plays a key role in agriculture. The fundamentals of pollination education are introduced in the elementary science educational standards. The program was developed in mind to prepare elementary educators with pollinator research experiences and content to then promote the fundamentals of agriculture science in these teacher's elementary classroom.

The AG-SEEDLINGS program is a federal funded 4-year grant. The primary focus of the grant is to give elementary educators the confidence to teach the fundamentals of pollination in our agriculture. Many elementary educators do not receive an adequate amount of professional learning to gain the confidence needed to teach science (Horizon Research 2013; McClure et al. 2017). In fact, 69% of elementary school teachers say they are not very well prepared to teach science in general (Horizon Research 2019; Highlights from the 2018 NSSME+). This program will provide immersive learning experiences for teachers to gain more in-depth knowledge about the growth of Pennsylvania's agriculture. Educators will also receive STEM aligned lessons that were developed to engage young learners in the science practices. This initial curriculum was developed by a collaboration of elementary educators and researchers from the Center for Science and the Schools and the Center of Pollination at PSU. Throughout the funded 4-year program, elementary educators can apply for this annual professional development opportunity. Fifty percent of the development time will be given to the educators' experiences inside the pollinator research and laboratory facilities at PSU. The other fifty percent of the time will be dedicated to teaching educators how to implement the science practices aligned with the developed pollinator curriculum. By the end of the professional development, the cohort of teachers will have gained the confidence and experience to apply the pollinator curriculum inside their own classroom.

Timeline of the Program

Currently, the AG-SEEDLINGS program is in year 2 of its funded timeline. The initial curriculum was developed in year 1, and the program is currently being piloted. The curriculum is being piloted by K-5 educators in different underrepresented rural areas and school districts throughout the state of Pennsylvania. While the piloting stage is ongoing, the AG-SEEDLINGS' planning committee is developing the mentioned hybrid professional development program which will take place in the summer of 2023. During the hybrid PD, educators will receive in-person experiences and then online instruction on how to deliver the pilot curricula to students. By the beginning of year 3, the Center for Science and the Schools will develop instructional online modules using the piloted curriculum. The AG-SEEDLINGS planning committee will also be recruiting a larger cohort of elementary educators to apply for the next professional development opportunity that will be no longer hybrid but rather fully online in the summer of 2024. This will eliminate the need for funds in travel expenses and increase the number of educators from rural areas who can participate in professional development without having to travel. The AG-SEEDLINGS program was created to naturally increase the number of educators participants every year. By year 4, a largest cohort of up to 30 educators will be selected for the online program. Throughout the funded, 4 years, the Center for Science and the Schools will continue to provide support for teachers who are selected for the program. By the end of year 4, the goal will be to support over 50 elementary educators that will then educate over 1300 elementary students on the importance of food security and the key role pollinators play in Pennsylvania agriculture.

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BROADENING PARTICIPATION: THE NSF-CREST CENTER FOR CELLULAR AND BIOMOLECULAR MACHINES AT THE UNIVERSITY OF CALIFORNIA, MERCED

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Abstract: The National Science Foundation-funded CREST Center for Cellular and Biomolecular Machines is a Center of Research Excellence in Science and Technology at the University of California, Merced – the newest campus of the UC system and designated as both a Minority Serving Institution and Hispanic Serving Institution. Through its research, education, and outreach goals, the Center aims to broaden participation in STEM fields and implement University goals in equity, diversity, justice, and inclusion.

Overview

The NSF-CREST Center for Cellular and Biomolecular Machines (CCBM) at the University of California, Merced is making a significant impact in educating underrepresented groups in Science, Technology, Engineering, and Mathematics (STEM). Located in the California Central Valley, a rural region and a historically socially and economically disadvantaged area with a large Latino/Hispanic population, the Center aims to broaden participation of those traditionally underrepresented in STEM fields at all levels, including faculty, postdoctoral researchers, graduate and undergraduate students, and K-12 students through a suite of programs and activities. The center has recruited and integrated diverse students in CCBM programs since 2016.

UC Merced is a diverse campus with almost 8,500 graduate and undergraduate students. 55% of undergraduate students identify as Latino/Hispanic and 19% as Asian, and 73% of undergraduates are first-generation college students. The 30 faculty of the CCBM are a diverse group, and the leadership of the Center is comprised of five women and three men in administrative, research, and programmatic roles. The current research thrust leads of the Center are all women.

Graduate Education

The Center hosts an interdisciplinary and integrated training program for graduate students that emphasizes physical and biological components. These students have access to Center activities including research meetings, training, professional development, networking, events, and more. Students can become involved in the new IB3 (Interdisciplinary Biophysical sciences, Biomaterials, Biotechnology) graduate emphasis program; gain first-priority access to two-week hands-on training modules in Imaging and Spectroscopy, NanoBio Technology, and Computation and Modeling; and mentor students in CCBM-led undergraduate research and outreach programs. They also have eligibility to become CCBM Fellows (and receive a renewable semester-by-semester fellowship). Finally, students have access to funds for research-related materials/supplies, travel, and training. The Center has been successful in funding diverse students (see Table 1), and 63% of graduate CCBM Fellowships from 2017-2022 awarded to students from underrepresented groups [including women, those with disabilities, and students from underrepresented racial and ethnic groups (Latino/Hispanic, Black/African American, American Indian or Alaska Native, and/or Native Hawaiian or Other Pacific Islander)]. By promoting team-based research, peer mentoring, outreach opportunities and personal and professional development, the Phase I Center produced highly trained graduates who have successfully been employed in the thriving biotech industry, as well as at premier academic institutions around the country. In Phase II (from 2021-2026), the Center is aiming to refine, augment, and institutionalize the CCBM's signature integrated, interdisciplinary graduate training program that combines scientific and professional skills with close mentoring in research and training experiences.

Undergraduate Education

The Center hosts two undergraduate research/training programs – one in the academic year for UC Merced students (CREST Fellows) and one in the summer targeting both external students from local universities and colleges and UC Merced

Table 1

CCBM Impact on Graduate and Undergraduate Students (2016-2022)

	Total funded	Total impacted	Women	Latino / Hispanic	Black / African American
Graduate students (G)	38	260+1	14	9	4
Undergraduate students (UG)	152	500+2	81	47	6
Total G / UG students	190	760+	95	56	10

1 through research, training modules and sessions, courses, seminars, workshops, and conferences
2 through research experiences, professional development, workshops, seminars, and events

students (CCBM Summer Internship Program or C-SIP). The CREST Fellows program integrates 10 hours of research per week, participation in weekly lab meetings, and monthly workshops focused on graduate school preparation, summer research experience applications, writing skills, and more, culminating in a research symposium at the end of the spring semester. CREST Fellows have conducted summer research at Research Experiences for Undergraduates (REU) programs hosted by our partner institutions (Stanford University, University of Pennsylvania, and UC Santa Barbara) as well as other institutions. C-SIP runs nine weeks in summer and includes research, training, mentoring, professional development, and social activities, with students participating in a large research symposium at the end of summer along with other program participants from across the campus. The Center has served 152 diverse students through these research programs (see Table 1) along with numerous other students through CCBM activities.

Outreach

The CCBM has managed robust outreach programs focused on K-12 and the community since 2017, resulting in over 2,000 student, teacher, and community experiences. The Center leads a suite of engaging outreach experiences for diverse participants from the California Central Valley and beyond and strategically connects its outreach to its research and education programs, as well as its overall broadening participation efforts. Overall, the Center's outreach programming focuses on integrating exciting and challenging topics of relevance and interest in an inclusive and enriching atmosphere. The CCBM highlights general STEM topics as well as Center research areas and strives to broaden participation of underrepresented groups in STEM.

The Center offers both in-person, hands-on and virtual sessions, with a Phase II goal of 80% of participants being women, those from underrepresented groups, low-income, first-generation, or those with disabilities. Annual programs planned for Phase II include: 1) CCBM Open House, 2) school and campus visits, 3) CCBM Virtual Sessions, 4) Science and Technology Enrichment Program/high school research program, 5) weeklong K-12 programs, 6) Science for Humanity Series (public talks), 7) teacher professional development workshops, and 8) development of STEM education/outreach and science communication resources with contributions from CREST Interns (undergraduate students) and CCBM Outreach Fellows (graduate students). CCBM outreach programming integrates hands-on labs and experiments, lectures, lab tours, mentored research experiences, interactions with scientists and engineers, discussions on ethics in research, fieldtrips, and more.

Evaluation

The Center continues to refine programs based on participant surveys and feedback from its External Evaluator, Associate Professor Ayesha Boyce (Arizona State University). The Center has made modifications and improvements in the education and outreach programming of the Center at the graduate, undergraduate, and K-12 levels based on these evaluation results and careful consideration of student needs. External evaluation has found that graduate and undergraduate students have benefited from their participation in hands-on modular training, innovative practical experiences, and the curriculum provided by the Center. For example, surveys showed that 40% of former CREST Fellows reported utilizing technical skills learned/developed in the program daily. According to one former participant, "Being a part of CREST is the reason why I applied to graduate school and has encouraged me to pursue a Ph.D." Evaluation of Center programs has concluded that 1) Center graduate programs have allowed graduate students opportunities to mentor and be mentored. Overall, graduate students experience the CREST Center climate as positive, understand their roles and responsibilities, and have increased skills. 2) Undergraduate research programs have increased participants' technical and research skills and provided them with new networks and connections. 3) Center outreach has been consistently rated as well-organized. Participants have noted that the outreach has provided useful information and that presenters were engaging, knowledgeable, and shared information effectively.

Phase II Center

Since the beginning, CCBM leadership and faculty have sought to support graduate and undergraduate students and have prioritized the quality of programming and opportunities. The Center is eager to continue to refine programs and activities at all levels for Phase II by utilizing student, faculty, and staff evaluation feedback. Some modifications include a revamped training module for graduate students and a brand-new course incorporating molecular and cellular biotechnology, which along with already established CCBM coursework will form the first graduate minor on campus. The CCBM also plans to include a new Summer Bridge program for entering graduate students, two new scientific writing workshop modules for graduate and undergraduate students, and a new formalized peer mentoring program.

Conclusion

The CREST Center has made a major impact on graduate and undergraduate students by providing access to research collaborations, educational/training and outreach opportunities, and funding opportunities. By integrating research, education, and outreach in this manner, the CCBM aims to develop robust pathways for underrepresented populations in the STEM workforce at all levels and produce graduates that feel comfortable in both physical and biological sciences who can thus pursue cross-disciplinary STEM careers in academia, labs, or industry thereby directly spurring growth in STEM fields in the Central Valley.

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EXPLORING THE IMPACT OF CIENCIA PUERTO RICO'S PARTNERSHIP WITH EL NUEVO DÍA TO INCREASE CULTURALLY RELEVANT SCIENCE COMMUNICATION IN LOCAL MEDIA

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Abstract: Since 2006, CienciaPR has collaborated with El Nuevo Día (END), Puerto Rico's newspaper of record, to increase culturally relevant stories in their science section. A comparative analysis shows that CienciaPR-authored articles are more likely to feature culturally relevant elements, be authored by STEM experts, and are more frequently located in Puerto Rico than articles from other sources. Our results demonstrate the value of scientist-media partnerships to improve the representation of locally relevant science in media.

Introduction

Communicating science in ways that are relevant to an audience's culture—their language, customs, beliefs, previous experiences and knowledge, and identities—and context can make science more pertinent to their lives, who they are, and what they care about (Manzini, 2003; Medin & Bang, 2014; University of Oregon School of Journalism & Communication, 2022)(2. Yet, too often, science is conveyed in ways that are inaccessible and disconnected from the realities of many publics, especially historically marginalized communities, which further excludes them from science (Barton et al., 2018; Canfield et al., 2020; Finlay et al., 2021) yet access to information and to opportunities for substantive public engagement with the processes and outcomes of science are still inequitably distributed. Even with increasing interest in science communication and public engagement with science, historically marginalized and minoritized individuals and communities are largely overlooked and undervalued in these efforts. To address this gap, this paper aims to define inclusive science communication and clarify and amplify the field. We present inclusive science communication as one path forward to redress the systemic problems of inequitable access to and engagement with STEMM (science, technology, engineering, mathematics, and medicine. For example, English is the de facto language of science in and outside of academia, including science communication, which can act as a gatekeeper of scientific knowledge and inclusion (Márquez & Porras, 2020). Even when science content is translated into non-English languages, it frequently does not "culturally translate"—meaning that translating information into someone's first language alone is not enough to make it relevant to their reality and context.

In Puerto Rico, where Spanish is the predominant language, historically there has been little coverage of science in local mass media outlets. Furthermore, that coverage has seldom focused on local issues, research, or scientists. For example, only one out of ~20 newspapers in Puerto Rico has a regular science section: El Nuevo Día (END), the newspaper of record (*Puerto Rico | The State of Latino News Media*, n.d.). Still, in 2006, less than 20% of the science stories published by END had Puerto Rico as its main location and more than 70% of the stories were sourced from news wires (Massarani & Buys, 2007). To address this gap, Ciencia Puerto Rico (CienciaPR), a nonprofit that brings together the largest network of Puerto Rican scientists and one of the largest networks of Hispanic/Latine scientists in the world (Guerrero-Medina et al., 2013), began collaborating with END in 2006, to have science, technology, engineering, and mathematics (STEM) experts publish locally relevant science stories in the newspaper.

We assessed the impact of CienciaPR's collaboration with END by performing a comparative analysis of articles published by the newspaper that were written by CienciaPR members and other sources. We quantified culturally relevant factors (e.g., referring to Puerto Rico, local landmarks, historic figures, slang), information about the articles (e.g., topics, location, framing, protagonist) and the authors to better understand how CienciaPR's efforts have contributed to increasing the amount of culturally relevant articles in END and, more generally, in Puerto Rican media. Our results indicate that our partnership has been successful.

Methods and Results

We randomly selected and analyzed 159 articles (80 authored by CienciaPR members and 79 articles by others not affiliated to CienciaPR) published in END's science section between 2012 and 2016, using a modified version of Massarani & Buys protocol (2007, Ramalho e Silva et al., 2012). Our analysis looked at six categories: cultural relevance elements, location of article, author information, article topic, framing, and article protagonist.

CienciaPR articles have substantially more culturally relevant elements when compared to articles from other sources. Seventy-four out of the 80 CienciaPR articles had at least one culturally relevant element, with 89% mentioning Puerto Rico or a place there, 57% a Puerto Rican institution (e.g., university), 54% a local landmark, 54% a Puerto Rican person, 47% using colloquial vocabulary or Puerto Rican slang, 39% referencing Puerto Rican culture, 31% using popular Puerto Rican phrases or sayings, and 13% mentioning a Puerto Rican scientific or historical figure. In comparison, only 14 out of the 79 articles by other sources contained at least one culturally relevant element. The most common culturally relevant element present in articles written by other sources was mentioning Puerto Rico or a place there (10% of articles). No other culturally relevant element surpassed the 10% mark in that group. Table 1 below highlights the culturally relevant elements present in articles by CienciaPR and from other sources. We should note that most CienciaPR articles contained more than one.

Table 1

Culturally relevant elements present in articles, by source (CienciaPR, Other sources)

	Other sources (79 articles)		CienciaPR (80 articles)	
Mentions PR or a place in PR	8	(10%)	71	(89%)
Mentions a Puerto Rican institution	5	(6%)	46	(57%)
Mentions landmarks in Puerto Rico	3	(4%)	43	(54%)
Mentions a Puerto Rican person	2	(3%)	43	(54%)
Colloquial vocabulary or Puerto Rican slang	6	(8%)	38	(47%)
References Puerto Rican culture	3	(4%)	31	(39%)
Uses popular Puerto Rican phrases or sayings	3	(4%)	25	(31%)
Mentions Puerto Rican scientific or historical figures	3	(4%)	10	(13%)
Total culturally relevant elements	33	(10%)	307	(90%)

More than two-thirds (55 of the 80 or 69%) of CienciaPR articles had Puerto Rico as their main location (i.e., setting of the story in the article). In contrast, only 3 out 79 articles (4%) by other sources were located in the archipelago. Additionally, all 80 CienciaPR articles were authored by STEM experts, a total of 24 different professionals in fields like chemistry, medicine, microbiology, and neuroscience, among others. Meanwhile, articles by other sources were mostly authored by journalists from END or news wires.

Conclusion

We show that CienciaPR's contributions to END featured more culturally and locally relevant references than articles not bylined by our members. CienciaPR articles are more likely to focus on Puerto Rico, showcase a Puerto Rican scientist, and be authored by STEM experts. While the analysis presented here spans articles published between 2012 and 2016, CienciaPR continues to regularly contribute articles to END. As of December 2022, a total of 344 articles had been published in END's science section, including the 80 analyzed in this sample. In recent years, our collaboration with END has expanded with our members regularly contributing to the newspaper's opinion section. This aspect of our partnership has been of special importance during the COVID-19 pandemic. From March 2020 to July 2022, science and public health experts from CienciaPR's network have published 80 op-eds about the biology and epidemiology of the coronavirus, its prevention, societal implications of the pandemic, and urging accountability from the government's response, among other topics. These efforts have helped contextualize the health emergency and communicate timely information in accurate and relevant ways. CienciaPR's long-standing collaboration with END has also paved the way for additional media partnerships in Puerto Rico.

Our results demonstrate that our partnership with END has been successful increasing the number of stories that are culturally relevant to Puerto Rican audiences in the newspaper. Moreover, they show that partnerships between scientists and scientific organizations with local outlets can improve media representation of locally relevant science topics, issues, and role models. Our contributions to END have made science more accessible and approachable for Puerto Ricans, showcased Puerto Rican contributions to science and highlighted the archipelago as a location of significant contributions to scientific knowledge. These efforts help counter stereotypes about who can be a scientist and colonial narratives about the importance of culture in science and where groundbreaking research is conducted.

This is the first analysis of culturally relevant science content in mainstream Puerto Rican media. We hope that our findings provide an important baseline for understanding the science communication landscape in Puerto Rico, the impact of culturally relevant science communication and the value of scientist-media partnerships to make science locally relevant and more accessible to different audiences.

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THE POLLINATOR GAME: DEVELOPMENT OF A RESEARCH-BASED LEARNING GAME

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** In Memoriam*

Abstract: This research-based pollinator diversity game was created through close cooperation between entomologists and education scientists in order to teach that variation in plant diversity leads to variation in pollinator diversity. Based upon findings reported in recent publications, the one-year process utilized iterative cycles of development between pollinator researchers and STEM education faculty in order to create the final design. The process had four steps: developing a robust model of the core learning objectives, developing a first approximation version of the ecological system in NetLogo, testing with pollinator scientists, and developing a teacher guide and testing the activity with target middle school educators. This poster will present the four-steps in detail to enable other BI researchers to make use of NetLogo and iterative design to create rich STEM learning activities based in deep research, but made ready for the K-12 classroom.

Introduction

Pollinators play a crucial role in our ecosystem by fertilizing plants, leading to the production of fruits, seeds, and nuts. However, pollinator populations have been declining due to habitat loss and environmental degradation. To address this issue, there is a need to educate students on the importance of plant-pollinator interactions and the role of plant diversity in maintaining pollinator diversity. This paper presents a pollinator diversity game that was developed through close collaboration between entomologists and education scientists to enhance STEM learning in middle school students.

Papert (1980) explores how computer-based tools and hands-on constructionist learning activities can empower children to learn through exploration and problem-solving. Resnick (1987) argues that learning by tinkering, or hands-on constructionist learning, can promote creativity, innovation, and problem-solving skills in students. Harel and Papert (1991) provide an overview of constructionism as a theory of learning that emphasizes active construction of knowledge through hands-on, experiential learning activities. Kafai and Resnick (1996) examine the use of constructionist learning principles in designing educational technologies that promote student engagement, creativity, and problem-solving skills. Eisenberg and Johnson (1997) review research on computer-supported cooperative learning in elementary education and highlight the benefits of constructionist learning approaches in promoting student collaboration and active learning. Kafai (2006) discusses the principles of constructionism and the importance of hands-on, experiential learning in fostering student engagement, creativity, and problem-solving skills. Piaget (1964) examines cognitive development in children and the role of active exploration and construction of knowledge in the learning process. Kuhn (2010) provides an overview of scientific thinking and its development in children, highlighting the importance of constructionist learning activities in promoting scientific inquiry and problem-solving skills. Wilensky (1999) introduced NetLogo a low floor-high-ceiling agent-based learning environment to learn through program complex systems models. Wilensky and Papert (2005) discuss the principles of constructionism and the role of agent-based modeling and simulation in fostering student engagement, creativity, and problem-solving skills. They introduce NetLogo, a programming language for creating agent-based models and simulations, as a tool for implementing constructionist learning activities. For example, Sengupta and Wilensky (2009) explore how constructionist learning activities in NetLogo can be used to teach complex scientific concepts, such as electricity, by providing students with hands-on experiences and opportunities to explore and experiment. Guo and Wilensky (2014) created bee-smart a complex systems curriculum to learn about honey colony collapse disorder and complex systems principles behind swarm behaviors like hive finding and recruitment through waggle dances.

Methodology

The development of the pollinator diversity game involved an iterative process that aimed to create a robust model of core learning objectives, a first approximation version of the ecological system in NetLogo, testing with pollinator scientists, and development of a teacher guide. The process was carried out over a year, and it involved close collaboration between pollinator researchers and STEM education faculty.

Results

The final design of the pollinator diversity game was based on recent findings reported in the literature, and it aimed to teach middle school students about the relationship between plant diversity and pollinator diversity. The game was designed to be interactive and engaging, with the goal of enhancing student motivation and learning outcomes.

Discussion

The use of NetLogo in the development of the pollinator diversity game was crucial as it enabled the creation of a simulation that accurately captured the complexity of the ecological system. The iterative design process allowed for feedback from pollinator scientists and middle school educators, leading to the development of a teacher guide that could be used to implement the game in the classroom.

Conclusion

The pollinator diversity game is an example of how close collaboration between scientists and educators can lead to the development of engaging and effective STEM learning activities. The use of NetLogo and iterative design can be applied to other BI research to create learning activities based on deep research and ready for the K-12 classroom.

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MEASURING BROADER IMPACTS ATTITUDES AND SELF-EFFICACY

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Abstract: Most broader impacts research to date has focused on assessing the impact of broader impacts activities on target audiences. Little research has been conducted to understand the impact of the broader impacts criterion from the perspective of researchers. This study aims to address that gap by developing and validating an instrument to measure researchers' attitudes towards and perceived self-efficacy related to the National Science Foundation's broader impacts criterion.

Introduction

The National Science Foundation (NSF) provides funding to support fundamental, applied, and social science research in STEM disciplines (Roberts, 2009). Proposals are judged using two review criteria, intellectual merit and broader impacts (NSF, 2021). Though researchers are required to address both criteria, the level of planning that goes into intellectual merit is not often mirrored in the broader impacts (NSB, 2011; Roberts, 2009). The goal of this study is to develop and validate an instrument to measure researchers' attitudes toward NSF's broader impacts criterion, and their perceived self-efficacy in developing and implementing broader impacts activities. Existing scholarship informs our understanding of the benefit of broader impacts and what sort of activities are included in successful NSF proposals (Bevan et al., 2018; Kamenetzky, 2013; Nadkarni & Stasch, 2013). What is lacking is an in-depth investigation of how the broader impacts criterion is viewed in the research community (Risien & Falk, 2013). This study aims to address that knowledge gap.

Methods

A draft instrument consisting of 35 items was developed to measure attitudes and self-efficacy relative to broader impacts. Ten scholars with broader impacts expertise conducted content validation, the results of which were used to revise the draft instrument. The revised instrument, now consisting of 22 items, was distributed through convenience and snowball sampling. Statistical analyses were used to determine the appropriateness of the pilot data ($n = 94$) for exploratory factor analysis (EFA). A preliminary and final EFA were conducted along with reliability testing.

Results

Table 1

Sample of Items from Pilot Instrument

Item	Factor
Broader impacts is an important review criteria	Attitude
I understand what types of activities are considered broader impacts	Self-Efficacy
Broader impacts is just another term for outreach	Attitude
I am willing to commit a portion of my budget to broader impacts activities	Attitude
I know where to go to find support for my broader impacts work	Self-Efficacy
I am confident in my ability to reach my target audience through my broader impacts work	Self-Efficacy
I am able to clearly articulate the broader impacts of my research	Self-Efficacy
I benefit professionally from the broader impacts activities I engage in	Attitude

Note: Scale - Strongly disagree, disagree, somewhat disagree, somewhat agree, agree, strongly agree

Exploratory Factor Analysis

Statistical analysis of the pilot data indicated the study had potential for stable factor solutions with a sample size less than 100 (McCoach et al., 2013). Results indicated factor solutions ranging from two to five (McCoach et al., 2013). The author opted to first explore the possibility of a three-factor solution to reduce the risk of an under extraction going unidentified. The three-factor final EFA resulted in no items loading onto factor two. It was determined that the factors were over-extracted in this model. A second EFA was conducted with the number of factors set to two. The resulting pattern matrix was analyzed with a minimum threshold of 0.5 required for item retention. Based on these results nine items were suggested for deletion. The remaining 13 items each loaded onto one of the two factors. This result supports the original assertion that the items represent two factors.

Reliability testing

Reliability testing was carried out on each of the two subscales, using a minimum value of .80 for Cronbach's alpha as evidence of reliability. Both the attitude scale ($\alpha = 0.86$) and the self-efficacy scale ($\alpha = 0.89$) showed evidence of reliability. A review of the Cronbach's alpha values if individual items were deleted from either scale revealed that item elimination would not result in higher Cronbach's alpha values.

Conclusions

Considering the aggregated results of this pilot study there seems to be initial evidence of validity and reliability for the use of this instrument to measure researchers' attitudes about and self-efficacy relative to the NSF's broader impacts criterion. Additional testing and analysis should be conducted before the instrument is deployed on a larger scale to answer specific research questions. Future studies will need a larger sample size to ensure a more representative pool of respondents. Care should be taken to gather responses with more equal representation from individuals across academic career stages from graduate student to full professor. The author plans to conduct cognitive interviews with individuals from the target population to better understand how each item is interpreted. Instrument revisions will be made based on the results of the cognitive interviews.

Table 2

Pattern Matrix for Two Factors

	Factor			Factor			Factor	
Item	1	2	Item	1	2	Item	1	2
1	**0.58**	-0.06	9	**0.63**	-0.11	17	**0.52**	-0.49
2	0.16	**-0.66**	10	**0.59**	-0.24	18	0.33	**-0.65**
3	0.31	0.06	11	0.43	-0.52	19	0.60	0.26
4	0.33	-0.37	12	0.20	-0.03	20	0.39	-0.19
5	0.07	**-0.85**	13	**0.78**	0.02	21	**0.54**	-0.42
6	0.32	**-0.65**	14	**0.71**	0.08	22	**0.71**	-0.01
7	**0.52**	-0.42	15	0.02	0.18			
8	**0.76**	-0.10	16	-0.02	**-0.76**			

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BROADER IMPACT THROUGH SCIENCE COMMUNICATION TRAINING

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Abstract: Experiential and practice-focused science communication training for graduate students supports the development of this critical competency and is a catalyst for meaningful, sustainable, and audience-centered broader impact community engagement. Through this curriculum-based training, students understand how audiences learn and engage with science, develop high-leverage practices that make their content more accessible, relevant, and engaging, create meaningful engagements with scientists and their research, and incorporate public engagement as an essential part of their professional practice.

Motivation

Effective science communication has long been recognized as an essential skill for researchers, yet training for this critical competency remains rare in graduate training programs (National Academies of Sciences, Engineering, and Medicine, 2014; Fischhoff, 2013). In 2011, founding academic leaders of the Pritzker School of Molecular Engineering (PME) understood this gap, and decided to purposefully embed within the educational program for doctoral students a set of communication learning goals, and to design a curriculum-based science communications program to support graduate student training in this area.

Our division's science communications program aims to train students to develop their ability to produce clear and convincing communication for a range of targeted audiences, analyze and evaluate communication for causes and consequences, create collaborative working relationships within a range of stakeholders, and leverage communication skills in their careers beyond the university. Beyond the academic context, a core element of these trainings is to foster graduate students' ability to understand, evaluate, and communicate engineering principles and ideas effectively within diverse cultural, social, public, and professional contexts.

Through this experiential and practice-focused training, students develop an understanding of how audiences learn and engage with science, build a toolkit of high-leverage practices to make content more accessible and relevant, and use this to create meaningful engagements that connect audiences to scientists and their research. In this way, students in the program incorporate public engagement as an essential part of their professional practice, engaging with the public through science to make it more accessible and relevant, generating more positive attitudes towards scientific research, and creating long-term connections with the community.

Program Structure

After completing most of their graduate coursework and matching into a research lab, graduate students are eligible to apply to the science communications program, a 2-year, 8 half-day workshop program with two public-outreach capstone projects. These highly participatory and practice-based training workshops are built on two key underlying principles:

1. constructivist approaches to teaching and learning, which center on audience-centered experiences where communicators facilitate sense-making through experiential and discourse-based engagements
2. improvisation training, which focuses on dynamic conversations and the ability to adapt on the spot to the needs and interests of the audience.

Framing communications through these lenses, students in the first year of the program learn, practice, and refine a set of communication strategies, use them to distill their research into a clear message, and learn how to asses and understand their audience so they can spontaneously tailor the scope and content of their communication to their needs and interests. As a capstone for year one, students apply their skills by creating and facilitating an interactive hands-on activity for public audiences at our local Museum of Science and Industry.

In the second year of the program, students continue refining their ability to understand and engage audiences by focusing on how emotions and storytelling can create personal connections, and revisit the idea that experiential learning is a highly effective mechanism for meaning-making. Throughout the four workshops of this year, students develop and eventually lead a Junior Science Café, a hands-on and inquiry-based learning experience, for a group of middle school students at a neighborhood school.

Ongoing evaluation of the program, including feedback on the capstone components from public and school-based audiences, has allowed us to continually refine the program components to best serve the needs and interests of participants, audiences, and other stakeholders. Because it provides a conduit for ongoing feedback and idea sharing, the evaluation structure also helped us to nimbly adapt the program and its outreach components to the virtual engagement that was the norm during the pandemic. As a result, we were one of the few units on campus that continued to engage in a range of outreach efforts with schools and community organizations throughout 2020-2021.

Outreach Outcomes

A primary aim of the outreach efforts at PME is to increase the access, participation, and engagement in STEM of historically underrepresented and underserved communities, especially those in the university's community. Within this context, the shortcomings that communication researchers have identified in the deficit-model approach to educational outreach (Nadkarni et al., 2019; National Academies of Sciences, Engineering, and Medicine, 2016; Sturgis et al. 2004) were particularly relevant to our educational mission and for the training of graduate students who directly engage with public audiences through outreach. As a result, the science communications program was designed with an audience-centered approach to engagement and an asset-based understanding of community partnerships, and has been a catalyst for meaningful, sustainable broader impact engagement with the university's community and throughout the city. Graduate students who participate in the science communications program are part of a community of ambassadors that works collaboratively and creatively to meaningfully engage a broad array of audiences through:

- Junior science cafés in neighborhood public school classrooms
- Family STEM Night events and career fairs at middle and high schools throughout the city
- Science Works and Engineer Your Future career fairs at the local Museum of Science and Industry
- The No Small Matter Molecular Engineering Fair, an on-campus hands-on exploration of molecular engineering concepts for middle schoolers
- A large-scale, multi-disciplinary, campus-wide STEM community engagement festival

A range of teaching and mentoring opportunities through summer research experience programs for undergraduates, teachers, and high school students

Overall, these outreach initiatives engage over 4,000 students and members of the public annually. Students who complete the PME science communications program and are interested in further developing their communication skills can also apply to become science communications fellows. Fellows work with the science communications team to implement the program, provide guidance and critical feedback to peers, and advance the science communication mission through sharing resources and leading events.

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WEAVING IMPACT IN DIGITAL MEDIA TO SUPPORT BROADENING PARTICIPATION, SUSTAINABLE BROADER IMPACTS AND CAPACITY BUILDING

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Abstract: Meet the Lab is a collaborative project led by PBS-Wisconsin that has created a collection of digital media resources that connects learners to relevant real-world science issues by integrating human stories of scientists and their journeys of discovery. The design of the project supports a growth in understanding of the personal and professional elements of lab teams on the cutting edge of research. Meet the Lab scientists and engineers support broadening the representations in the reflections of the mirrors of STEM with aspirations to spark broadening participation in STEM for individuals that are underrepresented in STEM. The Meet the Lab platform creates sustainable capacity building for new broader impacts activities as connective elements to the digital resources. This has resulted in the expansion of the project through broader impact plans that integrate Meet the Lab connected field trips, summer camps, community based expos, and hands-on activities as part of the learning experiences. The below sections of the project highlight opportunities to build upon and connect to for future broader impacts plans.

Scientists and What a Lab Looks Like in One Tidy Package

Extending a more authentic representation of the composition and function of a university research lab is an important part of the Meet the Lab project. Most youth learners connect to a 'named discovery' to learn about scientists through their classroom experiences. The conflict arises when youth learn about representations of individual researchers in association with key discoveries that advance knowledge. Labs are dynamic collaborative places with many unique, creative, motivated and persistent individuals seeking to answer new questions in science. What's missing from the typical narrative is the 'search for a discovery' and the uncertainty of all the possibilities that scientists have to address through strategic persistence. The sense of a scientist as someone who is in pursuit of knowledge as opposed to only distributing knowledge is a huge shift in the concept of what a scientist does. In addition Meet the Lab brings the personalities of the lab to life highlighting research teams of young scientists from diverse backgrounds and sparking a sense of their personalities seeing the scientists in the community, their homes and the research lab.

The Building of the Perception of Scientists Through Broader Impacts - Who Am I Really?

The limitation of science offerings in school settings, especially in elementary school, can further complicate early stage perceptions of the importance of science and scientists. Youth track the perceived value of educational opportunities by the frequency of the occurrences. If there are limited science offerings in family and school settings the perception of the value of Science, Technology, Engineering, Math (STEM) activities is reduced (Carlone et al., 2014; Hachey et al., 2022). Popular media such as movies and sitcoms shape the perception of who a scientist is. However these media portrayals are narrowly focused around predominantly white male scientists and when women scientists are part of popular media stories their character's science attributes are secondary to non-science attributes (Elena, 1997; Jackson, 2011; Noonan, 2005; Steinke, 2005; Steinke et al., 2007). The nature of 'doing science' and science as a collaborative endeavor is left behind in these media portrayals leaving it to the imagination of the viewer to fill in the gaps of how a scientist operates (Hüppauf & Weingart, 2008; Simis et al., 2015).

Youths' developing perception of scientists is also connected to exposure to scientists, science activities and conversations with the family (Atkins et al., 2020). The network effect of having friends and family who are practicing scientists is a key influencer to a more authentic understanding of scientists and the access to these mentor networks is unequal (Atkins et al., 2020; Sharum & Mentor, 2013). Meet the Lab provides a digital venue for youth to see role-models in STEM cooperatively working in a lab around a defined mission. Building and integrating broader impacts plans to help support a more authentic portrayal of scientists using Meet the Lab as an entry point could be an accessible pathway for many research labs.

What Do I Have in Common with a Scientist?

The inklings of science identity have already started by middle school but the formative potential to see oneself in STEM is still available (Cohen et al., 2021; Dou et al., 2019; Hachey, 2020; Singer et al., 2020). When individuals consider themselves on the outside of science looking in we need to build an entry point to find common ground. The Meet the Lab project created interactive 'Meet the Scientists' cards (Figure 1). The use of the interactive scientist cards as part of informal science learning activities has shown great power to make connections and are used in various forms in many programs. In figure 1 you might note the section titled 'Weirdest thing I love', the scientists create social-gravity through their sharing and the youth are pulled into orbit with debates, laughter, surprise about anime or Mukbang YouTube videos. Now that the youth have found a connection to a scientist there is a natural flow to learn more about the science practices in the lab and the impact of the research. These innately unique human elements of a scientist's personality build motivation to want to learn more about the scientist's story. The importance of creating belonging through representation is essential as part of shaping a STEM Identity (Atkins et al., 2020; Cox & Tamir, 2022; Singer et al., 2020). Broader Impacts plans can focus on finding common ground among youth and scientists. The Meet the Lab cards can be a spark to build off of with customized prompts and local event structures that exist.

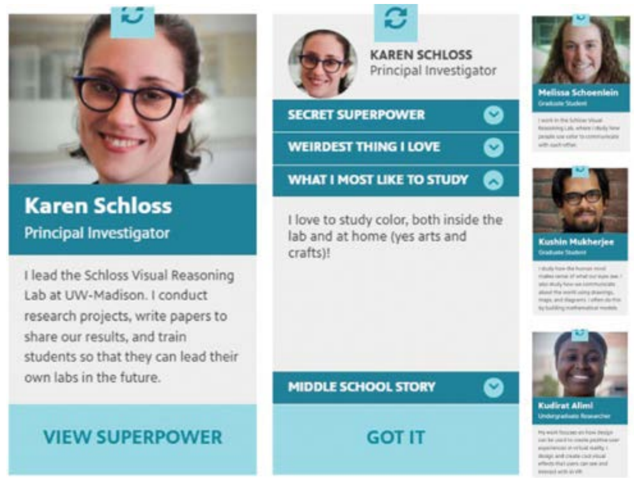

Figure 1: PBS-WI Meet the Lab meet the scientists cards. Meet the Visual Communicators provides a quick way to recognize the humanity of scientists and the opportunity to find elements of interest and common ground around the enjoyment of dance, ballet, the flute, anime and watching youtube videos. pbswisconsineducation.org/lab/visual-communicators

Motivation - Why Does All this Matter? The 'Drive' of Scientists

If youth are inspired by a famous sports star they often know the athlete's motivation to win a championship, set records, and leave their legacy as part of the sport. Similar drive and dedication exists for scientists and is not frequently featured as an attribute of a scientist. Science discoveries are wonderful but the story of what motivators fuel the persistence and creativity of science can be inspiring as well. Mini-documentaries of the impacts of science research are included in Meet the Lab to provide bridges to relevance and develop an emotional connection with science. Figure 2 displays a screenshot of one of these videos; the journey of Miranda in understanding bioengineering and stem cells to help improve health outcomes for individuals with spinal cord injuries. Building opportunities for Broader Impacts plans to connect to scientist's motivations and direct connections to the Meet the Lab stories can fit into many educational formats.

Figure 2: PBS-WI Meet the Lab Why Research Matters videos. These mini-documentaries tell a personal impact story that directly ties to the lab practices and the motivations of the scientists.
pbswisconsineducation.org/lab/nervous-system-engineers

I Got This - I'm Doing What a Scientist Does

The direct connection to a scientist guiding youth through scientific practices they do as part of their research was included to build a common experience in science between the youth and the scientists (Figure 3). Building confidence in STEM through participating in lab practices helps gain self-efficacy to advance their STEM Identity (Barton, 2005; Cohen et al., 2021). The scientists can state 'You are doing what I do' while the youth participants recognize their participation in scientific practices by the explicit design of the scientist's supportive guidance. Start with these examples of science practices and build a Broader Impacts plan to compare and contrast 'What a scientist does' in formats such as in-person or virtual question and answer sessions and science cafes.

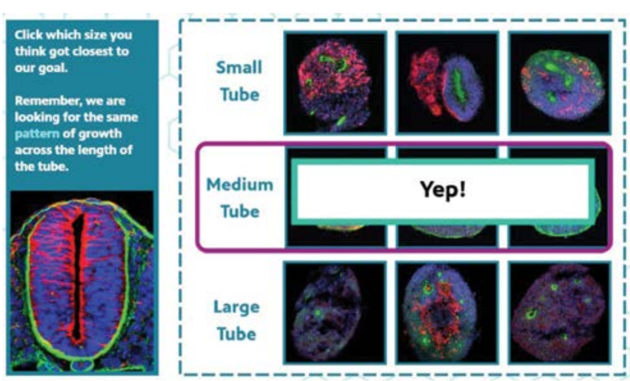

Figure 3: PBS-WI Meet the Lab Science Practices Activity. Building confidence in STEM through participating in lab practices helps youth gain a sense of self-efficacy in their STEM identity.
pbswisconsineducation.org/lab/nervous-system-engineers

Meet the Lab - A Platform for Future Broader Impacts and Aggregated Evaluation

The researchers who participated in the development of Meet the Lab as part of their NSF projects also created fertile ground for future Broader Impacts projects. The Meet the Lab digital collection has flexible options to connect to hands-on activities, mentorship, in-person and online field trips, summer camps and science cafes. Building the Meet the Lab collection to support sustainable development of future Broader Impacts projects was intentional and it has been exciting to see the integration of funded NSF Broader Impacts as well as proposed NSF Broader Impacts projects. One of the integrated projects, 'What Color is…?' has become a regular activity at a variety of settings, from campus football tailgates, to family science nights, to an entire semester of activities with middle school Girls Inc. members (NSF #1942099). The impact goals of 'What Color is…?' included learning about color perception, art, data and scientists (Flack et al., 2019). Meet the Lab elements that aligned with these impact goal(s) were integrated into informal science implementations to showcase the personal journeys and motivations of scientists in the lab. The alignment of these impact goals helped to springboard access to members of the lab who were not able to be on-site for events and provided asynchronous options for follow-up for learning facilitators.

Setting a long-term Broader Impacts strategy to align Broader Impacts partners while aggregating projects is essential to the success of building a linkable project infrastructure. This aggregated project framework provides a unique opportunity to measure impact of the learning activities. The development of an observational tool for aggregated evaluation of the project is underway. The evaluation tool measures the frequency of responsive and proactive instances of participants engagement in STEM practices and elements of STEM Identity. This evaluation tool may help to reveal if the core project design sparks interest in STEM and aligns to aspirations of broadening participation in STEM. These evaluative measures will be useful for all project partners to make data-informed decisions about their informal science activities implementation.

It's obvious how essential partnerships are to the success of Broader Impacts projects. Having linkable elements helps potential partners with entry points to design Broader Impacts plans. The Broader Impact professional is best suited to play the role to support collective impact (Kania & Kramer, 2011; Wynne, 2011) and lift all partners to reach their project goals. The impact of designing Broader Impacts projects to build infrastructure for future broader impacts amplifies the reach and impact of each individual project while allowing new broader impacts to creatively build their impact models with integration of Meet the Lab elements.

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COMMUNITY GUIDING VOICES FOR INCLUSIVE IMPACT IN BROADER IMPACTS DEVELOPMENT

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Abstract: The voices of community partners need to be front and center at the early stages of Broader Impacts planning. Yet, community partner voices are often not included until far downstream in the stages of grant proposals led by PIs from academic institutions (Dolan & Tanner, 2005). This 2021 ARIS Fellows project provides direct access to a small sampling of library and community based organization guiding voices for Broader Impacts collaborations that support persons with disabilities and aspiring scientists and engineers who are underrepresented in STEM. Guiding voices provides first-hand representation of community partners advice in the form of a summary document along with three podcast episodes for use by PIs and Broader Impacts professionals at early stages of Broader Impacts planning.

What's Typical - Power in the Hands of Higher Education Institutions (HEI)

Higher education institutions' influence in Broader Impacts planning in federal grant opportunities is oversized relative to community partners who may be part of the broader impacts plan. The familiarity and support of the logistics and understanding of the grant solicitation is well operationalized in HEIs relative to community partners. Items such as a biosketch, indirect rate calculations, current and pending support documents, etc. may not be available as readily with community partners as they are with members of an HEI. There are so many elements that tip the balance of power strongly to the HEI that community partners like a community library or community center have to 'step-up' to participate as a collaborating partner in a NSF grant proposal. The community partners have their own missions and standard operating procedures that are often not paramount in the process. This misalignment can influence the degree of 'reaching' that a community organization might find itself in due to operational conflicts of the planning process (Johnson et al., 2020). How can an HEI be a good collaborator while holding the keystone elements of grant development that influence the degree of power imbalance of the broader impacts planning? This project seeks to address some elements of this important question.

Community Partner Voices - Logistics to an Aligned Broader Impacts Mission

More direct dialogue with community partners to inform an HEI's Broader Impacts planning process

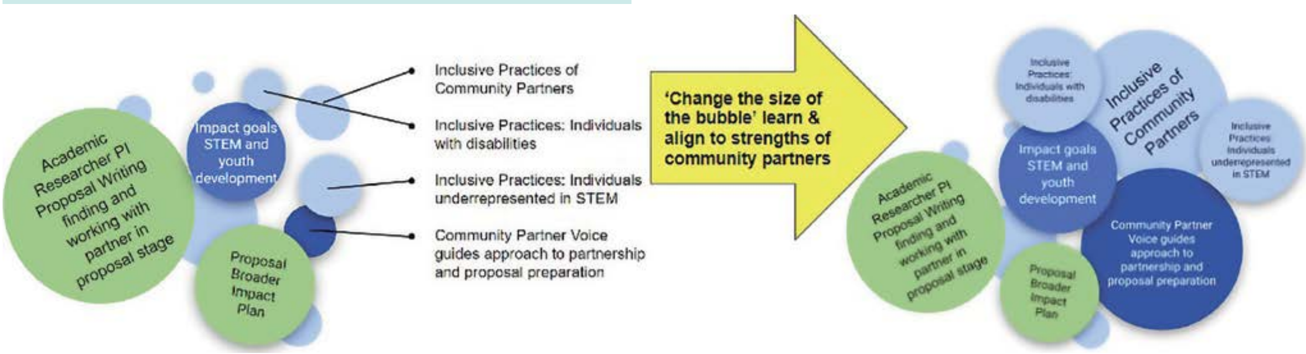

Figure 1: Without the guiding voices of community partners in early Broader Impacts planning their representation in the final plan is diminished (left). Ideally early strategic collaborations will allow a better representation of the STEM mission and values of community partners (right).

may help reduce the power imbalance (Figure 1). Our community partner interviews helped to remap key logistics, timelines and operational suggestions for PIs and Broader Impacts professionals. The community partners interviewed range from rural and urban library leaders, community based library workgroups focused on equity and access, community partners with existing broader impacts implementations and grant/development leaders at community centers.

What should a PI or Broader Impacts professional consider when working with community partners? Table 1 summarizes key takeaways: Operational logistics of community partners from the **guiding voices of community partners** expressed during the interviews and project meetings (N=22).

Table 1 - Community Partners' Operational Logistics - Building Awareness for PIs and BI Professionals

This table shows an aggregated summary of community partner responses (N=22) to this interview question: Approach: What logistical items (fiscal year, who to work with, prior-work, budget, co-creation process, etc.) are important for partnering on NSF projects of this type?

XXXXXXX
Timeline - initiate as early as possible to be able to be responsive to community based organization's capacity and inputs on the project
Ask about community partner's fiscal year and how it relates to annual funding and grants cycle (both in proposal development and implementation planning)
Consider that many community based organizations have board meetings where key decisions are made. Oftentimes community based organizations will have to develop presentations for potential grant projects for approval by their board of directors. Can a PI consider being involved in preparing for a community based organization board meeting as part of a pre-proposal item?
Community Partners often have a strategic plan that lasts for five years or more. Find out where the organization is in their timeline of implementation or planning of their strategic plan.
Who to talk to? Be intentional about your intentions when making first inquiries about Broader Impacts projects and ask who might be the right person to talk to. It can be inefficient and disruptive to reach out and start planning a project with the wrong people in the organization such as a volunteer or a LTE staff member supporting various programs. In general, find the right person in a leadership role at the organization; ask direct questions such as "Who helps with grant projects?".
Recognize the professional capacities of community based staff to support grant writing and budgeting. While the community based organization might not be 'NSF ready' they are 'grant-ready' across many development opportunities.

During our interviews our guiding voice partners provided their preferred practices with an eye towards identifying and serving physically, emotionally, racially, and socioeconomically diverse communities. The guiding voices of community partners set a pathway for essential alignments and common vision for impact and support of individuals with disabilities and individuals underrepresented in STEM. An outline of their guiding voices in these areas is in Table 2 below.

Table 2 - Impact Mission Alignment of Community Partners and Suggested Actions for PIs and BI Professionals

This table shows an aggregated summary of community partner responses (N=22) to this interview question: Approach: How might your organization partner or lead an NSF proposal to support inclusivity related to: 1) individuals with disabilities? 2) individuals underrepresented in STEM?

Impact mission alignment
A PI or Broader Impacts professional should do the work to find common ground for the project - Mission and innovations in STEM exist at community based organizations.
Show-up outside out of science - if possible volunteer at the Community-Based Organization (CBO)
Do background research to understand the core mission and values of the organization; oftentimes there are defined connections to diversity, equity and inclusion in STEM programs. There are easy places to start your research about potential community partners: Annual reports, strategic plan, mission and vision statements, website Relationship building prior to a grant or grant proposal
Community Based organizations are not a 'blank slate' - Inquire about community led initiatives and innovations.
Broader Impacts collaborations that support individuals with disabilities
There are ongoing measures to assure ADA compliance and operational alignment at community organizations to assure an inclusive and welcoming environment.
Programs are reflective of the community of patrons, members, and youth that are part of the general program structures. Community based organizations are responsive at the individual level to support full communication through assistive technology across many languages and formats. This requires training, support, and resources so when a new project is introduced it is a good idea to have support to extend these resources to the new project.
Broader Impacts collaborations that support individuals who are underrepresented in STEM.
Community based organizations are a 'partnership magnet' for other community partners; oftentimes this involves industry and workforce development with connections to STEM. Understanding that multiple partnerships coalescing around a common goal might have better results is an important planning consideration.
Community based organizations are often education centers for adults and seniors to learn computer skills and as a job retraining resource. Extending beyond K-12 thinking will help to support understanding of connections in STEM that could coalesce with these computer training programs that might lead to new career and leisure explorations in STEM.
Intergenerational events are very frequent at community based organizations. Some of the more successful STEAM programs such as makerspaces, art galleries, sound booths, gardens, cafes, etc. all bring communities together across age ranges. Consider the uniqueness of an intergenerational STEAM centered audience when developing broadening participation Broader Impacts goals.
Community forums often have topical STEM themes in programs such as community book reads, talk series, and policy forums in their meeting space. This is a great way for connecting role-models in STEM from demographics that are underrepresented in STEM to drive interest in their science topics to broaden participation.

BI Professionals Responsive Practices: Guiding Voices Aligned Impact and Logistical Efficiencies

Members of the HEI will certainly move forward for federal grant opportunities based on their primary interests being met. This momentum should not travel too far ahead to create difficulty in being responsive and flexible based on what assets and directions the guiding voices of community partners may provide. As an idealized general practice PIs and Broader Impacts professionals should build relationships and understanding of their STEM ecosystem prior to inquiring about projects with community partners. Understanding that the investment in making partner connections prior to the 'need' of the grant proposal will help support efficiencies in the work to a large degree. De-risking grant proposals by determining if there is an opportunity to be supportive of elements of the proposal if the grant is not funded helps to establish the authenticity of HEI members' stated purpose of a potential collaboration. This de-risking component has to be mapped by realistic capacity metering of the PI and assuring that there is not an over-promising which itself can create challenges in the initiation and sustainability of a partnership.

I encourage you to listen directly to three selected guiding voices of our community partners in the podcasts referenced (Tangen & Baker, 2022; Tangen & Khalil, 2021; Tangen & Rasmussen, 2022). Each thirty-minute episode will help generate clarity of process through their guiding voices resulting in better Broader Impacts collaborations.

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BUILDING A CULTURE OF EVALUATION THINKING IN THE U.S. STEM WORKFORCE

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Abstract: There has never been a time when science and innovation are so vital to the American economy. The U.S. needs bold plans to accelerate science and innovation to kick-start the economy and meet the societal challenges. Our investments in research and development (R&D) have been stagnant for more than half a century. The structural barriers to access and opportunity prevent many from benefiting of our innovation-based economy. Could evaluation help fulfill the premises of science?

Introduction

Science, technology, and innovation are the backbone of the American economy. They are essential for improving economic performance and well-being. A recent analysis of the Organization for Economic Co-operation and Development (OECD) shows that science, technology and innovation play a major role in economic performance (OECD, 2000). However, more evidence is needed to support the broader impact of science and innovation. Perhaps, the adoption of evaluative thinking as a way of doing business could offer new avenues for evidence seeking and broader impact perspectives.

Evaluative thinking contributes to new learning by providing evidence to chronicle, map and monitor the progress, successes, failures and roadblocks in the innovation as it unfolds. It involves thinking about what evidence will be useful during the course of the innovation activities, establishing the range of objectives and targets that make sense to determine their progress, and building knowledge and developing practical uses for the new information, throughout the trajectory of the innovation (Earl & Timperley, 2015, p.5).

For research to be successful, results must inform and shape socio-economic policies and be easily adaptable to society's needs (OECD, 2000). The rapid development of emerging technologies promotes the development of society and the economy (Xuan, Lihui, & Nian, 2015). However, due to the limited understanding of emerging technology, it is easy to overstate its role in the process of disseminating and applying new technology, which may even lead to negative consequences (Nicolaides, 2014).

The rise of modern science, especially in the age of high technology, the emergence and development of various scientific events not only affect people and social relations in the community, but also the nature, environments, subsistence, and the sustainability and production of the entire human race (Zheng & Zhang, 2011). Therefore, to maximize the positive effects of science and technology while minimizing their negative effects to truly serve the public interests, people must learn, understand and participate in science (Nicolaides, 2014). How do we know if science and technology are having a negative impact? How can more stakeholders participate and influence the decision to minimize these negative effects? Overcoming these obstacles requires training and nurturing evaluative thinking (Wang, 2008), which is building a culture of inquiry. This is a paradigm shift where deliberate evidence-seeking, self-reflection, and self-examination through systematic inquiry are encouraged and supported while the focus is on assessing the actual impact on people and planet. Many organizations offer professional development opportunities in evaluation, but often fall short when it comes to leadership support (e.g., time to thinking and reflection, necessary resources, etc.) and accountability. There is little incentive to actively seek evidence of research societal impact.

Scientists must fairly and reasonably assess the public values of scientific activities. They should evaluate scientific research topics on ethical and social values and examine the potential social impact of technology and the social value of scientific research (Rachels, 2006). Evaluation provides the public, government, and other stakeholders with objective knowledge of the real impact of science and technology on society and help minimize the negative influence of scientific gains on the social order (Zheng & Zhang, 2011).

Evaluative thinking is well beyond the economic perspective in technology management. There is a great need to integrate more elements of society, environment, ethics and public impact into assessment thinking tools (Zheng & Zhang, 2011). The public and social organizations need to improve awareness of the assessment and make a correct judgment (Zheng & Zhang, 2011). Scientific assessment requires public participation and majority decisions to ensure that the choice and decision meet the benefits of the majority (Rees, 2010). This not only reflects the principle that the public interest prevails, but also the necessary requirement for the development of a modern democratic society (Rees, 2010). The "lack of knowledge" between the public and the expert system must be reduced or eliminated by educating the public about science and participating in science to determine the responsibilities for society and the public at large (Guba & Lincoln, 1989).

However, there are still many practical difficulties for the public involved in technological decisions. The premise for the public to make an independent choice is the existence of a multiplex and diversified society as well as various views on a new object and is the integrity and diversity as well as the complete transmission of information (Wang, 2008). Public participation in decision-making still requires long-term exploration and efforts in mechanisms, culture and education, etc. In short, raising public awareness, improving public knowledge of science and cultivating public scientific thought assessment are extremely critical to making good judgment and appropriate choice during democratic decision-making (Zheng & Zhang, 2011). Having a continuous cycle of generating hypotheses, gathering evidence and reflecting on progress allows stakeholders (e.g., innovation leaders, policy makers, funders, the public) to try things, experiment, make mistakes and consider where they are, what worked and did not work, through a fresh and independent review of the course and the effects of research and innovation (Earl & Timperley, 2015).

Conclusion

Public participation in science and technology can overcome narrow-mindedness about technical risk and help to consider multiple values and requirements from all sectors of society as a whole. Evaluation is the basic way to get the most benefits for people. The most valuable evaluations depend on multiple perspectives. Leaders must inform staff of evaluative thinking and clearly explain what it means to take an evaluative approach, that is, ask important questions before making decisions, systematically collect and analyze data to inform decisions, communicate the results of findings in response to these important questions, and base responses largely on the results of analyses, and then set the stage for others by using evaluative thinking in the practice of scientific and technological applications and perpetuating an organizational interest in it. Leaders are responsible for integrating evaluation into organizational life. We need to integrate more elements of society, environment, ethics and public impact into evaluation thinking tools.

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NSF'S ADVANCING INFORMAL STEM LEARNING (AISL) AWARD PORTFOLIO: PATTERNS IN EVOLVING APPROACHES TO EQUITY FROM 2017-2022

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Abstract: The NSF Advancing Informal STEM Learning Program (AISL) funds research and practice dedicated to lifelong learning that occurs outside of formal education systems. AISL is committed to ensuring that all projects it funds center equity, belonging and broadening participation. This work seeks to evaluate approaches to equity over time in informal learning spaces and practices. We describe a qualitative coding analysis of equity concepts across projects funded throughout the 2017-2022 AISL Program solicitations.

Equity as an Advancing Informal STEM Learning (AISL) Program Goal

Informal Science, Technology, Engineering, and Mathematics (STEM) learning experiences and environments offer unique opportunities for impacting equity in STEM education given the interest-driven and often voluntary nature of informal learning and the fact that most learning over a lifetime occurs outside of formal education systems. For the last several decades, the National Science Foundation (NSF) Advancing Informal STEM Learning (AISL) program has encouraged submitters to broaden participation in and increase access to informal STEM experiences and environments in their proposals. As part of a strategic planning process recognizing the need for a more intentional and explicit strategy around equity, the program wanted to understand the way awarded projects discuss and address equity. This presentation describes patterns and evolutions in equity concepts in AISL-funded informal STEM education projects from 2017-2022, including where and how proposals are at the forefront of centering equity in STEM.

Methods

Sample

We sampled the AISL-funded projects made from 2017-2022. This selection spanned the years before, during and after the national racial reckoning following the murder of George Floyd amid disparate impacts of the COVID-19 pandemic. Broadening participation and/or equity-focused awards were identified from awarded AISL projects under the 2017-2022 solicitations using a keyword search. Awards were selected every other year starting one year after the solicitations began (2018, 2020 and 2022). Based on the variance across the AISL portfolio coded in a pilot study, a random sample of 50% of awards were selected. Full proposals received by AISL include: a cover page with general information; a one-page project summary; a project description of up to 15-18 pages that details the project rationale, project design, communication plan, evaluation processes and project management plan; budgets and budget justifications; references; data management plan; a post-doctoral mentoring plan (if applicable); and additional supplementary documents optionally and dependent on the project type. Analyses were completed using project descriptions from funded AISL projects.

Qualitative equity coding protocol

A qualitative equity coding framework was designed through an iterative process beginning with consideration of the AISL program priorities and expertise of members of the AISL program, a review of the literature, including but not limited to: Alim & Paris, 2017; Bang & Medin, 2010; Basile & Lopez, 2015; Gay, 2018; Loew, 2021; Nasir, 2020, attending presentations and workshops with experts on equity in education, discussions with NSF staff members with diverse expertise in educational research, racial equity and evaluation/qualitative methods, and discussions with other funding agencies that are developing guidelines for evaluating equity in proposals. An initial framework was outlined for deductive coding. In a pilot study, each project description from a sample of 80 active AISL-funded projects was coded for inclusion of an initial subset of equity concepts by one member of the AISL team. Emergent codes that arose from piloting the coding framework were discussed with other AISL team members and refined through subsequent rounds of coding. An excerpt from a larger and continually evolving coding scheme is summarized in Table 1. While the impact of each concept is highly context-dependent and they all exist on a spectrum, some concepts (denoted in red) are consistently counterproductive to equity. As the field continues to update practices, this framework and the interpretation of how concepts are applied within the AISL portfolio are likely to evolve as well. This framework is used solely for retrospective analysis of what has been funded by the AISL program. The guiding document for current proposal submissions is NSF 22-262 and the NSF Merit Review process.

Table 1

Concepts	Definitions
Disrupting Inequity	**Disrupting systems:** Actively disrupting inequity at levels of institutions, organizations, systems, economy, policy, etc.
Contextualizing Populations And Inequities	**Provides context for inequities:** Specifically citing/studying the structural factors underlying differences between excluded groups
	One-size-fits-all: Essentializing large groups of learners as "underrepresented," "minorities," etc. without accounting for variance within communities and solutions for different groups.
	Center dominant groups in definitions: Implicit definitions of "everyone" that center white, male, cis/heteronormative, ability-assumptive and other dominant perspectives.
	Gap gazing: Stating the presence and problem of underrepresentation (the "gap") without any justification, analysis or further discussion of underlying causes; such as in reporting statistics using the white population as a baseline.
Who Benefits	**Responsive/beneficial to learners:** Recognizing multiple pathways to success and designing activities and/or intended outcomes that provide a direct benefit for learners' well-being (personal, physical, social, financial, emotional, intellectual, etc.) that reflect excluded individuals' identities, values and priorities. Attention is given to emotional safety and belonging.
	Commodification: Assigning a market value to the labor and intellectual property of excluded groups; goal is to benefit dominant groups by strengthening the economy, enhancing national STEM competitiveness, etc.
Framing	**Asset:** Amplifying and valuing the unique strengths of people rooted in identity/culture.
	Deficit: Situating cause of problem of oppressive systems on the victims of the systems; use of ableist language/equating disability with deficit.
Cultural Responsiveness	**Community Agency:** Affirming community agency/addressing community-identified problems as an important component to STEM learning/action with consideration for sustainability of the program/relationship.
	Culture: Connecting culture, language, spirituality, identity, etc. to learning.
Positioning	**Authentic partnership with community:** Partnerships/leadership that center those most impacted by the research and/or experiences (consider project development, conceptualization, decision making, interpretation of results, dissemination, budget). Personal and/or professional expertise in equity present in leadership team.
	Community as consultant: Collaborations in which the community is positioned as consultants/advisers but not integrated into the leadership, budget, etc. of the project.
	Community as recipient: Community uninvolved in any stage of the design or activities proposed; activities are done for/to the community.

Results

From 2017 to 2022, nearly all randomly sampled AISL equity/broadening participation projects (n=60) provided context for inequities relevant to their work, described how the projects would be responsive and beneficial to learners, and incorporated culture and the voice of the focal communities (Figure 1). These findings reflect the fact that responsiveness to learners' interests and prioritization of their enjoyment and personal fulfillment are core to the field of informal STEM learning and AISL's longstanding funding priorities.

Proportion of AISL equity/broadening participation awards from 2017-2022 that include each of the specific equity concepts. Each awarded project is counted once for each concept regardless of the number of times a concept is addressed or in what level of detail. Concepts within categories are not mutually exclusive. Findings represent past awards throughout the time period, with results depicting the change over time below. Over time, concepts graphed in red that have been evidenced as counterproductive to equity have decreased in usage; n=60.

Digging deeper into some of the most common concepts, we can gain a clearer picture of the ways randomly sampled AISL equity/broadening participation awards (n=60) have evolved over time. Given that for the most common equity concepts, nearly all awards make some mention of them, we chose to specifically code for awards where equity concepts were central throughout the project to get a better understanding of the evolution over time. Projects where concepts were central were defined as: projects containing multiple references to equity concepts that do not intersect with counterproductive concepts and where deep discussion of equity concepts will be present and woven through all parts of the project, particularly in the actions that will be taken. Looking only at the proportion of equity/broadening participation projects where concepts were central to the project (as a percentage of the total sample of projects that either addressed concepts centrally, peripherally or did not address concepts at all), between 2018 and 2020, large increases occurred in the proportion of projects addressing common equity concepts—provide context for inequities, responsive/beneficial to learners, and culture (Figure 2). This change may reflect shifts across the nation in the wake of

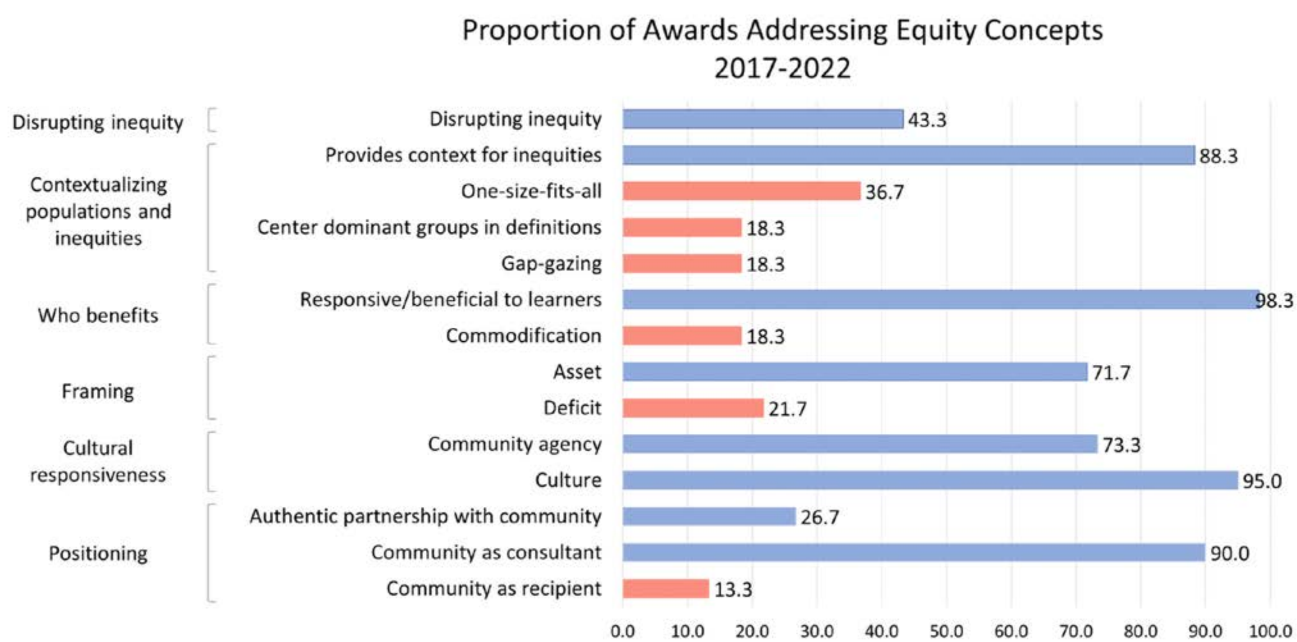

Figure 1: Proportion of Awards Addressing Equity Concepts 2017–2022

the national racial reckoning following the murder of George Floyd amid disparate impacts of the pandemic. Little change in either direction (e.g., additional increases or loss of gains) was seen from 2020 to 2022.

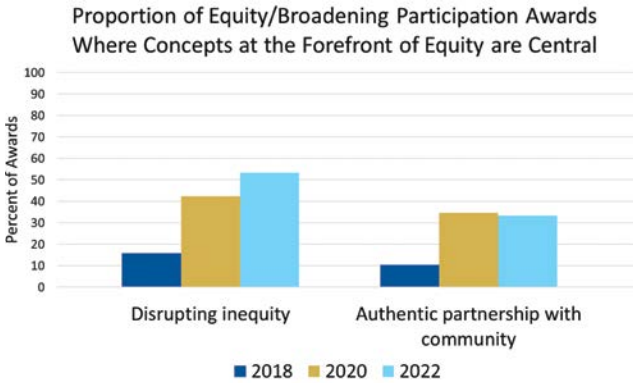

Figure 2: Proportion of equity/broadening participation awards where common equity concepts are central to the project over time. Each awarded project is counted once for each concept regardless of the number of times a concept is addressed; n=60

We also see large increases over time in the number of awards addressing less commonly addressed concepts likely to have a large impact, referred to as concepts "at the forefront" of equity in STEM—*disrupting inequity* and *authentic partnership with community* (Figure 3). While the concepts cited as "on the forefront" are not new to the researchers and practitioners who have been working toward achieving equity in education generally and in informal STEM experiences and environments from the beginning, this analysis confirms that they are not yet common enough to be considered mainstream and they are still important to acknowledge.

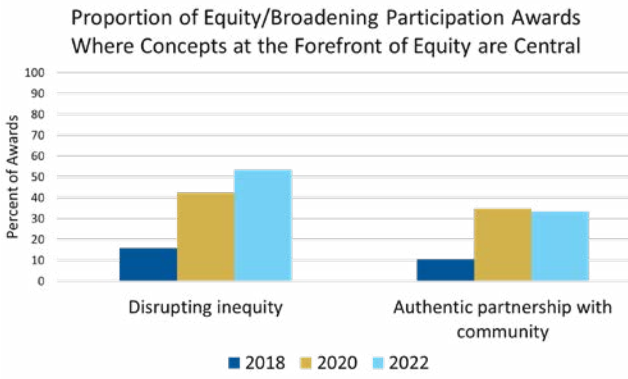

Figure 3 Proportion of equity/broadening participation awards where concepts at the forefront of equity are central to the project over time. Each awarded project is counted once for each concept regardless of the number of times a concept is addressed; n=60

Conclusions

Investigating the overall AISL portfolio from 2017-2022, we see that the majority of funded AISL projects contain equity and/or broadening participation goals. Analyzing a selection of equity/broadening participation awards between 2017-2022 for specific equity concepts, nearly all address how projects:

- Are responsive and beneficial to learners
- Incorporate culture
- Consult the focal communities in their design
- Across the entire time period, AISL awards have significant strengths relevant to advancing equity, but an evolution to increasingly center equity is apparent when analyzing approaches over time. The areas where AISL-funded projects are increasingly at the forefront of centering equity include:
  - Deep understanding of the broader structural barriers to equity specific to their project and organization
  - Elevating learners' assets
  - Prioritizing learners' wellbeing in ways inextricably linked to culture and intersections of identities
  - Moving away from one-size-fits-all approaches toward consideration of nuance and heterogeneity of lived experience and intersectionality

Looking at themes, we see that the above are achieved via authentic partnerships with focal communities, challenging norms, and applying lived and professional expertise in equity and social justice.

Following on the new AISL solicitation requiring proposals to address equity, belonging and broadening participation and funding of an equity resource center in 2022, there is potential for an increasing shift to push the boundaries and innovate in how AISL projects address equity.

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A TOOL KIT FOR DEVELOPING ONLINE SCIENCE POLICY & ADVOCACY CURRICULUM FOR STUDENTS

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Abstract: Scientists must play a significant role in the COVID-19 pandemic recovery process by educating policymakers and the public on the importance of evidence-based policy. To fill the identified gap in policy training in preparation for policy fellowships, during the peak pandemic years, we piloted an online **Science Policy & Advocacy for STEM Scientists Certificate Program**, with a focus on learning practical skills and concepts, and ways to transition into careers in these areas. As ARIS fellows (2022-2023), we developed a toolkit for universities to create training for graduate students that can fill in the gap prior to applying for science policy fellowships and help build a community of practice around science policy and broader impacts.

General Notes

As we prepare to recover from the COVID-19 pandemic, the discussions to prevent future pandemics are at the forefront. To ensure a sustainable recovery from the pandemic, it is imperative to develop effective and ethical policies. Scientists must play a significant role in the COVID-19 pandemic recovery process by educating policymakers and the public on the importance of evidence-based policy. This can be encouraged by providing STEM scientists (PhD students and postdocs) with a better understanding of science policy and advocacy through specialized training. Except for a few universities, no formal training mechanisms exist for providing knowledge and experience in science policy and advocacy for early career trainees.

To fill the identified gap in policy training in preparation for policy fellowships, during the peak pandemic years, The University of California, Irvine's Public Policy Prep (P3) program in conjunction with the *Journal of Science Policy & Governance* (JSPG) and UCI's Ridge to Reef program (later sponsored by Union of Concerned Scientists (UCS) and Stempeers) piloted an online **Science Policy & Advocacy for STEM Scientists Certificate Program** (for PhD students & postdocs), with a focus on learning practical skills and concepts, and ways to transition into careers in these areas.

As ARIS fellows (2022-2023), we have developed a toolkit for universities to create training for graduate students that can fill in the gap prior to applying for science policy fellowships and help build a community of practice around science policy and broader impacts. The toolkit is meant to be utilized by professionals involved in career and professional development training, such as university administrators and teaching faculty. Thus far, toolkit elements include an InterSECT Job Sim on science policy course and a padlet toolkit for program expansion using different modules. We also presented some of these findings in a poster at the National Postdoctoral Association conference in 2022 and other meetings and have received great interest in the program thus far.

We hope that these tools, along with the poster presentation and additional data, will help institutional training professionals to create a general syllabus for a full virtual course similarly to ours, or develop their own variations of the program to suit their needs and desired outcomes. In the future, we aim to publish the results from the pilot program, which includes evaluation data and additional outcomes to show its success thus far. Therefore, we did not include all the details in these proceedings.

Moreover, we plan to offer the course again later in 2023. The website is currently being updated, likely to be housed here: https://gps-stem.grad.uci.edu/sci-pol/.

Program development: The program was developed through an initial partnership between the GPS-STEM program at UCI and the *Journal of Science Policy and Governance*, which was enlisted to bring in the policy expertise for the program to be built. In subsequent years, additional partners were added who contributed expertise or helped fund the course in part. Given the program was started during the COVID-19 pandemic, we took advantage of the virtual space and enrolled a large number of students from across the world for two years in a row. The program did not have any restrictions in terms of geography or citizenship (which is often a barrier to science policy education and training), therefore anyone interested in science policy from across the world could enroll. To limit the number of students we were able to manage, we instituted an application process the second time around. The course included many speakers who generously donated their time to participate in various sessions, as well as an elevator pitch competition with prizes. To help with logistics, we had a number volunteer coordinators as well as reviewers who helped grade assignments and judges who helped grade the competition. The graduation rate was high for both years and students received certificates.

Program goals: The program goals were to foster the development of skills in science policy, including written and oral communication, as well as provide opportunities for networking with professionals and practical exercises in a number of areas. Each module had a pre-reading assignment beforehand, as well as several different types of homework after each session for which we solicited reviewer feedback, often in multiple rounds. In the original program offerings, we had 10 modules as follows:

1. Introduction to Science Policy and Advocacy
2. Course Orientation, Information, Q&A and Scientific Research Policy
3. Writing Module
4. STEM Education and Workforce Development
5. Effective Advocacy Strategies for Policymakers

6. AAAS STPF and State and Federal Policy Fellowships
7. Effective Strategies for Targeted Policy & Advocacy Engagement
8. Science Policy & Advocacy Engagement at the Local Level
9. Elevator Pitch Practice session for Pitch Competition
10. Elevator Pitch Competition Training Session

The final session was an elevator pitch competition with prizes, where all students could participate and see their classmates compete, and it was an open virtual event for anyone to join.

Program activities: The program had several activities during the various timepoints, including:

- Listening to SciPol SoundBites (JSPG) or GPS-STEM Radio on science policy careers
- Constructing an oral science policy elevator pitch
- Writing op-ed or policy memo on their policy topic of choice
- Designing an advocacy one pager document for policymakers
- Crafting a power mapping plan on their topic of interest
- Participating in the policy elevator pitch competition

Program deliverables: The program had several deliverables during the various timepoints, including:

- Podcast summary
- Elevator pitch video
- Policy writing piece
- One pager talking points document
- Informational interview with a policy professional
- Power mapping plan
- Public engagement plan
- Participation in policy pitch competition

Program outcomes: The program had several outcomes, including:

- Building expertise in giving a science policy pitch to policymakers
- Growing their network among peers and other science policy experts
- Performing informational interviews with science policy professionals
- Learning fundamentals of science policy and advocacy from various resources

Measures of success: The program had several measures of success, including:

- Surveys were performed at the start and end of the course to gauge satisfaction, quantified here
- We collected quotes from participants in terms of how much the program helped them
- For many trainees this program kickstarted their careers in policy, and several had a number of successes, some of which are in the poster and include:
  - Several became AAAS fellows (STPF or Mass media)
  - One student became a Mirzayan fellow
  - One student founded the UCI SPAN group
  - One student published his class paper in JSPG
  - One student became an associate editor with JSPG

References

InterSECT Job Sim on science policy course

Padlet toolkit

NPA poster

UCI SPAN group

Press release for certificate release

JSPG paper published: Toward a Sustainable Model of Scientific Publishing

Website: https://gps-stem.grad.uci.edu/sci-pol/

STEM OUTREACH LIAISONS: CONNECTING THE DOTS FOR RESEARCHERS' BROADER IMPACTS

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Abstract: Research grant writing is highly competitive and involves several challenges regarding Broader Impacts (BI). Creating connections and cultivating engaged relationships with BI stakeholders to deeply understand their unique needs is a critical and time-consuming challenge for researchers. STEM Outreach Liaisons are uniquely suited to take this responsibility off researchers so that they may focus on the academic merit of their proposals. A STEM outreach Liaison serves an important role as a disseminator of information to a broad range of stakeholders as well as the creator of opportunities for collaboration with stakeholders. Through using a variety of tools within the roles of disseminating information and creating opportunities of collaboration, a STEM Outreach Liaison can give a competitive edge to research institutions in a highly competitive grant proposal environment.

The Competitive Nature and Challenges of Addressing Broader Impacts in Research Grants

Research grant writing is highly competitive. Only about 25% of all competitive National Science Foundation (NSF) proposals receive awards (Figure 1). Only the most comprehensive grant proposals can receive awards. Novelty, innovation, clarity, external collaboration, methodology, impact, and a proven track record in obtaining and effectively implementing prior grants are important factors in grant award success. Building grant writing infrastructure that includes strong Broader Impact (BI) considerations can be an impactful pursuit.

The NSF asks two questions during the merit review of proposals: 1) What is the intellectual merit of the proposed activity, and 2) What are the broader impacts of the proposed activity? Most researchers understand the concept of Intellectual Merit in the review of a grant proposal as their career's work has been focused on their area of intellectual expertise. Understandably, BI has not been given the same attention in a researcher's career as their intellectual pursuits. To many researchers, BIs can seem fuzzy, vague, and confusing. In a profession that is centered on the precision of work and precision of measures of success, BIs can pose an inherent dissonance for researchers. Broader Impacts criterion (Figure 2) speaks directly to the importance of benefiting society through NSF-funded research projects (America Competes Reauthorization Act of 2010, 2010). Those are worthy pursuits but challenging to impact and assess.

Number of NSF Competitive Proposals, New Awards, and Funding Rates

Fiscal Year	Competitive Proposals	Awards	Funding Rate (percent)
FY 2017	49,425	11,456	23%
FY 2018	48,336	11,717	24%
FY 2019	41,033	11,252	27%
FY 2020	42,726	12,171	28%
FY 2021	43,617	11,349	26%

Figure 1: Yearly average funding rate of NSF proposals

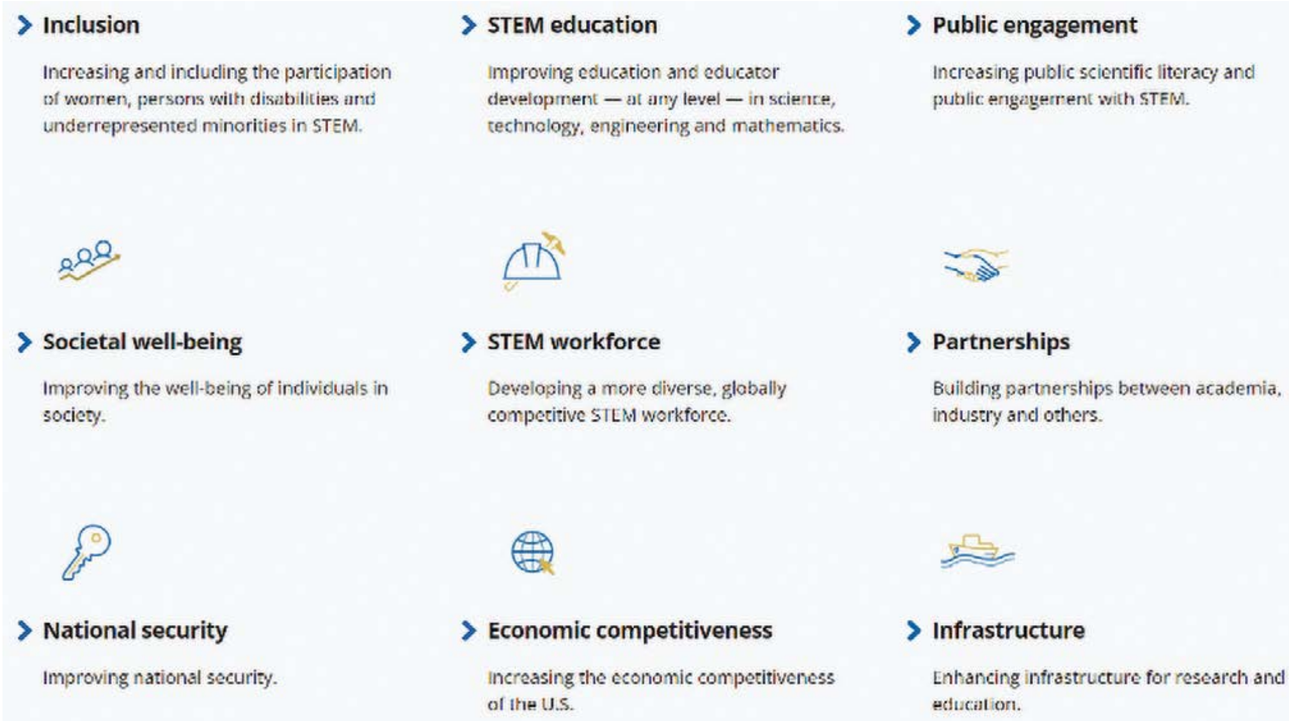

Figure 2: Categories of Broader Impacts goals as described by NSF

In their Guiding Principles for NSF Proposals, Advancing Research Impact in Society (ARIS) adds one additional criterion to strive for: 'Use of science and technology to inform public policy' (ARIS 2020). The ARIS resource also poses the following questions that may be beyond the normal expertise and experience of a researcher.

ARIS Guiding Questions

- How will the participants be recruited?
- What other partners or collaborators are you bringing to this activity?
- Are the participants being targeted clearly described and is the rationale for engaging them clearly justified?
- Is there a mechanism described for reaching audiences?
- Has the proposer described existing relationships or new partnerships, which will help them reach their audience?

These summarize the major challenges that researchers face regarding BI. With limited time and expertise in BI, researchers often struggle connecting with stakeholders. How can they cultivate and sustain meaningful and engaging stakeholder connections in a way to be able to draw on these established, trusting relationships into the future? How can researchers intimately understand the needs and barriers of their BI stakeholders and reliably impact them? How can they communicate their research to stakeholders and policymakers in a simplified way and share the fruits of their BI with diverse communities at large? These are all important, yet time-consuming aspects that researchers will need to continually address in the competitive grant proposal arena. Successful grant writing involves a delicate balance of addressing the intellectual merit of a proposal and the BI. If these tasks could be supported by someone who has connections inside stakeholder groups, understands them well, and can connect the dots for BI criterion, then the researcher can focus more on their own intellectual merit expertise, thus increasing the odds of receiving a grant proposal award.

STEM Outreach Liaisons as Broader Impact Experts

Nearly ten years ago, the Penn State College of Education's Center for Science and the Schools (CSATS) created the position of STEM Outreach Liaison (SOL) as part of a plan to create greater BI infrastructure at Penn State. Three people have held that position so this paper will speak of their combined work in the collective, as their BI infrastructure-building work has spanned several years. The two main areas of focus for the CSATS' SOL are the dissemination of information and the creation of opportunities.

Dissemination of Information

Dissemination of information is critical to BI infrastructure and success. It facilitates transparency, consistency, collaboration, trust-building, and stakeholder engagement. CSATS' SOL leads this effort by utilizing many modes of communication with intentionality when interacting with stakeholders through social media, websites, newsletters, and listservs all tied together with the threaded lens of storytelling. In addition, data can be used to disseminate information that tells stories of needs, failures, and successes. Therefore, database utilization is also a critical component of a SOL's role in disseminating information.

Social Media

CSATS' SOL builds and utilizes social media infrastructure in ways that would be beyond the capacity of a researcher. Social media is a valuable tool in disseminating information due to its broad reach, real-time updates of information, targeted communication, brand building, influencer trust, two-way engagement, and data analytics. CSATS utilizes a social media management platform called Social Pilot to enhance the attributes of social media. Like many social media management platforms, it allows for posting from several different social media accounts as well as provides the ability to repeat posts for deliberate redundancy of messaging, and it

Figures 3 and 4: Examples of a CSATS post (top) and a vetted article (bottom)

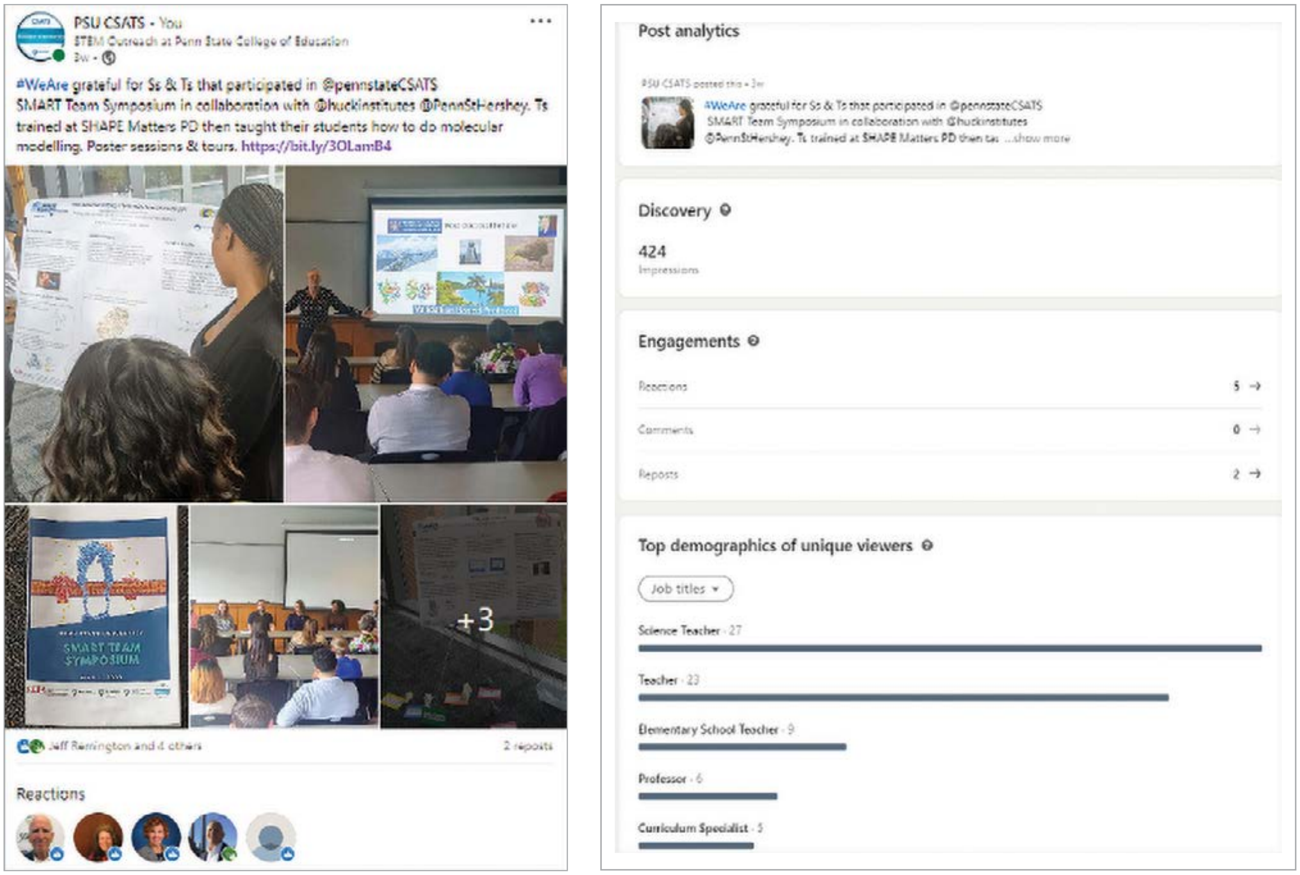

Figure 5: A Twitter post about SHAPE Matters (left) and a view of the post-analytics report (right)

can schedule posts out for weeks in advance. Posting on multiple social media accounts simultaneously casts a wide net for CSATS' current and potential stakeholders from a variety of demographics and allows for targeted posts to specific groups. For example, CSATS' BI teacher professional development offering entitled "SHAPE Matters" was geared toward high school biology teachers. By leveraging post to targeted social media groups such as the National Association of Biology Teachers (NABT), CSATS was able to fill all the required slots for the SHAPE Matters program noted in Figure 3. In that same post, a two-way engagement between CSATS' SOL and stakeholders is also evident. Social media can be a venue for providing daily posts on current topics related to STEM BI. In leveraging this function, the SOL builds CSATS' brand with stakeholders as that of a trusted source of reliable, vetted information (Figure 4). The vetting process is a result of the SOL setting topical Google Alerts as well as subscribing to topical newsletters. Daily, the SOL digests the information from these sources and leverages social media to disseminate news that is relevant to CSATS stakeholders. CSATS's SOL also weaves storytelling in posts where appropriate. The post in Figure 5 tells a story of students who created poster session event from CSATS' SHAPE Matters program. The data analytics of posts can also be analyzed by an SOL to influence the effectiveness of stakeholder engagement. Lastly, the SOL continually works to build the followership of CSATS social media accounts by seeking online connections and showing followers the value of following CSATS through relevant daily news, opportunities, and success stories related to CSATS work.

Websites

CSATS' SOL maintains and updates the content of websites as a stakeholder landing point of our programs, opportunities, and information. CSATS utilizes two websites that facilitate stakeholder engagement. Our main CSATS website (Figure 6) serves stakeholders from Pennsylvania and beyond. This website gives stakeholders access to all our current programs. Our social media posts and newsletters drive traffic to our website and the CSATS programs contained within it. The SOL's responsibilities on this website include assisting with the creation of and maintenance of specific CSATS program offerings as well as back-end data collection and data analysis of who is registering for our programs. This information is crucial to grant evaluations.

Figure 6: CSATS website landing page

CSATS' second website is associated with a collective impact collaborative known as the ENGINE STEM Ecosystem. The ENGINE website (Figure 7) serves stakeholders within 100 miles of CSATS and primarily targets K12 and local industry. The SOLs responsibilities on this website include collaborating with other ENGINE STEM Ecosystem leaders to create a digital information and opportunity resource for our local area. ENGINE's stakeholders are BI stakeholders as well. These websites provide essential infrastructure for CSATS and are the core foundation of our programming communication and registration.

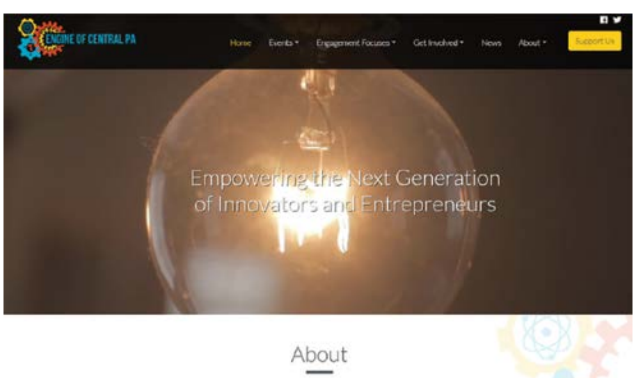

Figure 7: ENGINE website landing page

Newsletters and Listservs

CSATS' SOL constructs and distributes three monthly newsletters through a commercial email marketing platform, Constant Contact. The three monthly newsletters can be seen in Figure 8.

These newsletters follow similar themes to CSATS social media usage such as brand trust building, storytelling, information, and opportunity sharing as well as deliberate redundancy. The variation from CSATS' social media is in the specific audience they are intended for, the depth at which newsletter items can be covered in this format, and in the audience reach specific to email users. Our CSATS newsletter targets general CSATS stakeholders statewide and beyond and has a reach of about 3,000 subscribers. Our ENGINE of Central PA newsletter has about 500 subscribers and primarily targets K-12 teachers who are geographically within 100 miles of CSATS. Our PAEMST newsletter targets Pennsylvania's recognized elite STEM teaching community and has about 100 subscribers. Each of these newsletters can cover topics in greater depth without the character restrictions that social media posts impose. Since not everyone has a social media account but nearly everyone has an email account, these newsletters can fill a gap and increase CSATS' BI reach. Related to newsletters are internal listservs. CSATS' SOL utilizes these internal listservs to provide mass communication updates to researchers and other outreach related staff within CSATS' Penn State working community. Creating and distributing these more in-depth communication platforms are important yet time consuming work that goes above and beyond what a researcher has the capacity to do thus adding value to an institution's BI competitiveness in acquiring and maintaining stakeholder engagement.

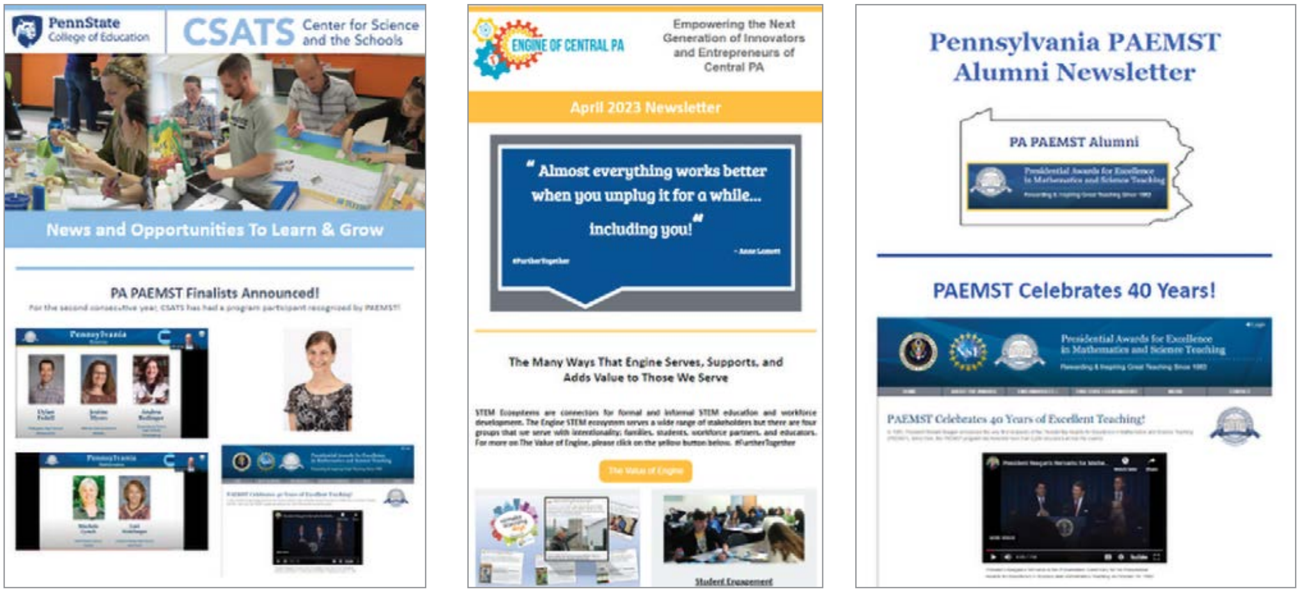

Figure 8: Three monthly newsletters created by CSATS' SOL

Databases

At times, information is disseminated about stories of needs and stories of successes. CSATS' SOL plays an important role in this endeavor. CSATS's SOL utilizes Excel spreadsheets, internal as well as external databases to seek out stakeholder communities of need, tell their story, and seek BI connections to assist with their needs. CSATS' main BI recipients are typically in the k-12 education space. The Great Schools website can be a helpful tool in discovering basic school demographics to uncover communities that could benefit from BI support. Great Schools utilizes available state data along with parent input to rate schools in areas such as Summary Ratings, Student Growth, Academic Progress, College Readiness, Equity, and Test Scores. Great Schools rates both public and private schools. The Penn State College of Education has a similar, but more comprehensive tool called NavigatED (Smith 2022) (Figure 9). NavigatED has a broad range of advanced search capabilities that can help STEM Outreach Liaisons find school communities of need. Categories such as race, income, location, and student aid are just some of the parameters that can be searched for using NavigatED. It is through utilizing these tools that BI success stories can be told. One such story is of Bald Eagle Area School District (BEASD), located in an extremely rural part of North Central Pennsylvania. CSATS identified BEASD rural school with 40% of the population is economically disadvantaged. Rural schools often lack resources and opportunities for students to explore divers career paths. Through the help of CSATS' SOL, a BI program was created to address this need through teacher training and classroom infrastructure that allowed BEASD students to reimagine their career paths and to creatively explore global sustainability challenges that they would not have been able to do without a BI intervention. The BEASD success story that resulted from a needs identification be found in the 2022, STEM For All Video Showcase (Figure 10).

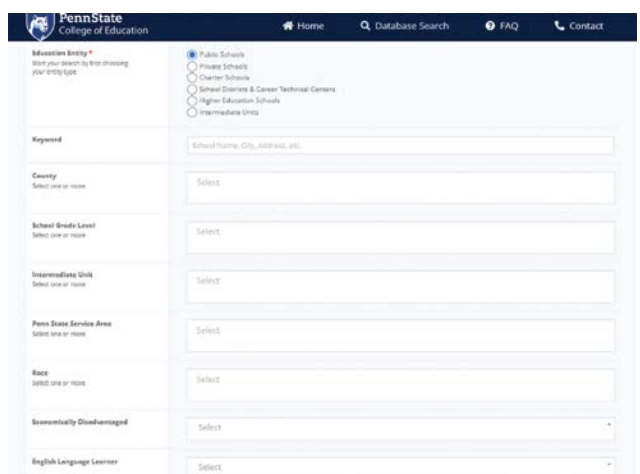

Figure 9: NavigatED database tool

Figure 10: STEM for All Video Showcase-An example of how the SOL can support dissemination of a successful project

Creation of Opportunities Through Building Relationships

Creating opportunities for CSATS contributes to growth, innovation, competitiveness, strategic partnerships, reputation enhancement, sustainability, and stakeholder satisfaction. CSATS' SOL creates opportunities through relationship building within the STEM education community, the business and industry community, the policy community, and the research and outreach communities. It is through relationship building that opportunities can be discovered, and key elements of grant infrastructure can be carried out such as letters of support for grant proposals and robust stakeholder participation in grant related programing. Relationship building involves demonstrating value to stakeholders and takes place through face to face and virtual connection opportunities. Face-to-face relationship building involves CSATS' SOL traveling to schools, workforce development centers, policy meetings, and STEM related events across Pennsylvania to listen to stakeholders needs and to share the value that CSATS can offer through BI programming. Although not as powerful as face-to-face connections, virtual connections are also part of the connection approach of CSATS' SOL. Key to any of those relation building activities is the capacity for a SOL to demonstrate genuine human relationship skills. CSATS's SOLs have been carefully vetted in their hiring process to make sure they are empathetic people connectors.

Contributing to STEM and Education Communities

CSATS' SOL has 35 years of classroom education experience and 25 years of higher education teacher training experience that affords great insight into the needs of education, students, and educators. CSATS' SOL leverages that experience by serving as a contributing member to many organizations that are connected to STEM and education. These organizations create opportunities for BI through each organization's unique stakeholders. Among the organizations CSATS' SOL contributes time and talent to are the ENGINE STEM Ecosystem, The Pennsylvania Statewide STEM Ecosystems (PSSE) (Figure 11), The National Science Teaching Association, The Presidential Award for Excellence in Mathematics and Science Teaching Alumni Association, The Varkey Foundation, and the Lebanon County Education Honor Society. The most impactful of these are the STEM Ecosystems. STEM Ecosystems are an emerging and powerful tool for BI work. STEM Ecosystems officially came into existence in 2015. Formally, a "STEM Learning Ecosystems is a Global Community of Practice with extensive sharing of resources and expertise among leaders from education, business and industry, non-profits, philanthropy, and others" (STEM Ecosystems 2022). STEM Ecosystems have been influenced by Stanford's Collective Impact Model. "Collective impact initiatives involve a centralized infrastructure, a dedicated staff, and a structured process that leads to a common agenda, shared measurement, continuous communication, and mutually reinforcing activities among all participants" (Kramer & Kania 2021). STEM Ecosystems do just that. As a collective of over 100 entities, STEM Ecosystems (Figure 12) exert influence on federal STEM policy and have helped to shape such initiatives as Charting a Course for Success: America's Strategy for STEM Education and The CHIPS and Science Act. CSATS' SOL serves on the executive leadership teams of both the ENGINE STEM Ecosystem and the Pennsylvania Statewide STEM Ecosystem.

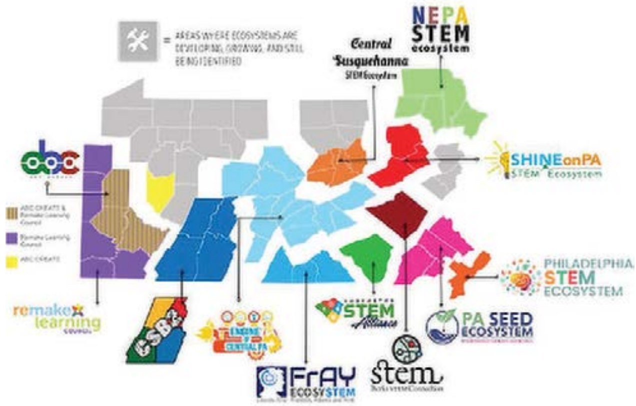

Figure 11: PSSE state ecosystems map

Figure 12: A map of 100 STEM Ecosystems in the US

Business and Industry Community Connections

CSATS' SOL creates opportunities for BI by developing relationships with industry connections. NSF solicitations increasingly call for collaborations between business, industry, academia, K12, and workforce development. Having strong connections with business and industry strengthens CSATS' ability to bring in grants for Penn State University CSATS' SOL attends local chambers of commerce meetings, meets with Chambers leadership as well as with statewide business and industry organizations such as the Pennsylvania Chamber of Commerce and TEAM PA. In addition, CSATS's SOL facilitates regional STEM workforce development connector events to bring cross sector stakeholders together, including business and industry. (Figure 13)

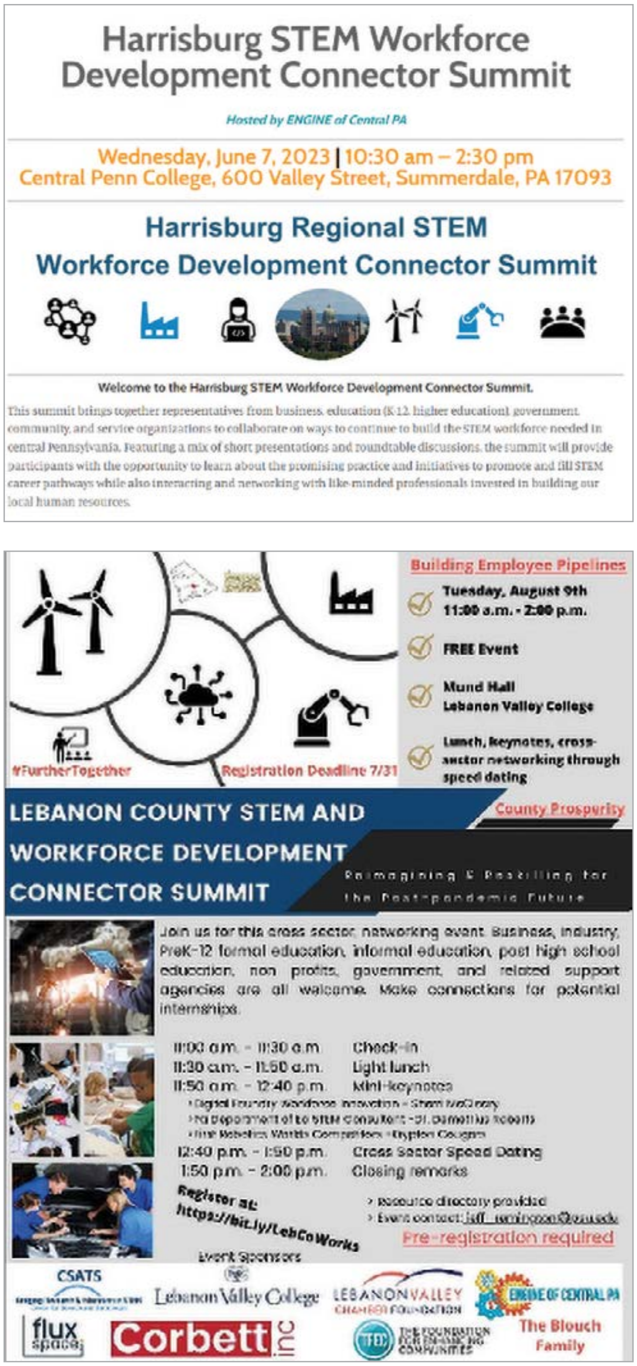

Figure 13: Examples of STEM workforce development connector events

Education and Workforce Policy Community Connections

CSATS' SOL was one of ten STEM teachers selected to be trained in Washington DC as a National STEM Teacher Ambassador. This program was part of an NSF grant to train practicing teachers in STEM education and workforce policy and advocacy. Organizations such as The STEM Education Coalition, The National Science Teaching Association, The National Council for Teachers of Mathematics, and The National Academies, contributed to this training. CSATS' SOL has leveraged that experience to develop relationships with policymakers at federal, state, and local levels and has enabled the SOL to be part of state government advisory boards for state departments of education, labor, and industry. These connections allow CSATS to be connected to the latest developments and opportunities of major state initiatives.

Research and Outreach Community Connections

CSATS' SOL connects with a variety of research and outreach communities within Penn State University by facilitation of connection events or by participating in connection events. A connection event that CSATS's SOL facilitates is a monthly outreach luncheon. This monthly outreach luncheon connects several outreach entities on campus as well as administrative leadership. At these luncheons, participants share communities of practice within BI as well as sharing opportunities for BI collaboration. CSATS' SOL participates in Penn State research connected subgroups such as ENTI (Entrepreneurship and Innovation), AIMI (Center for Applies Artificial Intelligence) and MASH (Mid Atlantic Semiconductor Hub). These subgroups share BI opportunities specific to the academic and research focus of those groups.

Conclusions

Grant proposal writing at research institutions continues to evolve in response to government initiatives as national priorities evolve. Intellectual merit and broader impacts will remain key components of the process of obtaining grants for the foreseeable future. But high-quality BI often requires relationships and activities that are outside the strengths of an academic researcher. It is prudent for research institutions to continually build BI infrastructure and to consider STEM Outreach Liaisons as a key component of that infrastructure. That infrastructure can help increase the chances of obtaining grant funding in an increasingly competitive grant funding atmosphere. More importantly, it will increase the likelihood that the research project has a real, tangible, and meaningful impact on our society. CSATS' STEM Outreach Liaisons have served Penn State researchers well by connecting the dots of BI and allowing researchers to not only make strides at making the world better through their research, but also benefit society through their relationships with community stakeholders and BI professionals.

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MICRO-CREDENTIALS AND CERTIFICATION PILOT PROGRAM FOR BROADER IMPACT PROFESSIONAL COMPETENCIES

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Abstract: As the Broader Impact/ (BI) profession has evolved through NABI and now ARIS, there is a growing need for recognition and professionalization of the field. To address this need, ARIS undertook a systematic process through two complementary studies to identify and codify the competencies to tackle BI work. The findings from these studies informed professional development opportunities and a certification pilot program. In this session, participants will learn about the ARIS micro-credentialing and certification program and the studies that informed it. A Delphi study involving a team of researchers reviewed and consolidated relevant competency frameworks into 65 competencies, involving 11 domains. Analysis of a community-wide survey and an expert panel review confirmed those competencies and reduced redundancies, resulting in 37 competencies grouped into 7 domains. These competencies were mapped to a model for certification. Participants will have an opportunity to review and discuss the competencies and the certification model.

Over the last several years the Advancing Research Impacts in Society (ARIS) center and other organizations have undertaken community discussions and studies aimed at defining the roles, competencies, and capacities for those working in the Broader Impact (BI) field (McNall et al, 2023; MacGregor & Phipps, 2020). Community discussions have encompassed a range of topics related to professionalizing the field including job descriptions, career advancement, position placement within university structures, and skills to support researchers in BI work. Developing and validating an empirically derived list of competencies was viewed as an important next step in informing further professional development tools, training offerings, and practices. Through ARIS, teams of researchers conducted two complementary studies aimed at identifying competencies related to excellent practice.

Identifying competencies provides a basis for further strategies of professionalizing a growing field. Accreditation, certification, credentialing and licensure are formal approaches that other fields have used to officially recognize the competencies of a profession. Where a professional field has universal standards for educational outcomes and curriculum and an established organization to act as an accrediting body program or institution, accreditation offers a recognized form of professionalization. Geoscience is one field where post baccalaureate licensure is established, but accreditation with an agreed upon standard curriculum has been a point of debate (Arthur et al., 2007; Bralower et al., 2008; Moses, 2014). The field of evaluation has also grappled with identifying competencies as a foundation for professionalizing its field. In examining the possibility of accreditation for evaluation, scholars looked to business management, accounting, and human resource development as fields where accreditation acted as one means to this end (McDavid & Huse, 2015). The two studies outlined in this paper identify competencies for Broader Impact (BI) professionals as a basis for a credentialing and certification process. Such a process could provide resources (e.g., curricular offering) and accompanying assessments (quiz, exam, or portfolio) that document an individual has the requisite knowledge, skills, or practical experience to meet qualifying criteria.

The two complementary and successive ARIS studies identify a set of BI competencies on which a credentialing and certification process could be established. First, researchers sought the expert community's view through a two-stage Delphi study. This method allowed a systematic approach to developing competencies, underpinned by scholarly literature and confirmed by 11 research impacts experts. The resulting 65 competencies fell into 11 domains. This study was followed by a community-wide survey where 276 individuals who identify a professional role in broader impacts rated the importance of each of the competencies and their perceived self-efficacy. A factor analysis study of survey responses from 247 of those participants, followed by an expert panel review, identified a more parsimonious set of 37 competencies that fell into seven factors, or areas of competency. These competencies underpin a certification program and self-assessment set of tools under development by ARIS.

This paper briefly summarizes the two studies, the resulting competencies identified, and describes the framework for the credentialing and certification program that is under development by a team at ARIS.

The Delphi Method

An initial set of 65 competencies for broader impacts professionals were identified by McNall and colleagues (McNall et at, 2023) using the Delphi method. The Delphi method is a frequently used technique for achieving consensus among a sample of experts (Dalkey, 1969, Hsu & Sandford, 2007; Rowe, Wright & Bolger, 1991; Yousuf, 2007). Five features are common to most Delphi studies: (1) a panel of experts, (2) multiple rounds of questionnaires, (3) anonymity of responses, (4) iterative feedback of prior responses to participants, and (5) reporting measures of the central tendency and dispersion of group responses to participants (Crisp et al., 1997; Toma & Picioreanu, 2016). One perceived advantage of Delphi studies over face-to-face group deliberation is that anonymity of responses is believed to diminish the influence of dominant individuals and group pressure to conform on participants' expressed opinions (Belton et al, 2019; Hsu & Sandford, 2007).

Although many Delphi studies begin with open-ended questions, some begin with an initial set of items identified through literature that respondents are asked to rate. In our study we used the latter approach. We developed the initial set of items through a literature review of published community engagement competencies, defined broadly to include service-learning, community engagement professionals, Extension professionals, knowledge mobilization, community-engaged researchers, and community-engaged faculty. In addition, we drew upon competencies developed by various community engagement organizations including those promoted by Campus Compact and preliminary work by ARIS. In the literature review's early stages, we identified 436 competencies and reduced the list to 83 by removing overlapping and repetitive items. Finally, the list of 83 was re-organized into 11 competency areas, which formed the basis of the Delphi study.

In the Delphi study conducted by McNall and colleagues (2023), the research team identified 36 individuals with expertise in broader impacts and/or community-engaged scholarship. Of these, 22 who represented a cross section of different types of higher education institutions (land-grant, urban-servings, minority-serving, private, public, four-year and two-year) were invited to participate in the study.

In the round-one questionnaire, participants were asked to rate the importance of 83 proposed competencies for broader impacts; comment on the clarity, wording or other aspects of each competency; and suggest any additional competencies relevant to a particular area of competence (e.g., institutional leadership). Of the 22 individuals invited to participate in the study, 11 (50%) responded to the first-round questionnaire.

Preparation for the round-two questionnaire involved (1) calculating measures of central tendency and dispersion (medians and interquartile ranges) to share with respondents in round two, (2) identifying whether consensus was achieved for each competency, (3) reviewing comments on the wording and clarity of competencies, and (4) reviewing suggestions for additional competencies. Positive consensus for a competency was defined as ≥ 75% of experts rating a competency very or extremely important, with an interquartile range (IQR) of less than 2.5 (Giannarou & Zervas, 2014). Forty of 83 competencies (48%) met this threshold in round one. Negative consensus was defined as < 51% of experts agreeing that a particular competency was very or extremely important, with an IQR less than or equal to 1.0. Only one competency met the criterion for a negative consensus.

Ratings and comments associated with each competency were reviewed to determine whether the item should be retained as a final competency, revised, or deleted. (For more details on the decision logic for retention, revision, or deletion see McNall et al.,2023) At the conclusion of round one, 29 competencies were accepted as final without revision and six were accepted as final with minor revisions. Two competencies were deleted because participants suggested they were redundant or unnecessary and one competency was deleted because it achieved a negative consensus. The round-two questionnaire consisted of 48 competencies: 22 revised, 23 without revisions, and three new based on participant suggestions. Nine of 11 round-one participants completed the round-two questionnaire. For revised or new competencies, participants were asked to rate how important it was for a BI professional to be able to perform each competency and comment on the clarity, wording or any other aspect of each competency. For competencies that were not revised, participants received the following information from round one to inform their second-round ratings: comments on each competency, group median ratings, and the participants' own ratings.

In round two, 30 of the 48 competencies (62.5%) met the threshold for consensus and were incorporated into the final set of competencies. Another 18 competencies did not meet the threshold for consensus and were dropped. Ratings and comments from rounds one and two suggested that a third-round questionnaire would not yield consensus on any additional competencies and that no additional revisions to competencies were necessary. The combined total of final competencies from rounds one and two was 65 (Figure 1).

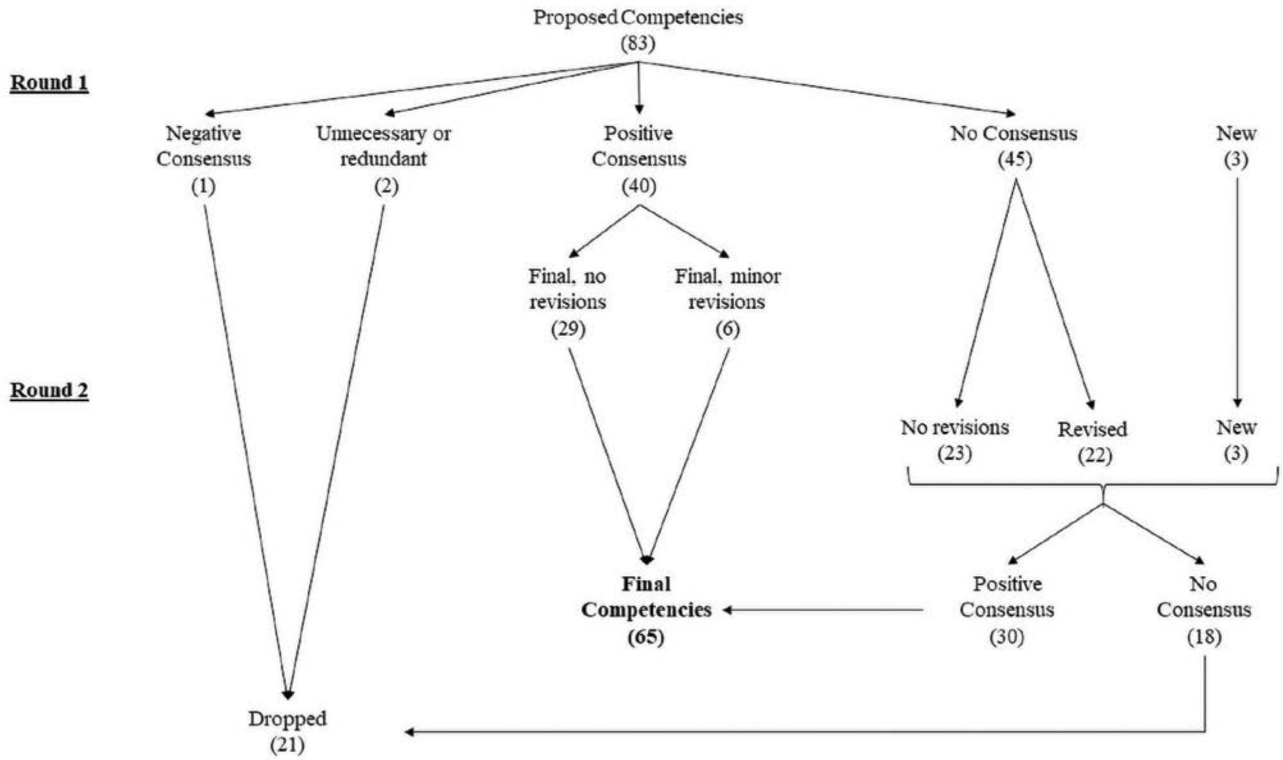

Figure 1: Delphi decision logic

BI competencies survey

In order to gather community insight and empirically test the 11-domain structure developed through the Delphi study, members of the ARIS community were invited to participate in the BI Competencies Survey. Participants rated each of the 65 proposed competencies on two scales: a) Importance (the perceived importance of the competency for BI professionals rated on a 1-5 scale where 1=Not at all important and 5=Critically important) and b) Self-Rating (their assessment of their own skill level, rated on a 1-5 where 1=Novice/no knowledge and 5=Expert), generating a total of up to 130 ratings.

Respondents

A total of 1,455 BI professionals, drawn from contact lists provided by ARIS, were invited to participate in the survey. They included, for example, people who have registered for ARIS events, opted into the ARIS on-line community, and ARIS Newsletter subscribers. Of those invited, 19% engaged with the survey. Respondents reported a range of levels of history of engagement in ARIS: 41% have opted into the community and are part of the regular communications, but may not have attended a recent event, 46% are ARIS community members who have either attended a webinar or Summit, and 14% are members who have attended multiple ARIS events. After 29 partial responses were removed due to insufficient response to the competencies rating items, data from 247 individuals were included in the ensuing analyses.

Summary of Results

Participants in the ARIS community appear to concur that the competencies identified through the Delphi study are, indeed, important for BI professionals and many have worked to hone those skills. The mean Importance ratings for all but 4 items were above 3.5 on the 5-point scale, while all but 3 Self-Rating items had means above 3.0. There is also a very high correlation between Importance scores and Self-Ratings for most items. As illustrated in Figure 2, areas where a larger gap exists between Importance and Self-Ratings on the final set of 37 competencies may indicate priority topics for future professional development opportunities.

Figure 2: Mean Importance and Self Ratings Across the 37 Competency Items

Data reduction: Moving toward a self-assessment tool

Although the conceptual validity of the 65 competencies and their importance to the field was affirmed by the results of the competencies survey and analyses, there were concerns among ARIS leadership and trainers that a tool with 65 items would be of limited use as a competency self-assessment tool, which is a key component of a training and credentialing process for BI professionals. The next logical step, therefore, was to use a data reduction method to identify a more parsimonious set of competencies suitable for assessment and training.

Exploratory Factor Analysis

The analysis plan called for exploratory factor analysis of the Importance items to examine the underlying structure of the data. If a strong factor structure was identified, analysis of respondent Self-Ratings would follow to examine whether those factors could effectively guide self-assessment of BI competencies. Because the data did not fall on a normal curve and are highly correlated, Principal Axis Factoring (PAF) with Promax rotation was selected. Although a 9-factor solution emerged, no items loaded on 2 of those factors more heavily than on other factors, so those 2 were discarded. The remaining 7 factors were retained for the ensuing steps of the process.

Conceptual labeling and item reduction

Next, a six member expert panel (composed of the researchers who implemented the previously discussed Delphi study and members of the ARIS Leadership Team) and members of the competency survey research team reviewed the seven factor solution to identify what each factor seemed to be measuring conceptually. The panel also identified items that they believe are essential to assess core competencies in BI, items they felt were unnecessary, and any items that appeared to be redundant. Items that were identified by all or most panel members as essential were retained, those identified as unnecessary by consensus or near consensus were removed. Among those that were identified as redundant, items identified as essential by the largest number of panel members were retained and those with less support were removed.

As a result of these two steps, the 65 original items were reduced to 37 items falling on 7 factors. Once the redundant and unnecessary items were removed, one factor was left with only one item, "Understand the variety of different types of BI activities (e.g., K-12 outreach, science communication, citizen science, etc.)." It was retained because, in addition to its mathematical fit with the model, it makes conceptual sense to include familiarity with BI broadly across settings and activities as an element of self-assessment and BI credentialing.

Confirmatory process

Finally, in order to assess whether the underlying data structure was impacted by the removal of the 28 "unnecessary" or "redundant" items, PAF was conducting using the remaining 37 items and requesting 9 factors. That test generated results that were virtually identical to the original PAF (as in the original PAF, nine factors emerged, but 2 had no items loaded more heavily on them than on other factors), validating the proposed model. Furthermore, with only 4 exceptions, all items loaded on a factor with the same items retained in this test as in the initial PAF. The seven factors that emerged from this process were labeled (adapted from the expert panel process):

1. BI Project Development, Administration, and Evaluation (PDAE)
2. Leading/Implementing Professional Development for BI (LIPD)
3. Understanding the history and barriers in campus-community engagement and building equitable relationships to promote JEDI (UHB)
4. Creating BI plans for proposals (CBIP)
5. Cultivating and Sustaining Partnerships for BI (CSPB)
6. Institutional Leadership for BI (ILB)
7. Broad Understanding of BI activities (BUB)

Cross-validating and Testing the Usefulness Of the Factor Structure

In order to test the ability of the model that emerged to serve as a meaningful and useful tool for self-assessment, researchers next turned to the Self-Rating items from the BI Competencies survey. The self-ratings of competencies that were statistically assigned to each factor in the preceding analysis were grouped together to form scales. Scale scores, defined as the mean self-rating on items assigned to each scale, were calculated for each participant. Those scale scores were then used to explore whether the scales held up in further analyses.

One important test of the model was whether the scale scores of BI professionals consistently correlate with their level of experience in the field. In short, we would expect more experienced BI professionals to score higher on an accurate measure of core competencies than those who are newer to the field and have had little opportunity to fully develop those skills. As presented in Table 1, this is the case for our model. Each scale is correlated with years in the BI field at a statistically significant level. As a final step, Analysis of Variance (ANOVA) was conducted to determine how effectively the 7 scales distinguish participants across years of experience. As illustrated in Table 2, the results were statistically significant indicating that the scales do,

Table 1

Correlations between Years in Field and Proposed Scales

	PDAE	LIPD	UHB	CBIP	CSPB	ILB	BUB
Years Working in BI	.526**	.437**	.379**	.474**	.403**	.340**	.385**

**. Correlation is significant at the 0.01 level (2-tailed).

indeed, effectively distinguish more experienced BI professionals from those who are newer to the field

Table 2

BI Competency Scales and Years of Experience in the Field

Scale	F	df	Sig.
BI Project Development, Administration, and Evaluation (PDAE)	27.01	(3,211)	0.00
Leading/Implementing Professional Development for BI (LIPD)	17.06	(3,211)	0.00
Understanding the history and barriers in campus-community engagement and building equitable relationships to promote JEDI (UHB)	13.05	(3,213)	0.00
Creating BI plans for proposals (CBIP)	23.71	(3,211)	0.00
Cultivating and Sustaining Partnerships for BI (CSPB)	14.24	(3,211)	0.00
Institutional Leadership for BI (ILB)	10.24	(3,213)	0.00
Broad Understanding of BI activities (BUB)	13.68	(3,210)	0.00

Implications of studies for a credentialing and certification process

The ARIS team intends to use the competencies identified through these two studies as the foundation for the development of a microcredentialing and certification program, designed to help professionalize the BI professional workforce. We define microcredentials as short, competencies-based recognition that allows a learner to demonstrate mastery in a particular area (National Education Association (NEA), 2020). Microcredentials are smaller in scale and scope than certification or licensure and represent specific knowledge and/or skills acquired and demonstrated. Once a learner demonstrates their competency, a badge is issued. Badges are a transferrable symbol used to verify the attainment of specific competencies and can be added to resumes and LinkedIn profiles or other social media platforms as recognition of an individual's skill set. Microcredentials can be "stacked" in various ways – like interlocking blocks – to build toward competencies needed for learners to attain their specific certification and/or employment goals and can be combined and issued as a certificate.

The competencies described in this paper, have been used by ARIS to design programmatic resources and assessments that are aligned to requisite knowledge, skills, attitudes required to support BI work. ARIS hopes to use this credentialing program to support and normalize the skills building needed by the BI professional workforce and members of ARIS. ARIS objective is to use the microcredentialing program to build a growth identity among BI professionals (IBSTPI, 2021; Altschuld & Engle,2015) that is:

- Personalized: allow individuals to create their pathway based on interests and career goals and address gaps in skills
- Flexible: addresses increasing need for flexible learning mechanisms; and
- Performance-based: awarded based on demonstrated mastery of the subject matter aligned to defined competencies.

In the Spring of 2023, ARIS piloted three of seven on-line professional development modules for BI professionals. Each completed module will award the participant a microcredential for that topic. When taken as a complete set, these modules will result in a complete ARIS Certification covering all competencies. The framework for these modules and how they will result in microcredentialing and certification is under development by ARIS (Figure 3). Next steps to be addressed include the completion of an initial set of modules, piloting the program with BI professionals and NSF focused researchers, evaluating the effectiveness of the implementation and use of microcredentialing and certification modules, and identification and remediation of content gaps that emerge.

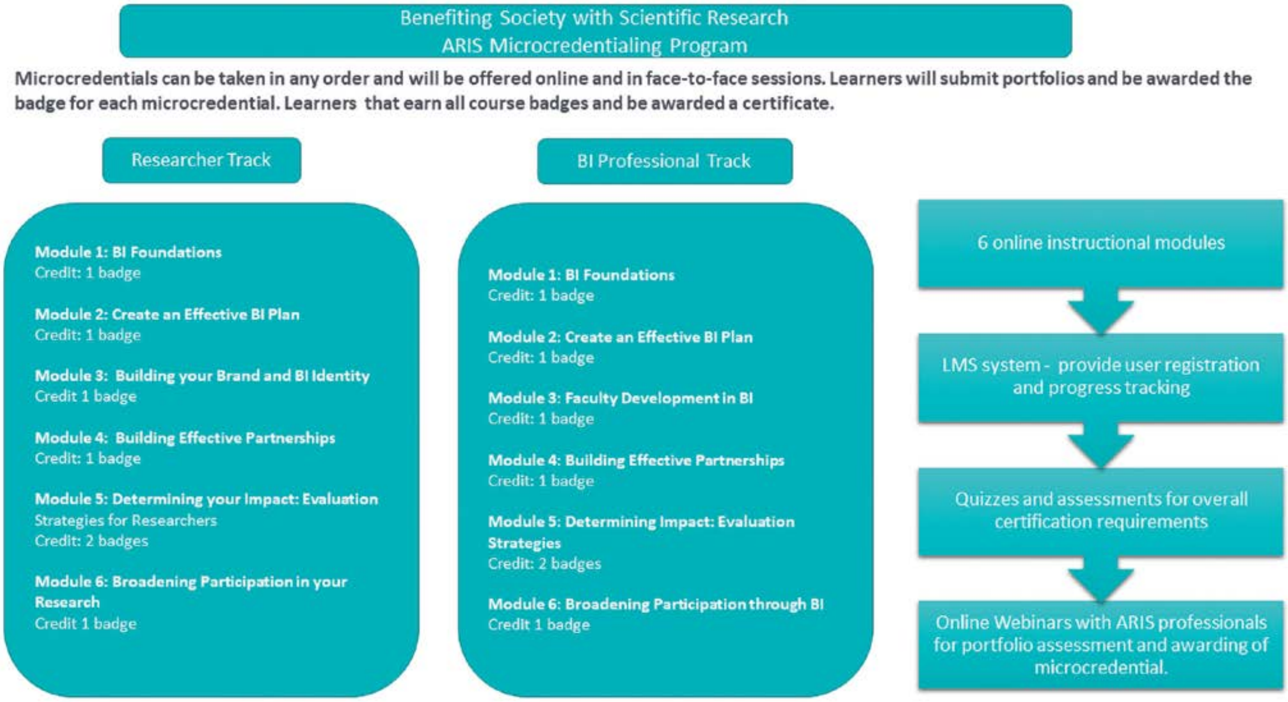

Figure 3: ARIS micro credentialing program

Finally, as the certification program progresses in development, the ARIS team will use the identified competencies to further support professional development within the BI field by creating a BI professional self-assessment tool. This tool will be an on-line interactive tool that BI professionals can use to assess their strengths and identify areas for additional training. This self-assessment will be integrated into the certification platform so that, as curricular training modules are developed, the assessment tool and competency skills will also be updated. The ARIS team envisions that this tool will also be useful for institutional administrators seeking to fill BI Professional positions at their institutions. Administrators will be able to see the factor areas and competencies, select the ones that make the most sense for their institution, and build those capacities into their position description and evaluation criteria.

Conclusion

A systematic process through two complementary studies, including the Delphi study followed by conceptual and statistical analysis of responses to an ARIS community survey, resulted in identification and validation of 37 competencies grouped into 7 domains. These, in turn, can serve as the foundation for self-assessment and identification of professional development needs among BI professionals. Micro-credentialing of BI professionals through ARIS, will satisfy a growing need for recognition and professionalization of the field. ARIS is testing and will continue to iterate on a robust and useful professional development infrastructure to support the growth and development of the emerging BI professional community.

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MOVING TOWARDS MORE AUTHENTIC SCIENCE LEARNING EXPERIENCES FOR STUDENTS

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Abstract: Immersing teachers in research experiences is a way to connect research to society through the K-12 classroom. Broader Impacts provides the opportunity for professionals working in teacher education to engage precollege educators in authentic research with scientists and engineers, however; teachers need support to translate authentic research back to their classrooms. Penn State Center for Science and the Schools (CSATS) developed a lesson series for their Research Experience for Teachers (RET) program to demonstrate scaffolded learning experiences that build from contrived K-12 science classroom experiences to authentic, research-based investigations over time. Teachers examined the lessons in terms of the level of sophistication of three critical lesson components. Evaluation data regarding this intervention showed shifts in teachers' understanding about how to translate authentic science and engineering to their classrooms, thus connecting research to society through teacher-research partnerships that have the capacity to improve STEM education and educator development.

Introduction

Current science education reform identifies eight science and engineering practices as part of the national science standards, Next Generation Science Standards (NGSS; Figure 1; NRC, 2012). These standards call for the engagement of students in the science and engineering practices to learn disciplinary core ideas in respective subject areas (NRC, 2012), yet many teachers do not have the experience in science and/or engineering research needed to successfully carry out this pedagogical transition. Broader Impacts work has the capacity to support teachers in improving their educational practice through teacher-researcher partnerships. In this paper, we will describe our work at the Penn State Center for Science and the Schools (CSATS) to connect Broader Impacts to K-12 education through our Research Experience for Teachers (RET) Program which is funded as a Broader Impacts component of technical research grants at Penn State University. First, we will describe current science education reform and the needs of in-service teachers. We will follow this with our argument towards a shift from contrived to authentic science and engineering classrooms and how we accomplish this with our teacher professional development through Broader Impacts work.

Prior scholars have identified that authentic classroom science "involves engaging students in answering scientific questions currently being investigated by scientists in today's world" (Crawford, 2012, p.113), yet in the typical science classroom, students engage in "simple inquiry tasks" (Chinn & Malhotra, 2002, p. 176) that do not reflect the day-to-day activities of practicing scientists (Chinn & Malhotra, 2002; Crawford, 2015; Wong & Hodson, 2010). Also referred to as school science (Crawford, 2015), these tasks typically include contrived activities where students are following steps to verify already known information (Crawford, 2015) that include limited or no student agency and require only basic reasoning (Chinn & Malhotra, 2002). These activities are incongruent with the expectations of NGSS with the focus on engaging students in the science and engineering practices, which were agreed upon by scientists and engineers on the NGSS planning committee as reflecting the way they carry out their work.

Penn State CSATS's summer RET program pairs in-service teachers with scientists and engineers at Penn State University as part of the researchers'

Broader Impacts for their technical research grants. The aim of our professional development (PD) is for teachers to successfully translate current, authentic research into their K-12 classrooms. We have built activities for our summer PD sessions to model authentic activities for teachers and we are currently developing an authenticity tool that teachers can use to evaluate their lessons and units for varying levels of authenticity. Through the PD sessions designed for the RET program, teachers are supported in creating and integrating authentic science and engineering activities in their classrooms that mimic or closely approximate the work of the scientists and engineers they partner with during the summer research experience.

Our PD contributes to three specific guiding principles of Broader Impacts: 1) improved STEM education and educator development, 2) increased partnerships between academia, industry, and others, and 3) development of a diverse, globally competitive STEM workforce (ARIS, 2020). Teacher-researcher partnerships connect university level research to K-12 education. Teachers are afforded the opportunity to gain access to the science and engineering community, thus enhancing their ability to bring discipline specific ways of thinking and conducting science and engineering into the precollege classroom. This provides opportunities for students to gain access to STEM habits of mind and career opportunities, and "try them on" in a low-stakes environment as precollege students.

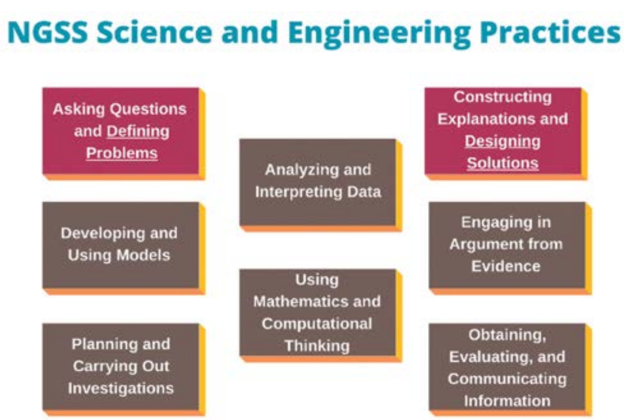

Figure 1: Eight science and engineering practices in NGSS (NRC, 2012). Engineering specific practices are underlined.

Three components of an authentic science classroom

Aligned with NGSS, our definition of authentic science and engineering includes three primary components specific to the precollege classroom. In our definition, we consider authentic science and engineering classroom activities to be situated in a research project that engage students in the science and engineering practices to investigate a phenomenon, whether scientific or relating to the design of a solution to an engineering problem. While we acknowledge that the work of practicing scientists will always be different than the scientific work of students (Crawford, 2015), we espouse that current science and engineering classrooms have the capacity to meaningfully engage students in work that is better aligned to that of scientists and engineers. Building on Burgin (2022), we argue that authentic science and engineering curriculum plans include three critical components: (1) scaffolded engagement in science and engineering practices, (2) student agency, and (3) purpose-driven activities.

Both teachers and students need guidance in working with the practices of scientists and engineers. Many students have not been taught in this manner of instruction (Chinn & Malhotra, 2002), so appropriate supports need to be embedded in instruction to successfully move students toward the science and engineering community of practice. Teachers in the RET program act as peripheral participants that slowly gain access to their research community of practice as they carry out their summer research project (Lave & Wenger, 1991). Similarly, the teachers need to create learning experiences for their students that prepare them for engaging in science and engineering projects. Teachers need to provide scaffolded activities for students as they investigate and explain phenomena and/or identify and develop solutions for engineering problems. This can be accomplished by slowing enculturating students into practices of science and engineering by providing them with teacher-driven experiences to begin, and incrementally releasing agency over time to ultimately enable students to lead themselves through investigations and solving engineering problems. For example, a science teacher may start

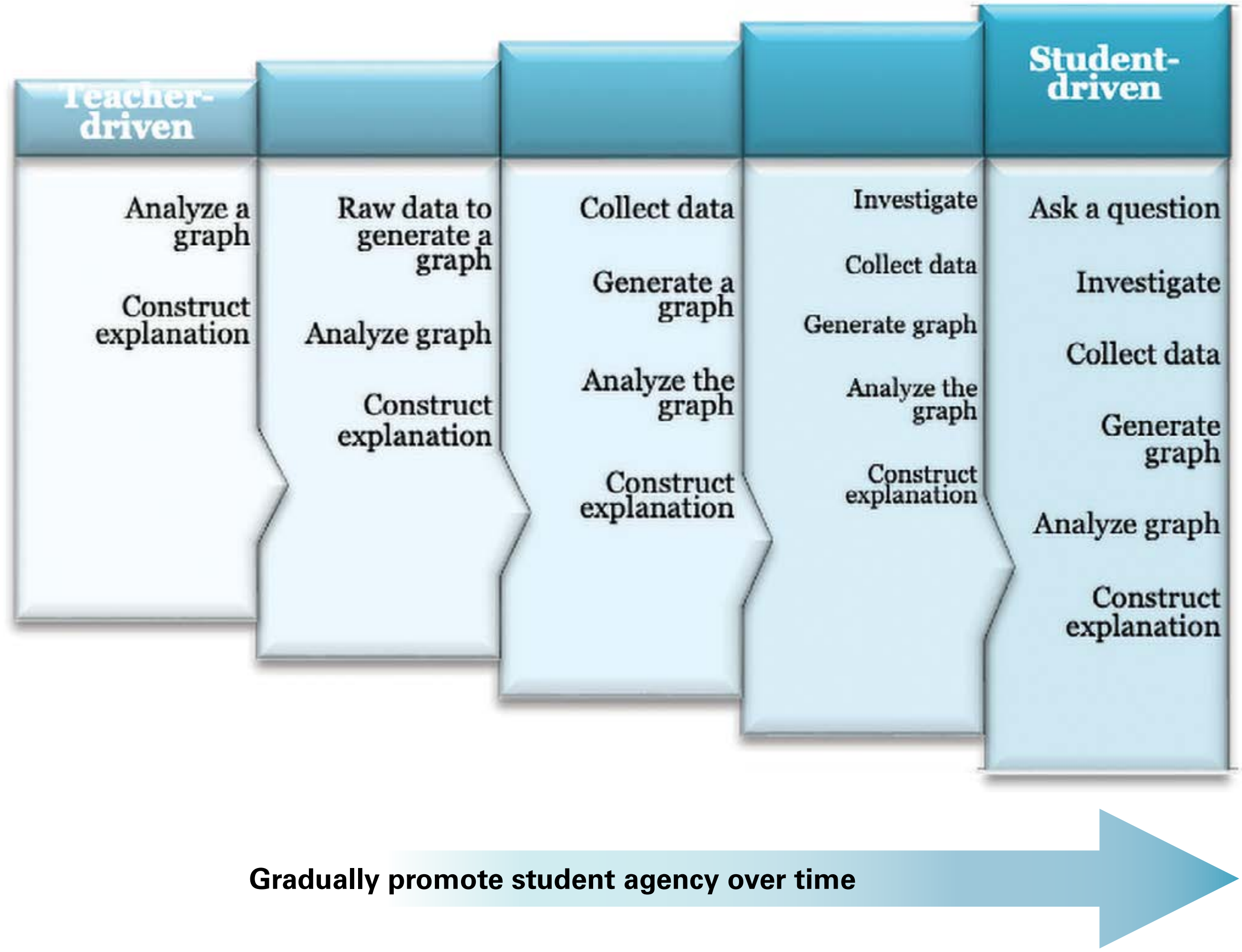

Figure 2: Gradually introducing science and engineering practices to students while releasing student agency.

with providing the students with a graph to analyze, then provide them with a template to help them construct an explanation of the phenomena under study based on their analysis (Figure 2). In the next activity, the teacher may provide raw data and ask the students to organize this data into a graph, then ask the students to construct an explanation of the phenomena based upon evidence in the data without a scaffold. Additional scaffolded activities would provide experiences for students to collect data and plan and carry out their own investigation. For the final activity, students would ask a question about the phenomenon or a related phenomenon, plan and carry out an investigation, analyze and interpret data, and construct an explanation. However, for the students to engage in authentic science or engineering, the teacher must plan activities that are purpose-driven.

We identify purpose-driven activities as classroom investigations or problems to solve that are situated in a meaningful and/or relevant context for the students. The activities are built upon one another in a way that the students can make meaning of, or even predict, why they are engaging in one activity to the next, and they are using their own knowledge and sense-making resources to derive these connections. Teachers should help students develop "practice-based identities" (Furtak & Penuel, 2019) that allow students to see that they are contributing to knowledge production by doing the work of professional scientists and engineers. Building students' identity in science, technology, engineering and math (STEM) can be accomplished by leading students through activities that are meaningful to them and allow them to fully engage in the process of science and/or engineering as it is intended by the discipline.

Activities leading to authentic science and engineering classroom experiences should take place over time. We emphasize that each of these components exist on a continuum. The level of sophistication of each component should build over units and throughout the school year. Early on, teachers drive student learning of engaging in the science and engineering practices. As the year progresses, teachers can use scaffolded activities to gradually increase student agency such that they drive their own engagement in the practices to investigate a phenomenon or solve a problem. The ultimate goal of integrating authentic science and engineering into classrooms is to have students investigate phenomena or solve problems in ways that scientists and engineers do their work.

Research Experiences for Teachers Program

The CSATS Summer RET program is a six-week immersive research experience in which teachers are placed in a host laboratory to carry out an authentic research project alongside scientists and engineers. Eleven secondary STEM teachers from eight states took part in a virtual RET program during summer 2022. Connecting research to the K-12 classroom, RET teachers receive professional development from CSATS science education faculty one day per week to help translate their experience back to the classroom. With focus on using planning tools, these weekly sessions support teachers in identifying disciplinary content and science and engineering practices that are translatable to their secondary classrooms. In working directly with researchers, teachers learn the practices used to conduct technical research. The scientist-/engineer-teacher partnership is critical to the success of teachers understanding authentic science and engineering research. The designed professional development sessions support teachers in translating their own technical research experience to integrate authentic science and engineering into their classrooms.

Classroom STEM Authenticity Tool

Over the past two years, CSATS has become interested in secondary teachers' views of authentic science and engineering as a discipline and what constitutes authentic science and engineering in the classroom. We are using these perceptions to inform our professional development to support teachers' understandings of what authentic science can look like in the classroom. CSATS is currently developing a STEM authenticity tool to support teachers in examining how activities for K-12 students can be designed to advance authentic research in classroom science and engineering. The basis for this framework is the three critical components of authentic science and engineering classrooms described above: (1) scaffolded engagement in science and engineering practices, (2) student agency, and (3) purpose-driven activities. During Week 5 of the RET PD sessions, teachers worked through lessons of a unit to determine how each lesson fit into the classroom science and engineering authenticity criteria.

An Example: Building Authenticity Over a Lesson Sequence

CSATS has developed an example watershed unit in conjunction with a watershed researcher at Penn State that builds towards an authentic science investigation in the students' local context, enabling students to incrementally make use of more sophisticated science and engineering practices over time. The unit includes four activities that support students to engage in the practice of developing and using models (NRC, 2012; Figure 3). The first lesson is a paper watershed modeling activity to support students' conceptual understanding of water movement on the landscape (Portland Water Bureau, n.d.). Then, students use a stormwater runoff simulation (Stroud Water Research Center, 2017b), which provides some quantitative values for various water movement conditions. After working with these initial models, students use Model My Watershed (Stroud Water Research Center, 2017a), to investigate questions about their local watershed using real-world hydrologic data. Finally, the students use the knowledge they have gained from the increasingly complex modeling exercises to complete a culminating project, a local stream study.

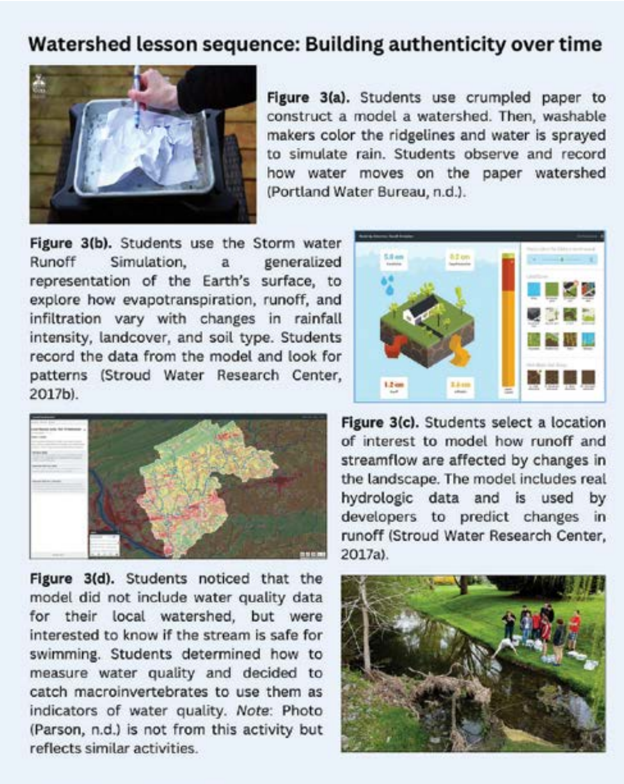

Figure 3: Example watershed lesson sequence building authenticity over time.

During Week 5 of the RET PD, teachers worked in small groups to conduct each activity, or in the case of the crumpled paper watershed, watch an abbreviated version of the activity, as the PD was conducted virtually. The teachers walked through each of the four activities of the sequence, one at a time, and discussed each activity in terms of the three critical components of authenticity. After each activity, the teachers returned to the main virtual session for the PD to discuss their thoughts about the activity and where the activity fell in sophistication for each of the components of authenticity. During this PD session, teachers initially argued that the paper watershed activity represented a use of models as scientists and engineers would engage in modeling; however, then realized after experiencing an increase in sophistication of modeling throughout the lesson sequence that the paper watershed modeling was actually used as a pedagogical tool to support introductory conceptual understanding a watershed dynamics. Over the course of the four lessons, the teachers articulated how they would envision students gaining agency in science and engineering throughout the lesson sequence and how this could support a culminating authentic science investigation for students.

Preliminary Outcomes: Teachers Shift in Articulation About Authentic Science

To evaluate the pilot of the authenticity intervention, we gathered teachers' conceptions of authentic vs. contrived science throughout the course of the summer PD. At the start of the program, teachers had basic ideas of what constitutes authentic science and engineering as research disciplines, but these were mainly descriptions based on what they have always taught about inquiry through the scientific method. The first week of teachers' journal entries included responses related to their classrooms when the prompts were asking them to describe science and engineering as a professional discipline. Also, many teachers mentioned things like "making sense of a phenomenon" or "solving a problem," which is language used in the NGSS (NRC, 2012) and typical language of science educators. In the Week 4 journal entries, teachers were asked, "What does it mean to have an authentic science or engineering classroom? Provide an example." At this point in the PD, the teachers had learned about the NGSS science and engineering practices, so many of the teachers referenced these in their responses; however, many of the teachers either included a vague description of a contrived activity or completely omitted an example of an authentic science or engineering classroom activity.

During Week 6, teachers were working to prepare their curriculum plans based upon their research experiences. We observed a shift in the teachers' responses to the questions, "How is your authentic research experience reflected in your classroom research project activities? What aspects of your research experience can you translate to the classroom? What can you not translate?" Each of the teachers were able to articulate an aspect of their research, either content or practices-related, that they would be able to translate to the classroom.

These examples were much more specific than the authentic science and engineering examples they posed in Week 4. For example, one teacher noted that their students would be "working with real soil, climate, and agricultural management data using the modeling tool, COMET-Planner" to "explore solutions to the problem of greenhouse gas emissions and carbon sequestration in soils from agriculture" (Teacher 1, personal communication, July 21, 2022). In their response, they cited opportunities for student agency, such as "students will be able to choose locations and management practices" (Teacher 1, personal communication, July 21, 2022) and described how the lesson series were scaffolded to support students in investigating how nature preserves in their area contribute to carbon sequestration, which is meaningful and relevant to students.

In the following the academic year, we plan to conduct follow up interviews with the teachers and develop a survey to capture teachers' conceptions of authentic disciplinary science and engineering vs. authentic classroom science and engineering prior to and after the program to more formally study teachers' changes in thinking as a result of the program. We are currently planning to study the use and effectiveness of the science and engineering classroom authenticity tool through design-based research beginning summer 2023. Design-based research is an approach to investigating learning environments to contribute to both theory and practice, rather than simply documenting successful interventions with teachers (Cobb et al., 2003). Our initial conjectures that have emerged as a result of the first iteration of this intervention will be subjected to testing through successive years of the program.

Implications for Broader Impacts and Science and Engineering Education

Numerous RET programs engage teachers in authentic research, but many programs do not report PD that facilitates translation to the classroom (Krim et al., 2019), limiting the impact on precollege students and their opportunities to engage in authentic science and engineering. Our aim is to develop a tool that helps support teachers' translation of current science and engineering research to the K-12 classroom as part of Broader Impacts work. By having teachers work directly with researchers to learn the practices they use to conduct their work, and providing the tools for teachers to successfully implement these practices in the classroom, CSATS connects research to society through teacher-research partnerships that have the capacity to improve STEM education and educator development while working to promote students as future STEM professionals (ARIS, 2020).

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"SEAWORTHY STEM™: A CONCEPTUAL FRAMEWORK FOR BUILDING STRONG FOUNDATIONS FOR STEM LITERACY THROUGH PARTNERSHIPS BETWEEN EDUCATORS AND STEM PROFESSIONALS."

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Abstract: This paper presents a conceptual framework for building strong foundations for STEM literacy through community partnerships, inspired by a partnership between the Naval Surface Warfare Center Carderock Division (NSWCCD) and the Department of Energy (DOE) Albert Einstein Distinguished Educator Fellowship Program (AEFP); and an outcome of the partnership, Seaworthy STEM™ in a Box. The development of the future naval STEM workforce is a primary concern of the Naval community. Seaworthy STEM™ in a Box provides enhanced Naval-relevant, standard-aligned, and hands-on activities to K-12 educators and students.

Introduction

The Federal STEM Strategy is a call to action for nationwide transformation of access to STEM education and defines a strategic framework for federal government organizations to invest in STEM education that ultimately allows the U.S. to maintain its competitiveness in STEM literacy, innovation, and employment. [1] The U.S. Department of Defense (DoD) is the federal government's largest organization, housing all military services (Army, Marine Corps, Navy, Air Force, Space Force, and Coast Guard) and fourth estate entities; and employs the majority of STEM professionals in the federal government. As such, DoD STEM communities have a vested interest in the overall DoD STEM mission to inspire, cultivate, and develop exceptional STEM talent to enrich our current and future DoD workforce. [2] A key theme included in both the Federal and DoD STEM Strategies, is echoed in the Naval STEM Strategy- for students of all ages, awareness of how STEM relates to their lives of the content and skills they are learning in school is the first step to inspiration." [3,4]

Following the review of these strategies, the Naval Surface Warfare Center Carderock Division (NSWCCD) sought to broaden their own STEM Education and Outreach initiatives to benefit all 21st century learners- including pre-service and in-service educators, and emphasis on making computational thinking a fundamental element of all programming. STEM skills are increasingly important for all people to succeed throughout their lives, and educators are the professionals working with students on a daily basis. Historically, NSWCCD focused on education and outreach initiatives for students created by STEM professionals (e.g., engineers, scientists, technologists, technicians, etc.). However, educators are responsible for teaching students the foundational knowledge they need to succeed and play a critical role in encouraging and fostering an interest in STEM from a young age. To gain an educator's perspective, NSWCCD partnered with the Department of Energy (DOE) Albert Einstein Distinguished Educator Fellowship (AEF) Program, to annually host an accomplished STEM educator for an 11-month term. This partnership resulted in not only a new Navy STEM Initiative "Seaworthy STEM™ in a Box", but it also transformed NSWCCD STEM programs with an institutionalized understanding of the barriers that educators face in the classroom. Understanding the K-12 classroom environment and educator barriers to teach STEM is crucial to providing relevant curriculum aids and learning opportunities that can be implemented in the classroom.

This paper presents a conceptual framework for building strong foundations for STEM literacy through community partnerships, inspired by a partnership between NSWCCD and the AEF Program; and an outcome of the partnership, Seaworthy STEM™ in a Box. [5]

NSWCCD STEM Gains an Educator's Perspective

For over a century, NSWCCD has overseen research and development to support the modeling and testing of surface and undersea vehicles associated with the U.S Navy Fleet. NSWCCD addresses the full spectrum of applied maritime science and technology, from the theoretical and conceptual beginnings, through design and acquisition, to implementation and follow-on engineering. This includes all technical aspects of improving the performance of ships, submarines, military watercraft and unmanned vehicles, as well as research for military implementation and follow-on engineering. This includes all technical aspects of improving the performance of ships, submarines, military watercraft and unmanned vehicles, as well as research for military logistics systems. The division employs over 2,000 civilian scientists and engineers dedicated to state-of-the-art research, engineering, modeling, and testing for ships and ship systems.

NSWCCD STEM1 supports a broad range of educational outreach programs, with the long-term goal of building a relevant and capable future STEM workforce. Educational program activities span from early elementary school science labs through university graduate-level-directed research, providing students a continuous thread of STEM experiences. Students work side-by-side with engineers, scientists and technicians on a variety of challenging, hands-on activities—which not only reinforce the basics tenets of engineering and physics, but also show students the importance of these principles in the work the Navy does every day. However, the capacity to meet the federal, DoD, and Naval STEM objectives relies on effective engagement with STEM educators.

To better understand and begin to address gaps in NSWCCD STEM programming for educators, NSWCCD partnered with the AEF program to design and implement programs that supported K-12 STEM educators as well as K-12 students. AEF is an opportunity for accomplished K-12 educators in STEM fields to work in Federal agencies or U.S. Congressional offices for 11 months. [6] Educators apply their experience and expertise to national education programs through development of new educational programs, implementing major components of programs, initiating partnerships, and creating web-based education tools. To date, NSWCCD has hosted 4 highly accomplished educators through the partnership. Participating educators have been experts in early childhood STEM education, STEM education technology, STEM learning in rural and urban environments, and educator partnerships supporting STEM curriculum in the classroom.

Each Fellow has contributed to NSWCCD's understanding of educator needs. There are many real and perceived barriers to quality STEM education in schools today, such as: "STEM takes extra time", "STEM requires expensive resources", and "transdisciplinary STEM is too tough to teach well". Due to resource limitations and lack of contextual knowledge of STEM applications, developing engaging STEM instruction can be challenging for many grades K-12 teachers. NSWCCD has a wealth of subject matter experts and examples of real-world applications that provide valuable context for fundamental STEM concepts taught in the classroom. To confront these barriers, the concept of Seaworthy STEM™ in a Box kits (and accompanying educator professional development) was created.

SeaworthySTEM™ In-A Box Methodology

The **Seaworthy STEM™ in a Box** kits were designed to guide students through scientific inquiry-based theory and the engineering design process, and support teachers as they select content, acquire materials and implement more hands-on STEM activities in their classrooms. The activities are grouped by themes and grade level to ease integration into educational environments and streamline training for DoD volunteers. Themed and standard-aligned resources allow teachers to develop their own curricular units to fit different learning environments (e.g., traditional classroom vs. homeschool, single grade level vs multiple grade levels, one-hour instruction vs. multiple hour instruction, etc.), student developmental needs, and schedules.

Therefore, the strategy for SeaworthySTEM™ In-A Box was built on the following approaches:

1. **An educator's perspective on appropriate grade-level curriculum is paramount to the success of the program.** All new activities will accommodate a wide range of learning environments and styles, with inclusive access to educational materials. Intentional efforts will be made to select a collaborative team of diverse members to best equip our team with different perspectives, lived experiences, and understanding of education challenges experienced by learners across the country-which include remote rural areas, underserved communities, and low-income districts. Integrating STEM in the classroom requires conceptual and foundational understanding of how students learn and apply their disciplinary knowledge. [7]

2. **Activities will be aligned to national standards such as Next Generation Science Standards (NGSS) which allow for easy implementation in the classroom.** National standards define the knowledge and skills students should gain throughout their grade K-12 education. The standards use evidence-based approaches, based on application of knowledge and developing innovative solutions to complex problems.

3. **Activities will be multi-disciplinary, focusing on real world problem solving with 21st century skills, technology applications, and project-based learning.** Equitable STEM literacy is the ability to apply concepts from multiple disciplines to solve problems that arise in everyday personal and professional lives.[8] All of the lessons include an engineering design challenge

capstone activity. High-quality STEM curricula possess not only clear connections to standards-based science, technology, engineering, and mathematics but should also include leveraging the aforementioned to create a prototype and/or the development of a system that will help accomplish a goal or solve a problem. This type of convergent thinking as well as working as part of an engineering design team utilizing an iterative design process ensures that the students not only apply new knowledge but also develop beneficial interpersonal skills.

4. **The activities will be free, open-source, and grouped by themes and grade level to ease integration into educational environments and streamline training for educators and DoD volunteers.** Themed resources will allow teachers to develop their own curricular units to fit different learning environments (e.g., traditional classroom vs. homeschool, single grade level vs. multiple grade levels, one-hour instruction vs. multiple hour instruction, etc.) and student developmental needs. A series of activities with a common theme can be offered over a longer term than a stand-alone activity and teach learners to tackle complex concepts using multiple disciplines. Themes will align with concepts supporting careers in Naval STEM, computational literacy, and topics that teachers struggle to convey in the classroom. These resources will be placed on our NAVSEA STEM publicly facing website for easy access.

5. **Content will show a diverse perspective and clear career connections, with contributions from across the commands in various technical fields and level of expertise.** Representation is a key component. Subject matter experts and educators featured in content showcase the diversity of our workforce, with a particular emphasis on showcasing females and those belonging to race and ethnic minorities that are historically underrepresented in STEM fields. This will positively impact participants' STEM perceptions and science identities. [9]

6. **The STEM In-A-Box train the trainer model increases equity in the k-12 learning space by providing free professional development opportunities for educators with all-inclusive kits.** Educator Training is one pathway to build strong foundations for STEM literacy, by contributing to teacher preparedness and confidence in STEM curricular unit development. Oftentimes educators are unable to implement project-based curriculum due to financial constraints and/or lack of proper lab equipment. Seaworthy STEM™ in a Box professional development concept helps eliminate this impediment as it supplies each educator with necessary materials and networking with STEM professionals, and other STEM educators. [10]

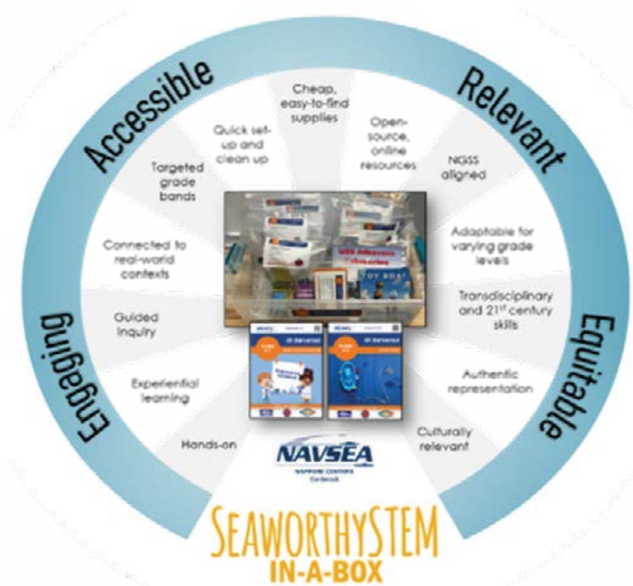

Figure 1: An example of the supplies and box

Seaworthy STEM™ in a Box Development

The development of this box series was initiated back in the fall of 2020. Currently the **Seaworthy STEM™ in a Box** series is targeted to be complete in development by the summer of 2023.

2020-2021 AEF Fellow, Suzanne Otto started the series content after relocating to the DMV area in 2020 from the rural area of Paris, Missouri. Prior to her fellowship, Otto spent over 17 years teaching physics and chemistry in a local public school that had minimum resources for accessing science experiences for students. Her goal as an AEF fellow was to develop a curriculum that aimed to build deep conceptual understanding in Naval-relevant STEM careers. The curriculum would be designed to help close the gap in the STEM pipeline by giving K-12 students opportunities that engaged them in science practices. The curriculum would also be designed as free to low-cost consumable kits to continue efforts in increasing participation of underserved and underrepresented groups in STEM. Otto collaborated with NSWCCD to design the overview of the curriculum program. In 2021, Suzanne Otto designed the first piloted kits for the 6th-8th grand band which was centered around density and buoyancy. A key scientific concept when designing Naval ships is relevant to Naval STEM careers.

To broaden the series, the partnership with STEM educators was continued. In 2021-2022, AEF fellow Stephanie Klixbull's expertise was in STEM education with the primary focus at the elementary level (K-5). During Klixbull's fellowship, she expanded the series to include two curriculum kits for elementary, K-2nd and 3rd-5th grade bands. Her goal was for the elementary curriculum to engage educators and students in effective ways that would teach complex Naval-relevant topics. From her career, Klixbull understood the present lack of elementary STEM resources and was keen in using her role to develop an additional source for the elementary science classroom. To achieve this goal, Klixbull worked with NSWCCD scientists and engineers and aligned the Naval-relevant science concepts with the Next Generation Science Standards and practices (NGSS 2019).

In 2022, AEF 2022-2023 fellow, Tom Jenkins is currently working with NSWCCD engineers and scientists to expand the program to include secondary level engineering design units of instruction for 9th-12th grade. Nearing the end of his fellowship, Jenkins is currently leveraging his existing relationship with the United States Patent and Trademark Office to integrate aspects of "Invention Education" into NSWCCD's **Seaworthy STEM™ in a Box** offerings.

Educator-Engineer Led Professional Development for Educators - Promising Practices

To date, all the published lessons have been piloted in classrooms and NSWCCD has hosted local educator professional development for the K-2, 3-5, and 6-8 sets. A unique facet of the presented professional development model is that classroom educators experience standards-based novel units of instruction which are team-taught by a classroom educator as well as an engineer. This not only ensures that the educators receive instruction in a pedagogically sound environment but also ensures that they receive guidance on how to effectively integrate authentic science and engineering practices within their learning space. This is extremely important as most elementary educators; even those with science teaching degrees, spend very little time in a laboratory or field setting throughout their collegiate experience. Being immersed and supported through every step of the unit not only ensures that educators understand the content but also models how to teach the skills that will be critical to the student's future academic and potentially professional success.

Conclusion

The presented work on NSWCCD's **Seaworthy STEM™ in a Box** initiative serves as a conceptual framework for similar agencies to cultivate partnerships with educators to provide authentic and culturally relevant STEM and experiences for students and educators. Throughout the past three years, NSWCCD has been able to grow the series program due to the collaborative efforts with the AEF program. The success of the series is due to the collective K-12 educator perspectives and teamwork from NSWCCD scientists and engineers. To make a successful and continuous program, the AEF fellows and NSWCCD both understood the need for each other's input and content expertise to amplify offerings that cut through the complexity of integrating STEM in the classroom. This collaborative effort was a leading way to promote authentic STEM experiences in the K-12 classroom and bring one step closer to closing the gap in the STEM pipeline.

Moving forward, NSWCCD will continue to engage local educational agencies to promote and host additional professional development opportunities for pre-service and in-service educators. NSWCCD is hopeful that the **Seaworthy STEM™ in a Box** series will positively change perception of STEM in the classroom and motivate educators to work across subject matter disciplines.

Endnotes

1. NSWCCD STEM efforts are a component of Naval Sea Systems (NAVSEA) STEM, supporting Naval STEM (the Department of the Navy and Marine Corps education and outreach programs). NAVSEA STEM communities are located throughout the U.S., comprised of STEM Coordinators and their passionate volunteer workforce at 10 Warfare Centers, 4 shipyards, and NAVSEA Headquarters.

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