SCIENCE EDUCATION & CIVIC ENGAGEMENT

AN INTERNATIONAL JOURNAL

VOLUME TEN
ISSUE ONE
WINTER 2018

SCIENCE EDUCATION & CIVIC ENGAGEMENT
AN INTERNATIONAL JOURNAL

VOLUME 10 ISSUE 1 · WINTER 2018

ISSN: 2167-1230

National Center for Science and Civic Engagement
2000 P Street NW Suite 308
Washington, DC 20036
202.483.4600
www.ncsce.net

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

VOLUME TEN
ISSUE ONE
WINTER 2018

Contents

About the Journal

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

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

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

WWW.SECEIJ.NET

From the Editors

We are pleased to announce the Winter 2018 issue of *Science Education and Civic Engagement: An International Journal*.

What is the connection between civic engagement and informal science education? This important question is thoughtfully examined in an article by **Larry Bell**, Senior Vice President for Strategic Initiatives at the Museum of Science in Boston. Beginning with a deconstruction of the meanings of "civic engagement" and "civic life," the article proposes a model for the development of civic engagement within informal science education and emphasizes the role of museums as civic spaces. This article is introduced by **David Ucko**, who previously served as president of the Kansas City Museum and deputy director of the Division of Research on Learning in Formal and Informal Settings at the National Science Foundation

Rachel A. Bergstrom (Beloit College) reveals the educational benefits that arise when undergraduate students are engaged as partners in authentic scientific research. She describes a research course in which students participate in a translational research program in epilepsy. The positive impact of this experience was documented with student research outcomes and an assessment of student learning gains

Dr. Pamela Leggett-Robinson and **Naranja Davis** from Georgia State University, together with **Dr. Brandi Villa** from Belay Consulting, describe a support and persistence program for STEM students at a two-year institution. The objective of the program is to enhance STEM identity by promoting civic engagement that enabled students to use their knowledge and skills for community improvement. Data collected over several years demonstrates that participation in the program increased student persistence and graduate rates.

A team of educators (**Areeba Iqbal**, **Kayla Natal**, **Melanie Villatoro** and **Diana Samaroo**) from the New York City College of Technology, City University of New York, have partnered with **Servena Narine** at P.S. 307 Daniel Hale Williams School to develop a variety of STEM activities aimed at elementary school students. By engaging students early in their schooling, the educators aim to stimulate interest in the study of STEM in college and future STEM career.

Jeff Secor, a teacher at the Dalton School in New York, explains the role of science in democratic decision-making in a volunteer-run community garden. When deliberating the construction of a new greenhouse, the community members had to consider factors such as location, size, and light transmission within the framework of city regulations. By fostering democratic dialogue and utilizing appropriate scientific evidence, the garden community were able to successfully complete their project.

We round out the issue with a website review by *SECEIJ* co-editor **Matt Fisher** (Saint Vincent College). *Our World in Data* is a valuable data resource developed by a team at the University of Oxford. It provides engaging data visualizations and downloadable data sets on topics that include population, economics, and infectious diseases. The website is particularly valuable to educators who wish to integrate a global dimension into their courses.

In conclusion, we wish to thank all the authors for sharing their accomplishments with the readers of this journal.

Matt Fisher
Trace Jordan
Co-Editors-in-Chief

Civic Engagement and Informal Science Education

LARRY BELL
Museum of Science, Boston

Introduction by
DAVID UCKO
Visitors Studies Association

Introduction

The following article by Larry Bell (Museum of Science, Boston) represents reflection and analysis generated by the National Science Foundation project "Maximizing Collective Impact Through Cross-Sector Partnerships: Planning a SENCER and NISE Net Collaboration" (DRL-1612376). This National Center for Science & Civic Engagement grant was the latest in a series of efforts to explore partnerships between higher education institutions and informal learning organizations based on civic engagement strategies. As Bell points out, one of the challenges in such collaboration is arriving at a common understanding of the meaning and implications of that term. In this piece, he suggests ways for science centers and children's museums to think about civic engagement and its future role in their activities.

Fruitful connections between SENCER and informal learning were discussed in earlier articles in this journal (Friedman & Mappen 2011; Ucko 2015). They became the basis for grants from NSF, the Noyce Foundation, and the Institute of Museum and Library Services that funded 15 cross-sector partnerships. As noted in a recent overview of those projects, "collaboration between informal science organizations and higher education institutions based on civic engagement offers potential benefits for the partners, the students, and the public" (Semmel & Ucko 2017).

In deconstructing its definition, Bell emphasizes the value of a civic engagement focus in providing tools and knowledge that prepare individuals for future participation, both nationally and locally. At the same time, it can enhance learning among students by increasing motivation and demonstrating the relevance of STEM content to their wider interests and concerns. This complementarity and its positive impact on faculty practice became a basis for characterizing SENCER as a "community of transformation" in STEM education reform (Kezar & Gehrke 2015).

Many avenues exist for participation in civic activities that complement and enhance STEM knowledge and understanding . For example, community-based citizen science projects often have been the platform for higher education-informal learning partnerships. We hope that this article and its proposed model for civic engagement will encourage new strategies for effective collaboration involving informal learning organizations.

—*David Ucko*

Civic Engagement and Informal Science Education

Leaders of the National Informal STEM Education Network (NISE Net) were fortunate to be part of a collaborative planning grant led by the National Center for Science and Civic Engagement to explore a strategic collaboration between Science Education for New Civic Engagements and Responsibilities-Informal Science Education (SENCER-ISE) and NISE Net, two extensive STEM networks with overlapping missions, but with distinct organizational assets and constituencies. One of the challenges NISE Net leaders had from the original conception of the project was to get a clear understanding of what "civic engagement" might mean for science and children's museums. It is not unusual for museums, steeped in the approaches of informal science education and oriented toward supporting K-12 formal education, to be unfamiliar with related but different approaches to engaging learners in science and technology. As an example, the Center for Advancing Informal Science Education (CAISE) led an inquiry group nearly a decade ago and wrote a report about "how public engagement with science (PES), in the context of informal science education (ISE), can provide opportunities for public awareness of, and participation in, science and technology" (McCallie et al. 2009). The field is exploring its potential roles in PES today.

Similarly, engaging with the leaders of the National Center for Science and Civic Engagement and the SENCER initiative raised questions about what "civic engagement" might mean for science museums. Initial discussions revealed that "civic engagement" might encompass a wide range of activities for which SENCER model courses might provide examples, but NISE Net leaders felt that they needed some kind of working model to understand how "civic engagement" relates to a variety of activities that NISE Net partner organizations already engage in. We also wanted to understand how characteristics of civic engagement might be differentiated from current practices in informal science education.

Deconstructing a Definition of Civic Engagement

As a way of thinking about this question, we searched for a variety of definitions of civic engagement and decided for this exercise to use one we found in the New York Times (2006), which was actually an excerpt from *Civic Responsibility and Higher Education*, edited by Thomas Ehrlich:

> Civic engagement means working to make a difference in the civic life of our communities and developing the combination of knowledge, skills, values and motivation to make that difference. (Ehrlich 2000, vi)

A first step in exploring this definition required further examination of some of its components. A key question for ISE organizations is *who* is "working to make a difference"? At the workshop in March, some NISE Net leaders noted that they had been interpreting the SENCER initiative incorrectly since their first exposure to it several years ago. They thought SENCER was an acronym for "science education *through* new civic engagement and responsibility" and that SENCER courses involved students in civic projects in the community during the course of which they learned the science they needed to carry out the projects. But at the March meeting, David Burns clarified that SENCER was the acronym for "science education *for* new civic engagement and responsibility." The learning did not necessarily take place by participating in a community-based civic engagement project (although it might) but rather was designed to provide students with tools that they might need for their own future civic engagement. Similarly for ISE organizations, the question thus arises whether the civic engagement work of ISE organizations might be designed around preparing members of their audience for carrying out future civic engagement activities or whether the ISE organizations would organize civic engagement activities of their own in which members of their audience might or might not participate.

Civic Life

The next term in the definition of civic engagement that needed exploration was "civic life." For this the National Standards for Civics and Government provided a definition.

Civic life is the **public** life of the citizen concerned with the affairs of the community and nation as contrasted with private or **personal** life, which is devoted to the pursuit of private and personal interests. (Center for Civic Engagement 2014)

NISE Net leaders felt that science museums had a long history of focusing on the personal life of their audience members. This includes both personal opportunity (children should have the opportunity to pursue careers that involve science and technology) and beneficial choices in their personal life (people should have nutritional food choices). NISE Net leaders were less clear on the extent to which science museums focused explicitly on "affairs of the community and nation" but recognized that recent developments in the governance of the country raised questions about the connections between scientific evidence and sound policy decisions. That was causing some members of the ISE community to ask questions about whether the field was doing enough about science and public policy.

Values and Motivation

Another term in the definition of civic engagement that raised questions was "combination of knowledge, skills, values and motivation." Many ISE organizations are familiar with a set of potential ISE impacts outlined in *Framework for Evaluating Impacts of Informal Science Education Projects* (Friedman 2008), which NSF references in its solicitations for Advancing Informal STEM Learning proposals. That document identifies the following potential impacts: awareness, knowledge, understanding, engagement, interest, attitude, behavior, and skills. Values and motivation are new potential impacts of ISE for civic engagement. The Framework speaks of "motivation" as a characteristic audiences bring to their ISE experience rather than as an impact of the experience.

Civic Responsibility and Higher Education describes motivation for civic engagement in this way:

A morally and civically responsible individual recognizes himself or herself as a member of a larger social fabric and therefore considers social problems to be at least partly his or her own; such an individual is willing to see the moral and civic dimensions of issues, to make and justify informed moral and civic judgments, and to take action when appropriate. (Ehrlich 2009, introduction, xxvi)

The CAISE report on PES explicitly identifies the following values in connection with the goals of public engagement activities in ISE for individuals or communities:

> Recognition of the importance of multiple perspectives and domains of knowledge, including scientific understandings, personal and cultural values, and social and ethical concerns, to understanding and decision making related to science and to science and society issues. (McCallie et al. 2009)

Making a Difference

The final element to note in the definition of civic engagement that the New York Times pulled from Ehrlich is that the purpose of civic engagement is to "make a difference." Several sources describe what making a difference might mean:

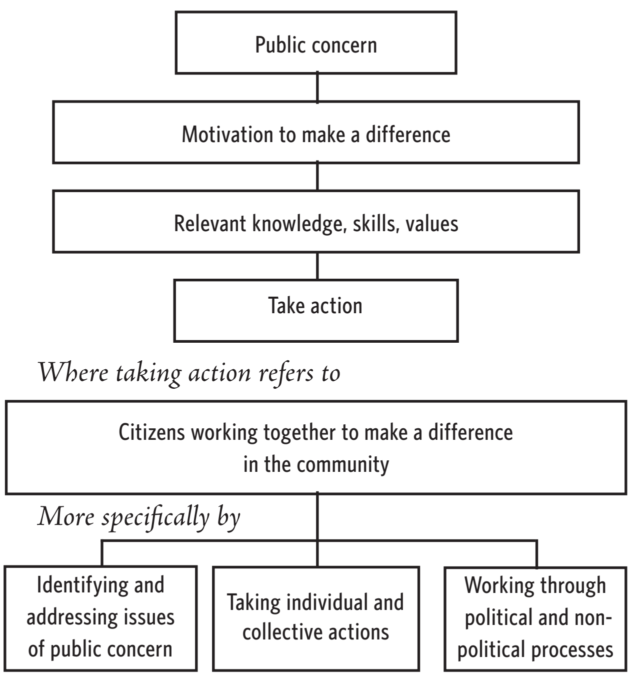
"Civic engagement is… individual and collective action designed to **identify and address issues of public concern**." (American Psychological Association (APA) 2018)

It can be defined as citizens working together to **make a change**. (Wikipedia, 2017)

It means **promoting the quality of life in a community**, through both **political and non-political** processes. (Ehrlich 2000)

Constructing a Model for Civic Engagement in ISE

What emerges from the definition used here and the exploration of some of the terms is a potential model for civic engagement in informal science education. Civic engagement starts with a public concern; requires motivation to make a difference and the acquisition of relevant knowledge, skills, and values; and proceeds with taking action to make a difference.



Furthermore, ISE organizations motivated for civic engagement have some options related to the question raised earlier about *who* is taking action to make a difference:

- The museum provides *members of its audience* with knowledge, skills, and perhaps values and motivations to support their civic engagement activities.
- *The museum* develops civic engagement projects of its own to make a difference in the community.
- The *museum and other community organizations* partner to carry out civic engagement projects.

Perhaps the aspects of civic engagement identified on this page can help ISE professionals think about civic engagement in terms of the things ISE organizations currently do or do not do.

Science and Children's Museums Themselves Are Civic Engagement Activities

On the most fundamental level, the very existence of science and children's museums is a kind of civic engagement. Their classification as 501(c)(3) charitable organizations is recognition that their purpose is to "promote the quality of life in a community" principally or exclusively through non-political processes. Science museums may consider several different **public concerns** as the ones that drive their mission. For example,

- The talent pool for STEM innovation is too small, resulting in lower national achievement and prosperity.
- Opportunities in STEM are not equally distributed among those in the community.
- Many of the complex issues that shape our daily lives and our future require an understanding of basic science, math, engineering, and technology in order to make informed decisions.
- As science and technology pervade our lives, our societal challenges become more complex.
- There is a lack of communication between the scientific community and various publics.
- The school system alone is not adequate for stimulating children's interest and self-efficacy in STEM.

Individuals are **motivated to address these concerns** though science museums in a variety of ways. Some work for science museums and develop a career doing so, working in a variety of ways to strengthen the effectiveness of their own organization and other similar organizations. Many volunteer their time and talents without financial compensation, working for science museums because they find the work meaningful and fulfilling. Others donate money in small amounts or in very large amounts because they feel the organization is doing good for the community and addressing specific public concerns at both national and community levels.

Science museums work to gain the **knowledge and skills** needed to be effective in their work. Grants from National Science Foundation, Institute for Museum and Library Sciences, and other sources acknowledge the efforts to advance the knowledge and skills of individual organizations and of the field as a whole. Organizations like the Association of Science-Technology Centers, the Association of Children's Museums, the American Association of Museums, the Visitor Studies Association, and the Center for the Advancement of Informal Science Education all support the efforts of the field to advance its knowledge and skills and to support the values of the profession.

Science museums also **take action** to address the public concerns at the heart of their missions. Furthermore they recruit individuals, corporations, and other organizations in their communities to work together with them in addressing those concerns.

In addition to the overall work of such organizations, science and children's museums also undertake projects that are aimed at addressing specific community needs.

- The *Computer Clubhouse* (http://www.computerclubhouse.org), for instance, originally developed by The Computer Museum in Boston, is aimed at a gap in opportunity for youth from underserved communities and now supports a global community of 100 Clubhouses in 19 countries.
- The *Engineering is Elementary* curriculum and teacher support activities (https://www.eie.org) developed by the Museum of Science are aimed at a significant content gap in formal elementary education.
- Science museums conduct a variety of teacher training programs, because elementary and middle school teachers often have little training in science or science education. (Association of Science-Technology Centers [ASTC] 2014)

Not everything science and children's museums do is in fulfillment of civic engagement goals, but on a fundamental level they can be seen as civic engagement efforts for the purpose of stimulating youth in areas of STEM learning.

But now we step aside from this fundamental perspective and look at other more specific ways in which science museums can support civic engagement.

Support for Visitors' Future Civic Engagement

First we explore the idea that the museum is not organizing a civic engagement activity in the community itself, any more than it is conducting a wide range of scientific research itself, but is helping to prepare its visitors for civic engagement (or scientific research roles) in their future, much in the way that SENCER courses do for students.

In this regard, comments in NISE Net's *Nanotechnology and Society Guide* (Wetmore et al. 2013) outline societal concerns that explain the motivation behind the Guide, which seems to come from a civic engagement perspective.

> *The decisions we make about science and technology have profound effects on people.... nanotechnology is poised to have a significant impact on our lives in the coming years, and as such it is very important that we engage in open conversations about what it is, what is possible, and where we would like it to go. But sometimes people's voices about science and technology are muted because it can be difficult to know how to engage in these discussions. Nanotechnology can be especially intimidating, as many people do not even know what it is. [It is] important to give everyday citizens a voice.*

The Guide describes a societal problem and works to motivate everyday citizens to take an active role by participating in open conversations and letting their voices be heard. The Guide and associated hands-on materials, training activities, and other supporting resources all provide knowledge and skills necessary to everyday citizens so that they can play a role. All of this material stops short of the "take action" step. It suggests there is opportunity to take action, but it provides no direct means for doing so, leaving such action to play out in other domains apart from the science or children's museum, except, of course, for the universal take action plan of such organizations: "learn more."

Another kind of "take action" step that ISE organizations often promote is donating funds to the organization itself to carry out its work. An interesting example of incorporating giving to a worthy cause was built into the Bronx Zoo's Congo Rainforest Gorilla experience almost two decades ago. After walking through the forest, viewing a movie about gorilla research, and seeing the live gorillas, visitors get to decide which of the Zoo's conservation projects their admission fee should be directed toward. In 2009 the Wildlife Conservation Society reported that the exhibit had raised $10.6 million to fund the conservation of Central Africa's Congo Basin rainforest and wildlife and turned seven million visitors into conservationists!

A couple of examples of "take action" steps in a temporary exhibition at the Museum of Science decades ago were incorporated by MOS staff into a Smithsonian traveling exhibition about the destruction of tropical rainforests. Evaluation reports about the exhibition at earlier sites noted that the exhibit left some visitors who care about the environment unclear about what they could do about the situation. Museum staff added to the exhibition a small gift shop of rainforest sustaining products along with their stories. There also was an area about environmental organizations that focus on rainforest support actions, with postcards visitors could fill out to get more information or to get on the mailing list of those organizations. Visitors could fill out a card and drop it in a mailbox in the exhibition to get connected with an organization to take action.

These are just a few examples. There are many others. But it is not typical for science museums to get all the way to the "take action" stage in their exhibitions and programs. Most provide support for visitors who can find their own path to action.

Identifying and Addressing Issues of Public Concern

A characteristic of civic engagement is that it involves identifying and addressing issues of public concern. Except for the overall concerns about science education, most science museum exhibits don't evolve from public concerns. Perhaps the biggest exception to that may be in the area of environmental conservation and climate change.

A scan of a few webites that list high-priority public concerns turn up a number of topics:

United Nations Global Issues

- Aging
- AIDS
- Atomic energy
- Big data for the Sustainable Development Goals (SDGs)
- Children
- Climate Change
- Decolonization
- Democracy
- Food
- Human rights
- International law and justice
- Oceans and the Law of the Sea
- Peace and security
- Population
- Refugees
- Water
- Women

Ten Social Issues Americans Talk the Most About on Twitter (Dwyer, 2014)

- Better job opportunities
- Freedom from discrimination
- A good education
- An honest and responsive government
- Political freedoms
- Action taken on climate change
- Protecting forests, rivers, and oceans
- Equality between men and women
- Reliable energy at home
- Better transportation and roads

There are many lists like these two. Some topics may be more familiar to science museum environments: AIDS, aging, climate change, food, heath, oceans, population, water, and education to name a few. Science Museum of Minnesota's *Race: Are We So Different?* exhibition is a notable recent example. New technologies like nanotechnology and synthetic biology are topics we have covered in forums, but they are generally little known by the public and so usually come not from a current widespread public concern but rather from an anticipated future public concern. One question for any large-scale collaborative project, then, is whether there is a particular global or national public concern that tens or hundreds of organizations would want to work on together, or if organizations would prefer to address their own local concerns.

Role a Science Museum Could Play

Assuming that a science museum, or group of museums, is particularly interested in an issue of public concern and does not want to organize its own civic engagement activity, but would like to support their visitors' civic engagement capacity, there are a number of things the museum(s) could do. If civic engagement *for individuals* involves development of *knowledge, skills, values, and motivation to make a difference*, then for whatever issue one might choose, museums could, for instance:

- Provide visitors with background knowledge relevant to the social issue, such as
    - Awareness of the issue
    - Scientific data related to the issue

- Provide visitors with skill development activities related to taking action, such as
    - Getting further information
    - Talking with others about the issue in productive ways
    - Recognizing elements of arguments: scientific evidence, personal experience, social values

- Provide visitors with experience related to the range of values associated with the issue:
    - Exposure to the views of others in connection with the issue
    - Visitor activity in which participants explore their own values in connection with the issue

- Provide visitors with information about and connections with other organizations through which visitors could get involved in activities related to the issue.

This is similar to what museums have done recently for nanotechnology and synthetic biology, except that they might:

- Be more specific about the public concern
- Put additional effort into building motivation for involvement, and
- Incorporate a "take action" component if appropriate.

If an organization like NISE Net took this approach, it would need to consider if it would tackle one particular concern, spend a couple of years working on it, and then disseminate materials to use in connection with that concern broadly; or if it would try to create tools to help individual partners develop materials of their own for the different specific problems they wish to address. All of this would be done with the ultimate goal of providing members of museum audiences with support *for their own civic engagement*.

Partnering for Civic Engagement

A different approach to civic engagement that a museum might take is to partner with other community organizations to work on solving societal problems directly, rather than preparing their visitors to be able to do that on their own. The NISE Net submitted a proposal to NSF in 2016, *STEM Community Partnerships*, which is an example of that kind of civic engagement. The proposal identified a social issue:

> To secure our nation's future in science and technology, the US needs a workforce that has both broad general competency in STEM and deep specialized talent in the STEM fields, and that benefits from diverse perspectives, knowledge, and abilities. Currently, the STEM workforce does not represent the U.S. population as a whole. The U.S. Department of Commerce reports that women, Hispanics, and non-Hispanic Blacks have been consistently underrepresented in the STEM fields, and are only half as likely as all workers to hold STEM jobs. The underrepresentation of women, persons of color, and other groups in the STEM workforce is not only a STEM capacity issue but also a social justice issue, reflecting a profound disparity of opportunities and resources across the population. (Ostman 2006)The project description goes on to describe partnerships among science museums and YMCA branches, similar to work that the Children's Museum of Houston does, to produce and deliver out-of-school-time experiences designed to reach underrepresented youth with engagement in STEM. The project

calls for local partnerships in each participating community and a national partnership to support the local ones. The national partnership is designed to support the professionals at museums and YMCA branches in taking action to address the concern.

Unfortunately, the proposed project has not yet been funded.

Certainly science museums have the capacity to form local partnerships to address local issues. Many such partnerships likely already exist. One question about a large-scale network project is how the network could help organizations establish these kinds of local partnerships and initiatives. Perhaps the recent and existing SENCER-ISE partnerships fit within this category.

Conclusions

Thinking about civic engagement and informal science education raises a number of questions for the science museum community.

Would science museums prefer a model where the museum organizations help to build their visitors' capacities for their own civic engagement? This may be parallel to the main focus of SENCER and is perhaps closer to what museums do now but with a somewhat different focus.

Or would science museums prefer a model where the museum organization partners with other organizations to solve civic problems directly? This may be different from what museums are doing now if the civic problem is beyond access to quality education.

Are there societal issues beyond access to good education that science and children's museums might be interested in pursuing? NISE Net asked partners in an annual partner survey and at regional meetings a few years ago about topics NISE Net partners might be interested in. The favorite topics in order of priority were energy, new emerging technologies, engineering, convergent technologies, climate change, brain and neuroscience, maker spaces, synthetic biology, societal and ethical implications, computer science, and big data. NISE Net did not, however, ask them about specific public concerns or societal issues related to these topics.

Would science museums collectively want to tackle an issue with national scope and develop resources centrally to support partner organizations in addressing the particular issue selected, with the opportunity for some customization locally? This is essentially what NISE Net has done with nanotechnology, synthetic biology, space and earth science, and other topics, but without a focus on a set of societal issues.

Alternatively would science museums want to tackle specific local issues with partners in their own communities and perhaps get help in doing so from an organization like NISE? NISE Net's past activities have all supported local partnerships, for instance, between universities doing nano research and science museums, or between community organizations and science museums.

Exploration of these questions could help members of the science museum community and organizations like NISE Net map out possible courses for the future of civic engagement in informal science education.

About the Authors

Larry Bell is Senior Vice President for Strategic Initiatives at the Museum of Science in Boston and was the principal investigator and director of the Nanoscale Informal Science Education Network from 2005 until 2017. Currently he is interested in public engagement with societal implications of science and technology, activities that engage the public in dialogue and deliberation about socio-scientific issues, and in how research in science communication can inform informal science education practices.

David Ucko has served as deputy director of the Division of Research on Learning in Formal and Informal Settings at the National Science Foundation (NSF), president of the Kansas City Museum, chief deputy director of the California Museum of Science and Industry, and vice president of programs and director of science at the Museum of Science and Industry in Chicago. He is currently vice president for organizational development of the Visitors Studies Association, co-chair for the National Research Committee on Communicating Chemistry in Informal Settings, and president of Museums+more, LLC, where he works on developing innovative approaches to informal learning. He holds a B.A. in chemistry from Columbia College of Columbia University and a Ph.D. in inorganic chemistry from Massachusetts Institute of Technology.

References

American Psychological Association (APA). (2018). Civic engagement. Retrieved February 2, 2018 from http://www.apa.org/education/undergrad/civic-engagement.aspx.

Association of Science-Technology Centers (ASTC). (2014, November/December). Reconstructing STEM in our schools. Dimensions. Retrieved February 2, 2018 from http://www.astc.org/astc-dimensions/reconstructing-stem-schools/.

Center for Civic Engagement (CCE). (2014). What are civic life, politics, and government? In National standards for Civics and Government, 5–8 content standards. Retrieved February 2, 2018 from http://www.civiced.org/standards?page=58erica.

Dwyer, L. (2014, July 12). Social issues Americans talk the most about on Twitter. TakePart, Participant Media. https://www.takepart.com/photos/10-social-issues-americans-talk-about-twitter-most/.

Ehrlich, T. (Ed.). (2000). Civic responsibility and higher education. Phoenix: The Oryx Press.

Friedman, A. (Ed.). (2008). Framework for evaluating informal science education projects. Report from a National Science Foundation workshop. Retrieved February 2, 2018 from http://informalscience.org/sites/default/files/Eval_Framework.pdf.

McCallie, E., Bell, L., Lohwater, T., Falk, J. H., Lehr, J. L., Lewenstein, B. V., Needham, C., & Wiehe, B. (2009). Many experts, many audiences: public engagement with science and informal science education. Washington, DC: Center for Advancement of Informal Science Education (CAISE).

New York Times. (2006). The definition of civic engagement. Retrieved February 2, 2018 from http://www.nytimes.com/ref/college/collegespecial2/coll_aascu_defi.html.

Ostman, R. (2006). STEM community partnerships and organizational change: Testing a scalable model to engage underrepresented children and families. Proposal to National Science Foundation from the Science Museum of Minnesota.

United Nations. Global issues overview. Retrieved February 2, 2018 from http://www.un.org/en/sections/issues-depth/global-issues-overview/index.html.

Wildlife Conservation Society (WCS). (2009, June 24). Congo gorilla forest celebrates 10 years and $10.6 million raised for Central African parks. WCS Newsroom. Retrieved February 2, 2018 from https://newsroom.wcs.org/News-Releases/articleType/ArticleView/articleId/4891/Congo-Gorilla-Forest-Celebrates-10-Years-and-106-Million-Raised-for-Central-African-Parks.aspx.

Wetmore, J., Bennett, I., Jackson, A., & Herring, B. (2013). Nanotechnology and society: A practical guide to engaging museum visitors in conversations. NISE Net and The Center for Nanotechnology in Society. Retrieved February 2, 2018 from http://www.nisenet.org/catalog/nanotechnology-and-society-guide.

Wikipedia. 2017. Civic engagement. Retrieved February 2, 2018 from https://en.wikipedia.org/wiki/Civic_engagement.

References (Introduction)

Friedman, A. J., & Mappen, E. (2011). SENCER-ISE: Establishing connections between formal and informal science educators to advance STEM learning through civic engagement. Science Education & Civic Engagement, 3(2), 31–37.

Kezar, A., & Gehrke, S. (2015). Communities of transformation and their work scaling STEM reform.Los Angeles: Pullias Center for Higher Education, Rossier School of Education, University of Southern California. Retrieved February 2, 2018 from https://pullias.usc.edu/wp-content/uploads/2016/01/communities-of-trans.pdf.

Semmel, M., & Ucko, D. (2017). Building communities of transformation: SENCER and SENCER-ISE. Informal Learning Review, 146(Sept/Oct), 3–7.

Ucko, D. (2015). SENCER synergies with informal learning. Science Education & Civic Engagement, 7(2), 16–19.

Building a New Translational Research Program with Undergraduates: A Student-driven Research Class

Rachel A. Bergstrom
Beloit College

Abstract

Course-based undergraduate research is an effective active, inquiry-based pedagogical tool. In many cases, these research experiences build on established research programs. This project report describes a research course designed to establish a new translational research program in epilepsy and to test the feasibility of engaging students early on in the research process. The outcomes of this class, including research deliverables and student learning gains assessments, indicate that engaging students in research at a very early stage in project development is a meaningful and productive pedagogical framework for student and faculty development. This high-risk model for course and research development is a novel and exciting method for engaging students in mentored research at the undergraduate level.

Introduction

Mentored research at the undergraduate level is considered a high-impact pedagogical practice (Kuh, O'Donnell, & Reed, 2013), and many STEM courses incorporate students into established research programs and projects. The benefits of course-based research are not limited to students, as faculty research progress can be boosted by the concentrated student collaboration found in these courses. Moreover, students can bring fresh perspectives and make important contributions to research at the point of new project development. Involving students in "early" research (e.g. establishing research aims, refining protocols and procedures, and collecting and analyzing background data) can be a context for simultaneously robust student learning and faculty professional development. However, the risks of failure associated with early research may make faculty reluctant to consider building a research course specifically centered on developing a new and untested project. The course described below provides evidence in favor of building a course around a new research program, using the example of a successful pilot of course-based translational neuroscience research at the undergraduate level. The work of this course, offered at a small liberal arts college, set the stage for a robust, student-centered translational research program that also advanced the instructor's research agenda.

Translational research: from basic science to disease intervention

The confirmation in humans of the results of basic science research using cell and animal models is a critical step in developing patient-centered interventions to improve human health (US Department of Health and Human Services [USD HHS], 2015). Translational research, which bridges basic science and clinical research, is a major focus of NIH funding and support through the National Center for Advancing Translational Sciences. However, it can be challenging to implement translational research at small colleges and universities, as many of these institutions are not in a position to conduct clinical and patient-centered translational research. These shortcomings may be circumvented through the use of publicly available online databases that provide students and faculty with the opportunity to work directly with human data collected under IRB approval from large research institutions. As funding for basic science research decreases, engaging undergraduate students in the process of translational research is critical to the enhancement of their understanding and appreciation of the fundamental role of basic science in improving the health and well-being of the broader population (Hobin et al., 2012).

Epilepsy and EEG

Approximately two percent (+/- 0.11) of Americans suffer from epilepsy (US DHHS, 2017), a family of disorders in which a person who has previously had a seizure is likely to experience another unprovoked seizure (Fisher et al., 2014). The etiologies of epilepsy are varied and, in many cases, still unknown (Shorvon, 2011). Thus much of the effort in the clinic is aimed at seizure management and prevention.

The monitoring of the epileptic brain via electroencephalography, or the recording and analysis of the electrical signals of the brain, is critical to the management of epilepsy. In particular, many patients with intractable epilepsy, i.e. epilepsy that is resistant to management by medication, undergo long-term intracranial electroencephalography in the inpatient hospital setting to collect electroencephalogram (EEG) signals from up to hundreds of locations across the cortex of the brain over the course of several days. The signals are analyzed to determine whether surgical resection of the epileptic locus, or the portion of the brain implicated in the start of seizure activity, is a possible epilepsy management strategy. Yet EEG analysis is time-consuming and subject to low inter-observer reliability, especially regarding the precise timing and location of seizure onset in the brain (Abend et al., 2011; Benbadis et al., 2009; Tatum, 2013). Therefore, research on the development and use of automated, standardized, and quantitative EEG analysis through computer is an expanding field of inquiry (Acharya et al., 2013; Halford et al., 2011).

Course structure and implementation

Translational research towards understanding how EEG analysis is similar or different among rodent models of epilepsy and human epilepsy in the clinical setting serves as the foundation for the research course described in this report. An advanced topics course (BIOL 373, Advanced Neuroscience Research) was developed and implemented in spring 2017 to model a translational EEG research laboratory environment for eleven undergraduate students. The three goals for this course were to: (1) engage multiple students in a semester-long mentored research experience, (2) determine whether student learning gains through engagement with an early research project are similar to those of students in established research projects, and (3) determine the feasibility of conducting and developing the background work for translational epilepsy research at Beloit College, a small liberal arts college with no clinical research affiliation. In this model, students were full partners with the instructor in the research process to determine the goals and direction of the project. Students gained experience with the research process and its challenges, became familiar with the procedures and outcomes of a basic science investigation of seizure detection in mice (Bergstrom et al., 2013), identified and mined a publicly available human intracranial EEG database, revised and tested a MATLAB-based algorithm—originally developed for seizure identification in mice—on human EEG signal, and established and validated a procedure for quantitative analysis of human intracranial EEG signal.

The course began with a review of research in the analysis of rodent EEG (Bergstrom et al., 2013) and a discussion of the function of translational research. The students and instructor collaboratively identified a strategy for goal-setting and reflection-based assessment that would be completed every two weeks throughout the 15-week semester, with one single-week goal-setting and reflection cycle before the mid-term break. Major assessments for the class were: (1) a public works-in-progress seminar at the Beloit College Student Research Symposium and (2) smaller weekly student-driven lecture/discussion presentations on timely research-related questions of neuroscience and epilepsy in the literature, e.g. neuron and brain anatomy, the action potential, the contribution of interictal spiking brain activity to epileptogenesis, and automated EEG analysis tools. Additional assessments included (1) pre- and post-course Course Undergraduate Research Experience (CURE) survey (Denofrio et al., 2007; Lopatto et al., 2008), (2) Student Assessment of Learning Gains, or SALG survey (Carroll, 2010), (3) and completion of the standard Beloit College end-of-semester course evaluations. Data collection and reporting procedures were approved by the Beloit College Institutional Review Board, and students provided informed consent for their participation in this study.

Students self-identified interests within the project and formed small groups to develop and accomplish sub-goals for the research project. Groups of two to six students were fixed for each two-week goal-setting/reflection period in the first half of the term and worked on goals within the broader research aims, such as identifying data sources, learning basic seizure analysis in EEG, and annotating and implementing MATLAB code. At the midterm, students re-organized into stable groups for the remainder of the semester. These groups were focused on preparing a literature review (four students), establishing a strategy for manual scoring of EEG signals (three students), and revising and analyzing MATLAB algorithm code (three students). One student served as an official liaison between the manual scoring and code revision groups (eleven students total). The two-week reflection cycle was maintained through the second half of the course. Class time (twice a week for 110 minutes per meeting) was used primarily for weekly lab group meetings, student presentations of relevant neuroscience topics, and individual and group work interactions with the instructor. Students were expected to be largely self-directed and to allot additional time outside of class, though logs of work were not required.

Preliminary observations and outcomes

Seven of the eleven course participants completed both the pre- and post-course surveys. Their responses indicate that students in this course made similar learning gains in relevant research skills to those of the CURE survey comparison groups (Denofrio et al., 2007; Lopatto et al., 2008) ($n \leq 9603$, Figures 1 and 2, two-sample t test, $p > 0.05$ for all comparisons). This indicates that engaging students in a course-based project at a very early stage is a meaningful mechanism for research at the undergraduate level and also performs an important role for faculty interested in establishing a new research project or trajectory.

Student responses from the SALG survey and Beloit College course evaluation seem to indicate that students, even while doing translational research, did not make significant connections between the concepts of basic science and translational research. For example, they did not mention translational research in any of their long-form comments. However, students did report in the course evaluations and the SALG that they made clear gains in self-directed learning (Box 1). It is important to note that, while most students had little or no prior experience with neuroscience, epilepsy, EEG, or the MATLAB programming environment, they were junior- or senior-level students who had already had extensive experience with

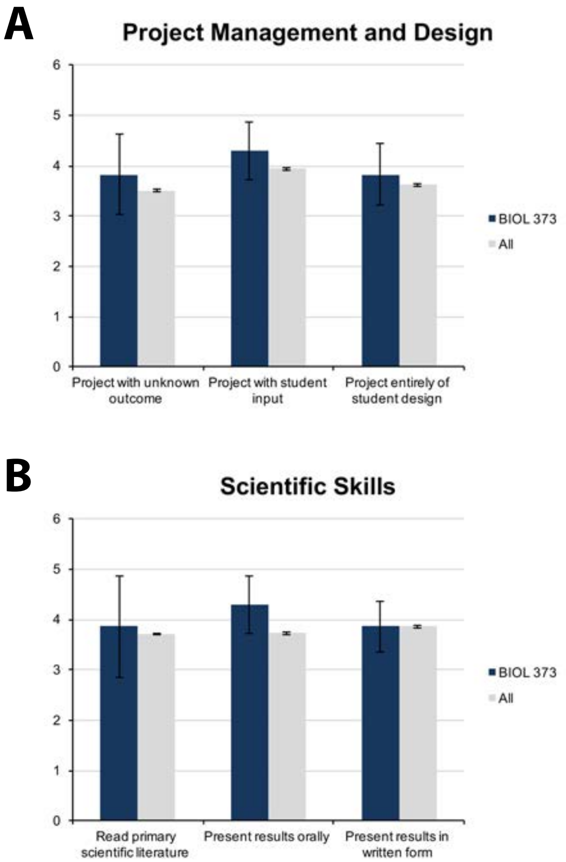


FIGURE 1:

Students reported learning gains in skills associated with research.

In this class, students were responsible for starting and defining a new research project that would continue beyond the course. Because starting a new project is, in many ways, different from continuing an established project, learning gains were assessed in areas similar to those made by students engaging in established research programs through course-based research activities. Students in BIOL 373 Advanced Neuroscience Research (blue bars) made learning gains similar to national averages (gray bars) in skills related to project management and design (A) and scientific research (B), indicating that engaging students in the research process early in a new project is a meaningful way to involve students in faculty research and development (two-sample t test, $p > 0.05$ for all comparisons). Though there was no statistically significant difference between this course and national averages for these assessment categories, gains associated with project management and design (A) were slightly higher than national averages, perhaps because the students were deeply involved in determining the progress and trajectory of the research plan. A larger gain was also noted in skills related to oral presentation of results (B) because one of the main assessments for the course was a public works-in-progress presentation as a part of our institutional student research symposium. 1 = little gain, 5 = great gain. Error bars represent 95% CI.

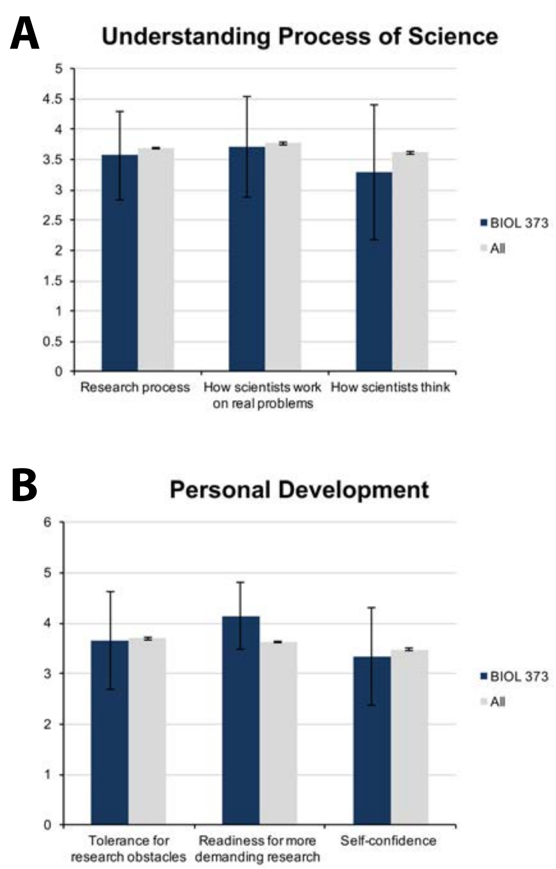


FIGURE 2:

Course benefits.

The benefits of mentored research extend far beyond learning basic scientific content. These CURE survey results indicate that students make valuable learning gains related to scientific research, even at a very early stage in the research project. Students in BIOL 373 Advanced Neuroscience Research (blue bars) made learning gains in personal development (A) and understanding the process of science (B) similar to national averages, indicating that engaging students early in the research process can be an impactful research experience (CURE survey). Together, these results suggest that undergraduate educators should consider engaging students at all stages of the research project, especially including the evaluation of project feasibility and the gathering of background data and information. 1 = little gain, 5 = great gain. Error bars represent 95% CI.

student-driven learning and research design through the broader Beloit College curriculum. Thus it is possible that students at an earlier level of academic development might not have made similar learning gains (Kirschner, Sweller, & Clark, 2006).

Establishing a new research project: engaging students in faculty development

In many course-based research projects, students are inserted into an already-established research project and are given a single task or experiment to complete by the end of the class. This course was different, in that the students were involved in establishing a new research program from the ground up and therefore were required to consider not only their role in the project but also how the project fit into a much broader context of sustained research. This challenging authentic research experience provided students with many opportunities to develop cognitive skills and resilience around the challenges of research and learning, especially self-directed learning and identifying research and educational resources. Assessment of the learning outcomes of this project indicate that involving students in research at a very early point in the process, even before research aims and procedures are fully developed, can be a powerful learning tool for students.

Involving students early in the development of a new research project can also be an efficient mechanism for increasing faculty research output. The translational research outcomes of this course were significant; the deliverables completed in the class which are relevant to starting a new research project are summarized in Box 2. Further, this preliminary work set the stage for three of the eleven students in the course to continue work with the faculty member on this project after the course, including serving as mentors for two new student researchers. Additional students will be recruited to this project in the future and will eventually see it through to completion and publication.

Together, the research deliverables and learning outcomes analyses suggest that situating early research project activities and goals as the context for a structured undergraduate course is an effective mechanism for faculty to test-drive or establish a new research

Box 1: Student Comments

SALG:

Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER key ideas.

- Because we mostly worked autonomously and spent a lot of time learning how to teach ourselves the things we needed to learn in order to move on with the project, the knowledge gained was a lot more active and integrated in the discovery process.
- I don't think there was much "teaching" involved per se. We had a lot of guidance and mentorship, but I learned a lot on my own. I also don't think we had many key ideas. Shared goals of course, but I think in terms of class content and understanding, we each walked away with different things.

College Course Evaluation:

Please reflect on both the strengths of the course and areas for improvement.

- I think taking a course like this is invaluable. It certainly was for me. Working doing research on a brand new subject for me and doing so outside of a wet lab was very interesting and formative. And structuring it as a work environment helped the students to become a good team.
- This course challenged me to find sources and information that I needed in order to understand this neuroscience and effectively try to apply it to our research work and to the general public.
- [I] wish there was more structure and guidance. We are not a big research lab, we aren't even just an undergraduate lab, we are a class, in a classroom, with class times, grades and all the class stuff. Sometimes I felt like cheap labor because I wasn't getting much out of it, but ambivalently was also getting lots of experience.

College Course Evaluation:

Would you recommend this course to others? Why or why not? (n = 11, all responded "Yes")

- Yes. It is a good stepping stone into what the real world team work is like. The professor will challenge but help you move along with the student's individual ideas. Class and professor also provide a great deal of practice and opportunities to better our presentation skills, and effective ways of presenting our knowledge to the general public.
- Yes, 300-level biol course, good to take for independence, synthesis, and "upper level" skills and independence.

program that extends beyond the course and, at the same time, engage more students in mentored research.

Challenges and Recommendations

The overt link to the unique niche of translational research within the biomedical community did not come through in the analysis of student responses, even though students were actively engaged with the process. The concept of translational research is new to most students, and so more careful attention to highlighting the important role of this type of work is needed in models like this. Because this was a laboratory course designed to focus on analysis of EEG signal, the student presentations were primarily focused on the neurological concepts relevant to the project. However, more attention could have been directed to the impact and structure of the bench-to-bedside research model.

A future course is planned around this research project, but it will be situated at a different point in the research process than the course described here. This new course could provide additional opportunities for students to engage with the research process and to gain a broader understanding of the clinical aspects of epilepsy. Three potential additions to the course could include (1) inviting a physician to meet with the class to discuss epilepsy and EEG in the clinical context, (2) including a conference call or in-person meeting with an epilepsy researcher at a large research institution to provide additional input to the project and to model effective research collaboration, and (3) assigning students to prepare patient-centered documents or presentations to explain epilepsy, EEG, and the analysis tools that they are developing.

Finally, it is important to note that this model requires significant buy-in and trust from the students, as it is a high-risk project for both the students and the faculty member, and many students expressed uncertainty regarding their progress at some point in the course. For instance, one student commented on a lack of typical "classroom-like" learning (Box 1) while also noting clear gains in experience. While a neuroscience "crash course" or more regular lectures and activities centered on the concepts of neuroscience might have been useful for content acquisition, it is important to help students recognize that these may be common feelings as they transition from a more typical undergraduate lecture-discussion course format to a student-centered project in which students themselves are responsible for identifying and structuring their learning content. It was useful to have regular check-ins with students to help to normalize feelings of frustration and uncertainty as they encountered research roadblocks and conflicting information from published reports. Still, it is possible that recognizing the emotional investment inherent in research can help students at this stage of their academic career build resilience for future challenges. This hypothesis must be tested as we build new models for engaging students in research at the undergraduate level and in preparation for broader participation within the STEM fields.

Box 2: Research Deliverables

The students completed the following research tasks by the end of the semester, building a strong background core for continued work on the research project.

- A literature review, summarizing the current state of wavelet-based EEG analysis, a core element of the neuroscience research component of the course.
- A library guide as an introduction to the project for student and faculty use at http://guides.beloit.edu/BIOL373.
- Identification of and interface with a public database of human intracranial EEG at ieeg.org.
- Analysis and annotation of murine EEG analysis code with special emphasis on identification of relevant parameters for testing in human EEG.
- Development of a quantitative manual EEG scoring strategy and description for novice evaluators that results in high reproducibility and inter-observer reliability.

Conclusion

Mentored research is a high-impact undergraduate education practice (Kuh, O'Donnell, & Reed, 2013), and STEM educators in particular must therefore be creative and develop more opportunities for students to be involved with and learn from the process. Students can and do make important learning gains through the process of investigating the feasibility of a translational research project and gathering background data and material in support of a larger project. The dual purpose of this course, to engage students in research and to develop a new avenue for a faculty member's research, situates it as a model through which instructors can recognize and harness the power of students at this stage of the research project. These results should encourage faculty to consider course-based research as a powerful tool that they may wish to use to develop new lines of inquiry, and student contributions to faculty work at all other stages of a research project should be considered an essential component of research at undergraduate institutions.

About the Author

Rachel A. Bergstrom is an assistant professor of biology at Beloit College in Beloit, WI. She is a SENCER Leadership Fellow with two major arms to her research agenda: 1) identification and quantification of ictal and interictal events in EEG, with a focus on seizure diagnosis and prediction, and 2) the intersection of identity and education in STEM, specifically how group work impacts the student experience in the classroom and is related to persistence in STEM.

References

Abend, N. S., Gutierrez-Colina, A., Zhao, H., Guo, R., Marsh, E., Clancy, R. R., & Dlugos, D. J. (2011). Interobserver reproducibility of electroencephalogram interpretation in critically ill children. *Journal of Clinical Neurophysiology : Official Publication of the American Electroencephalographic Society*, *28*(1), 15–19. https://doi.org/10.1097/WNP.0b013e3182051123

Acharya, U. R., Vinitha Sree, S., Swapna, G., Martis, R. J., & Suri, J. S. (2013). Automated EEG analysis of epilepsy: A review. *Knowledge-Based Systems*, *45*(Supplement C), 147–165. https://doi.org/10.1016/j.knosys.2013.02.014Benbadis, S. R., LaFrance, W. C., Papandonatos, G. D., Korabathina, K., Lin, K., Kraemer, H. C., & For the NES Treatment Workshop. (2009). Interrater reliability of EEG-video monitoring. *Neurology*, *73*(11), 843–846. https://doi.org/10.1212/WNL.0b013e3181b78425

Bergstrom, R. A., Choi, J. H., Manduca, A., Shin, H.-S., Worrell, G. A., & Howe, C. L. (2013). Automated identification of multiple seizure-related and interictal epileptiform event types in the EEG of mice. *Scientific Reports*, *3*, 1483. https://doi.org/10.1038/srep01483

Carroll, S. B. (2010). Engaging assessment: Using the SENCER-SALG to improve teaching and learning. In R. D. Sheardy (Ed.), *Science education and civic engagement: The SENCER approach* (Vol. 1037, pp. 149–198). Washington, DC: American Chemical Society. https://doi.org/10.1021/bk-2010-1037.ch010

Denofrio, L. A., Russell, B., Lopatto, D., & Lu, Y. (2007). Mentoring: Linking student interests to science curricula. *Science*, *318*(5858), 1872–1873. https://doi.org/10.1126/science.1150788

Fisher, R. S., Acevedo, C., Arzimanoglou, A., Bogacz, A., Cross, J. H., Elger, C. E., … Wiebe, S. (2014). ILAE official report: a practical clinical definition of epilepsy. *Epilepsia*, *55*(4), 475–482. https://doi.org/10.1111/epi.12550

Halford, J. J., Pressly, W. B., Benbadis, S. R., Tatum, W. O., Turner, R. P., Arain, A., … Dean, B. C. (2011). Web-based collection of expert opinion on routine scalp EEG: Software development and interrater reliability. *Journal of Clinical Neurophysiology*, *28*(2), 178–184. https://doi.org/10.1097/WNP.0b013e31821215e3

Hobin, J. A., Deschamps, A. M., Bockman, R., Cohen, S., Dechow, P., Eng, C., … Galbraith, R. (2012). Engaging basic scientists in translational research: Identifying opportunities, overcoming obstacles. *Journal of Translational Medicine*, *10*, 72. https://doi.org/10.1186/1479-5876-10-72

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75–86. https://doi.org/10.1207/s15326985ep4102_1

Kuh, G. D., O'Donnell, K., & Reed, S. (2013). *Ensuring quality & taking high-impact practices to scale*. Washington, DC: American Association of Colleges and Universities.

Lopatto, D., Alvarez, C., Barnard, D., Chandrasekaran, C., Chung, H.-M., Du, C., … Elgin, S. C. R. (2008). Undergraduate research. Genomics education partnership. *Science*, *322*(5902), 684–685. https://doi.org/10.1126/science.1165351

Shorvon, S. D. (2011). The etiologic classification of epilepsy. *Epilepsia*, *52*(6), 1052–1057. https://doi.org/10.1111/j.1528-1167.2011.03041.x

Tatum, W. O. (2013). How not to read an EEG: Introductory statements. *Neurology*, *80*(1 Supplement 1), S1–S3. https://doi.org/10.1212/WNL.0b013e318279730e

US Department of Health and Human Services (USDHHS). (2015). Translational science spectrum. Retrieved January 17, 2018, from https://ncats.nih.gov/translation/spectrum

US Department of Health and Human Services (USDHHS). (2017). NIH categorical spending - NIH research portfolio online reporting tools (RePORT). Retrieved January 17, 2018, from https://report.nih.gov/categorical_spending.aspx

Review of Digital Publication: Our World in Data

Matt Fisher
Science Education and Civic Engagement: An International Journal

Our World in Data is an online publication that will be of interest to many readers of Science Education and Civic Engagement: An International Journal. It brings together in one location data about a number of different topics related to how the world is changing. The site is produced at the University of Oxford by a team led by Max Roser, an economist at the university. Amazingly, the entire project is available free of charge as a public good!

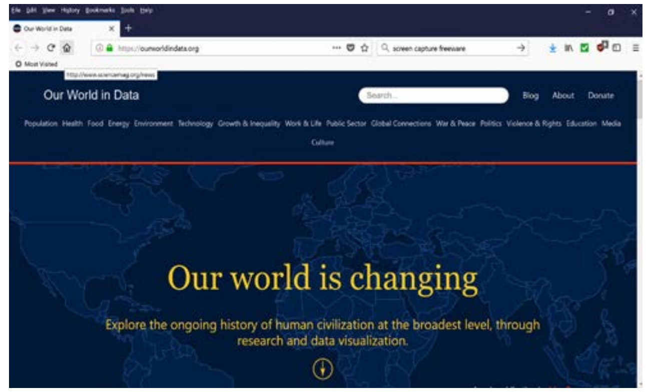
Roser began the project in 2011 and for several years was the sole author until grant funding allowed him to add team members. The long-term goal is to create 275 distinct entries in the site. Entries are gathered into thematic sections; as of January 2018, these include Population, Health, Food, Energy, Environment, Technology, Growth & Inequality, Work & Life, Public Sector, Global Connections, War & Peace, Politics, Violence & Rights, Education, Media, and Culture.

There are several features of the site that make it attractive to educators. The Energy section, for example, is divided into a number of subsections—energy production and changing energy sources, fossil fuels, renewables, carbon dioxide and other greenhouse gases. The section on energy production and changing energy sources is further divided into sections titled "Empirical View," "Correlates, Determinants, and Consequences," and "Data Sources."

There are numerous visualizations for topics such as energy production by source, energy production over time, energy intensities of the economies in various parts of the world, access to electricity, and per capita energy consumption, among many others. Some visualizations present the data over time and allow one to focus on a particular year. Other visualizations provide the option for changing from a graph to a map or changing the axes on a particular graph. Images can easily be downloaded as .png files for use in presentations or other documents. Data used in a particular visualization can be downloaded as a .CSV file that can be opened in Excel. All data are clearly identified regarding point of origin, and the sources appear to be reliable—academic sites, United Nations agencies, the World Bank, the World Health Organization, and others—and one section of the website explains how the team chooses the data that are presented. The site also contains an essay that explains the rationale for Our World in Data: to support better understanding, involvement, and policy making by presenting an accurate picture of global progress in development. Overall, the site conveys a commitment to transparency that is commendable.

I have used some of the visualizations from the site in three different courses this semester: information on energy consumption (per capita and by source) in General Chemistry II and in a course for nonscience majors focused on sustainability, and information on malaria in my biochemistry class. They added a dimension to the classes that would have been very difficult for me to accomplish otherwise.

For educators who want to bring a global dimension to their incorporation of civic engagement into a course, Our World in Data will be an invaluable resource. I highly recommend it.



https://ourworldindata.org/

Cultivating STEM Identity and Belonging through Civic Engagement:

Increasing Student Success (Self-efficacy and Persistence) for the Two-year College STEM Student

PAMELA LEGGETT-ROBINSON
Georgia State University

NARANJA DAVIS
Georgia State University

BRANDI VILLA
Belay Consulting

Abstract

Retention efforts in STEM have become a priority of colleges and universities. Two-year college STEM students are particularly affected by factors that contribute to low retention and persistence. To address STEM retention problems, a student support program was developed through National Science Foundation funding to support STEM student success. The program sought to enhance STEM identity, thereby increasing persistence. Participants were required to engage in STEM civic engagement, using their STEM knowledge and skills for community betterment. This study sought to examine the effects of these activities on students' STEM identity and ultimate persistence. Data were collected over years from participant surveys and interviews. We found that students had cultivated a sense of STEM identity, and that graduation and transfer rates increased as a result of their increased civic engagement. Students who engage in their community develop cultural competency, communication skills, and critical thinking ability and have opportunities to apply their knowledge.

Introduction

The Role of Two- year Colleges in STEM Education

Two-year colleges are an often overlooked but essential component in the pathway to Science, Technology, Engineering, and Mathematics (STEM) higher education (National Academies of Sciences, Engineering, and Medicine [NASEM] 2016; National Research Council [NRC] 2012). They play a unique role in STEM education, enrolling nearly half of the nation's undergraduate students (American Association of Community Colleges [AACC] 2014). Community colleges in the United States enroll more than eight million students annually, including 43% of U.S. undergraduates (AACC 2011; Mullin 2012). Approximately 50% of all college students who eventually earn bachelor's degrees in STEM begin their undergraduate education at two-year colleges (Tsapogas 2004; Starobin & Laanan 2010), and 20% of students who were awarded science and engineering doctoral degrees earned credits at a two-year college at some point in their academic careers (Chen 2013).

Community colleges provide a diverse student body (people of color, women, older students, veterans, international students, first-generation college students, low-income students, and working parents) with access to higher education. According to the American Association of Community Colleges, 52% percent of Hispanic students, 44% of African American students, 55% of Native American students, and 45% of Asian-Pacific Islander students attend two-year colleges (AACC 2011). Additional reports (Provasnik & Planty 2008) show the median age of two-year college students is 24, with 35% of the student population 30 or older. Further data show that 20% of two-year college students are married with children, and an additional 15% are single parents (Provasnik & Planty 2008; Li 2007). Almost half of college-going students attend community colleges at some point in their academic careers; low-income, first generation, and under-represented minority students are more likely to enroll in two-year institutions (NASEM 2016).

Two-year colleges attract many students by providing affordable tuition, flexible scheduling, small class sizes, and access to faculty. These institutional attributes accommodate those two-year college students who take a nonlinear path to degree completion due to family and work obligations (Pérez & Ceja 2009). On account of the rich diversity of their student population, two-year colleges have the potential to increase participation of non-traditional and underrepresented students in STEM.

Retention and Persistence for Community College STEM Students

Retention and persistence of all STEM students continue to be of significant concern as data reveal that more than half of freshman who initially declare STEM majors leave these fields before graduation (President's Council of Advisors for Science and Technology [PCAST] 2012; Chen 2009; Chen 2013). Among all students who declared their intentions to pursue STEM majors, only 43% were still in a STEM major at the time of their last enrollment, with the others all transitioning to other majors. Even more problematic, only 7.3% of STEM students who began at a two-year college received a STEM bachelor's degree after six years, compared with 45% of students who started in a four-year program (Chen 2013).

Factors influencing retention and persistence in STEM majors are diverse and often interconnected. Leading reasons for low STEM retention and persistence at both the two-year and four-year colleges are uninspiring introductory courses, lack of math preparation, and an academic culture not welcoming of women, minorities, and non-traditional students (PCAST 2012; Seymour and Hewett 2000; Griffith 2010; Huang, Taddese, & Walter 2000). Additionally, STEM students at the two-year college are affected by external circumstances such as work and family obligations and have fewer economic and social resources and fewer STEM role models than their four-year traditional student counterparts. For the two-year college STEM student, these external circumstances coupled with an unwelcoming STEM culture undermine their sense of identity, belonging, and self-efficacy, which are critical to their STEM retention and persistence.

The Culture of STEM

The explicit and implicit customs, behaviors, and values that are normative within STEM education make up the culture of STEM (NRC 2009). An examination of the culture of STEM education is important because the social, psychological, and structural dimensions of STEM education in two-year and four-year colleges influence student identity, belonging, self-efficacy, and encouragement. The experiences students gather during their interactions with the "STEM culture" of the department or institution drive student awareness and understanding of program standards, academic expectations, STEM identity, and their sense of belonging in the program. More importantly, student experiences within the STEM culture and the encouragement or lack thereof can have a profound impact on the student's self-efficacy and desire to persist (Cabrera et al. 1999; Eccles, Wigfield, & Schiefele 1998; Reid & Radhakrishnan 2003; Pérez, Cromley, & Kaplan 2014).

Identity/Belongingness, Encouragement, and Self-efficacy

Self-perceptions regarding academic competence are framed by personal and collective identities. Each student has many such identities—racial, ethnic, socioeconomic, professional, sexual/gender, and family. These identities are framed by upbringing, experiences, and society at large and can shift across time either unconsciously or through deliberate effort (Good 2012). Students' positive identification with their discipline can enhance academic engagement and belongingness and prove to be a great source of encouragement. However, more commonly the obverse is true, especially for non-traditional and underrepresented STEM students. These students often experience challenges such as isolation, invisibility, discrimination, and a sense of not belonging and disconnectedness from external social and cultural networks (Ong 2001; NRC 2012).

Belonging to valued social groups is a fundamental human need; a sense of inclusion is particularly important for underrepresented groups in STEM when stereotypes imply that they might be unsuited to certain settings, such as rigorous academic classes (Baumeister & Leary 1995; Dovidio, Major, & Crocker 2000; Walton & Cohen 2007; Cohen & Steele 2002). Feeling a sense of belonging and acceptance by others in STEM (faculty and peers) is crucial to retention and persistence for these STEM students (Johnson 2012; Palmer, Maramba, & Dancy 2011).

Stereotypical ideas about what constitute appropriate fields of study for two-year college students or comments regarding academic preparedness/achievement in math and science can serve as critical barriers to retention and persistence. According to Starobin & Laanan (2008), even when these students possess a strong math or science background, they often receive little encouragement or support from faculty. Creating a sense of encouragement and a support system for two-year college STEM students is paramount to increasing retention and persistence. Studies show non-traditional and underrepresented minorities need proactive personal encouragement and positive media messages to counteract the status quo "culture of STEM" (Hanover Research, 2014). Programs and activities that facilitate healthy positive relationships and offer encouragement among peers and from faculty promote student engagement and feelings of belonging.

Academic self-efficacy is commonly defined as the belief in one's capabilities to achieve a goal or an outcome using one's skills under certain circumstances, and that performance and motivation are determined by how effective people believe they can be. (Snyder & Lopez 2007; Bandura 1982). More specifically, for many two-year STEM students, academic self-efficacy is entangled with STEM identity as it refers to the belief or conviction that they can successfully obtain a STEM degree (Marra et al. 2009).

A major source of academic self-efficacy is simply having the raw knowledge, skills, and experience required to successfully reach a goal or to complete a task; this source of efficacy is commonly referred to as mastery experience (Bandura 1997). In the context of two-year STEM students, this means having a positive experience in completing a STEM task, specific course, and/or obtaining an associate's degree.

STEM Civic Engagement through Peer Tutoring

STEM civic engagement covers a wide array of activities and learning outcomes in which students participate in the formal and informal STEM processes that address community needs and seek to improve the quality of life for individuals, groups, and entire communities. In this context, STEM civic engagement contributes to student growth by connecting authentic and meaningful service to communities with content and skills acquired in the classroom. Civic engagement activities, such as tutoring others in STEM content, present students with opportunities to reflect upon their own academic goals (also known as metacognition) (NRC, 2000), transform their communities, and identify and address social challenges that are specific to our society, i.e. the lack of STEM subject understanding, the lack of STEM role models, etc.

It is well documented that tutoring has beneficial effects on both the tutor and the tutee. In particular, many studies have shown that tutoring increases the content knowledge as well as the self-concept of the tutor (Britz, Dixon, & McLaughlin1989; Cohen, Kulik, & Kulik1982; Early 1998). Students who tutor feel more positive towards themselves as students, and they display an improved academic self-concept. Through this enhanced self-concept, students identify themselves more strongly as students of their discipline (Early 1998). Furthermore, students in STEM disciplines who serve as leaders among their peers experience increased self-efficacy and retention, and studies have shown that this trend applies to both majority and underrepresented students. Thus, peer leadership may provide a path for improving retention of underrepresented groups in the field (Hug, Thiry, & Tedford 2011). Additional outcomes for STEM leaders (mentors or tutors) include increased participation in internships and higher GPAs (Monte, Sleeman, & Hein 2007). Other studies indicate that the opportunity to tutor or mentor others allows STEM students to develop a sense of belonging and social relationships that aid in student retention; to some extent, this can be attributed to improved experience with and understanding of STEM culture at the students' institutions (Kiyama 2014; Kiyama et al. 2014).

Existing research provides a limited understanding of the relationship between identity/belonging, encouragement, self-efficacy, civic engagement, and retention rates for two-year college STEM students. Our study explored the effects of civic engagement volunteer activities on student identity/belonging, encouragement, and self-efficacy. The results show a relationship between these activities and STEM persistence and retention for two-year college STEM students.

Institution and Program

Perimeter College is part of Georgia State University, a diverse, multi-campus urban research university in metropolitan Atlanta. The college is the major provider of associate's degrees and student transfer opportunities in Georgia and a gateway to higher education, easing students' entry into college-level study. More than 21,000 students, representing all ages and backgrounds, are enrolled in Perimeter College. Through the college, Georgia State serves the largest number of dual enrollment, international, online, transfer, and first-time freshman students in the University System of Georgia.

Beginning in Spring 2012, through National Science Foundation funding, a Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) was developed for two-year, full-time students, with a minimum 2.8 grade point average. To participate, students must have U.S. citizenship or status as permanent resident alien or refugee alien and be majoring in a STEM field of study, declared at any point but usually after the first year of coursework. The objectives of the program are two-fold: (a) to increase the number of students who persist in all STEM fields at the institution (chemistry, biology, math, geology, physics, computer science, and engineering) and (b) to increase the number of students who graduate and/or transfer to four-year colleges/universities to complete their STEM baccalaureate degrees. The demographic breakdown of the STEP participants throughout the lifetime of the program mirrored that of the STEM majors in the institution; the majority of STEP students are underrepresented minorities.

Students participate in the program for an average of three semesters (including a summer semester). Stipends are given to those participants who meet the following criteria each semester: (a) are enrolled as a full-time student (12 credit hours during the fall and spring semester); (b) maintain a cumulative minimum GPA of 2.8 and a minimum semester GPA of 2.5; (c) participate in a minimum of 10 hours of STEM civic engagement activities per semester; (d) participate in a minimum of six STEM–related activities (STEP-sponsored and others). Stipend amounts vary depending on the academic classification of the participant. Additional stipends are given for participation in the Summer Bridge I undergraduate research experience (three weeks), Summer Bridge II undergraduate research experience (eight weeks), and participation in the NSF's Research Experiences for Undergraduates program. STEP sponsors multiple STEM activities each semester, including STEM industry visits and college visits.

STEM Civic Engagement Activities

Program participants are engaged in the STEM community in a number of ways, some of which are required elements and others that are optional. All program participants are required to attend a number of career workshops and to visit industry sites and four-year institutions. Additionally, throughout their tenure in the program, participants are required to complete a minimum of 10 hours of civic engagement per semester. Many of the students fulfill this requirement by serving as tutors in on-campus student support facilities or off campus in their communities. Additional civic engagement opportunities are available to the students through outreach activities (such as science festivals), environmental clean-ups, and other STEM-related events. Many students (73%) completed more than the required 10 hours per semester of service; the average contribution per semester is 12 hours of service.

Methods

In order to determine student outcomes, we tracked students through their program experience and after graduation and transfer to four-year institutions. During their tenure in the program, participants were asked to complete a number of surveys and focus group interviews to determine their reactions to and the perceived outcomes of the various student support activities. Surveys were retrospective in design: students were asked to think back to how they felt at the beginning of the program and compare that to how they felt at the time of taking the survey (usually after one year in the program). This approach maximizes ability to match responses and also eliminates pretest sensitivity and response shift bias, wherein students tend to underestimate or overestimate their attitudes towards the unknown prior to the start of an intervention (Howard 1980; Pratt, McGuigan, & Katzev 2000). In addition to surveys given during students' tenure in the program, we also administered an alumni survey to those who had completed the program.

In particular, our 23-item student survey drew upon existing instruments designed to assess changes in STEM engagement (Fredricks et al. 2005), STEM identity and belonging, encouragement (Leonowich-Graham & Condley 2010), math and science anxiety (Bai et al. 2009; Glynn and Koballa 2006), commitment to research, and intent to persist (Tocker 2010). Further definition of these psychosocial constructs is presented in Table 1,

TABLE 1.

Psychosocial Constructs Measured by the STEP Student Survey

Construct	Definition	Sample Item
STEM Engagement	Student engagement can be examined in terms of behavioral engagement (demonstration of interest), emotional engagement (positive reactions), and cognitive engagement (student investment in learning).	I enjoy my STEM coursework.
STEM Identity and Belonging	A sense of belongingness and identifying with STEM contributes to student pursuit of STEM careers.	I can see myself in a STEM career.
Comfort with Math and Science	Previous research on math and science anxiety has shown that it is a multi-dimensional psychological construct that involves complex factors, such as feelings of pressure, performance inadequacy, and test anxiety that interfere with the manipulation of numbers and solving math problems. The comfort with math and science measure is intended to assess the feelings of anxiety, dread, and nervousness associated with mathematics.	I am comfortable with science.
Encouragement	Studies attempting to get at influences that lead students to major in Computer Science have elucidated encouragement as a major factor in this decision. Furthermore, feeling encouraged can be a predictor of whether or not students are likely to major in a STEM discipline.	I feel encouraged to get a STEM degree.
Intent to Persist	Student intention to persist is highly indicative of actual persistence. Intent to persist can be examined in a temporal manner, looking at short-term degree attainment and long-term commitment.	I intend to take more courses in STEM.

TABLE 2.
Growth in Student Attitudes towards STEM and Self as Measured by Annual Student, Surveys throughout the Program

Construct		Fall 2012 (n=23)		Spring 2013 (n=29)		Spring 2014 (n=33)		Spring 2015 (n=36)		Spring 2016 (n=25)	
		Mean[1]	Change[2]	Mean[1]	Change[2]	Mean[1]	Change[2]	Mean[1]	Change[2]	Mean[1]	Change[2]
STEM Engagement	Before	4.11	+0.22 (p=0.017)	4.04	+0.36 (p<0.001)	4.28	+0.23 (p=0.008)	3.83	+0.46 (p=0.002)	4.28	+0.35 (p=0.002)
	Now	4.33		4.40		4.51		4.30		4.63	
STEM Identity & Belonging	Before	4.00	+0.54 (p<0.001)	4.16	+0.29 (p=0.004)	4.28	+0.31 (p=0.014)	3.78	+0.61 (p<0.001)	4.40	+0.32 (p=0.005)
	Now	4.54		4.45		4.59		4.39		4.72	
Comfort with Math & Science	Before	4.12	+0.18 (p=0.008)	4.37	+0.06 (p=0.491)	4.23	+0.24 (p=0.008)	3.78	+0.37 (p=0.014)	4.37	+0.22 (p=0.029)
	Now	4.30		4.43		4.48		4.15		4.59	
Encouragement	Before	4.04	+0.52 (p=0.030	4.07	+0.32 (p=0.059)	4.31	+0.32 (p=0.023)	3.82	+0.76 (p<0.001)	4.36	+0.36 (p=0.026)
	Now	4.57		4.39		4.64		4.59		4.72	
Intent to Persist	Before	4.33	+0.30 (p<0.001)	4.40	+0.21 (p=0.024)	4.44	+0.19 (p=0.073)	3.98	+0.49 (p=0.002)	4.53	+0.16 (p=0.056)
	Now	4.64		4.61		4.64		4.47		4.69	

Note. [1]Scale=1, Strongly Disagree to 5, Strongly Agree. [2]Change is calculated by subtracting the Before scores from the Now scores. Only students with matched Before and Now data were assessed for significance.

along with example survey items. Students were asked to respond to survey items using a 5-point Likert scale of agreement (1=Strongly Disagree to 5=Strongly Agree).

To collect qualitative data, students were assembled in groups of 812 to participate in annual focus group interviews. During these interviews, students were asked probing questions regarding their experiences in the program and how they affected their identity, engagement, and intent to persist in STEM. The focus group interview protocol included questions such as the following:

- Describe civic engagement activities that you participated in.
- Did these activities change the way you think about yourself? About your intended career?
- Are you making different decisions because of participating in this program? Explain.

To further explore the link between persistence and gains made by students as a result of the program and civic engagement activities, a multiple regression analysis was conducted whereby the outcome variable was Intention To Persist and the predictor variables were STEM Engagement, STEM Identity and Belongingness, Math and Science Anxiety, Research, and Encouragement. To compute the outcome and predictor values for this analysis, items from the student survey were averaged for each corresponding construct.

Results

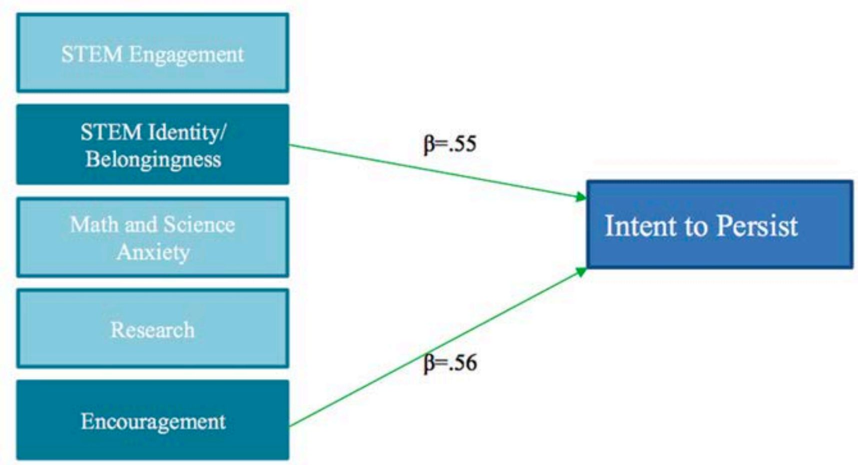
Qualitative data gleaned from participants' open-ended responses to surveys and during focus group interviews suggested that the STEP program positively impacted their motivation to pursue STEM education and careers by enhancing their sense of STEM identity and belonging and by providing social support and encouragement.

> *[STEP] helped me to be confident and to trust myself that I can do better things if I have the will. It also helped me make the decision that I belong to a STEM family.*
>
> *STEP enhanced my vision of being a scientist.*
>
> *I was about to give up on my school.…[A]fter meeting and getting help from different people, I was able to rethink my major and continue my studies.*

Additionally, annual surveys completed by program participants demonstrated that they made significant gains in terms of STEM engagement, STEM identity and belongingness, comfort with math and science, encouragement, and intent to persist. Table 2 shows statistically significant gains in attitude measured by these surveys over the course of the program.

FIG 1.

Regression Analysis of Aalumni Survey Data (n=39)



Note. Numbers along directional paths represent standardized ß. Solid green line= significant at p<.05.

Figure 1 summarizes the results of the regression analysis, conducted using data from the alumni surveys administered in 2013 and 2015 (n=39). Students taking the alumni survey had all completed their program and/or transferred to a four-year institution. Alumni survey data were chosen for this regression analysis in order to limit the findings to that of a longer-term student perspective; these students had the benefit of looking back over their entire program experience, and these data represent a more complete picture. The regression model with all five predictors explained 95% of the variance in the outcome variable ($R2=.948$, $F(5,33)= 119.18$, $p<.001$). Controlling for other variables in the model, the results indicate that two variables statistically significantly predict intent to persist:

- STEM Identity and Belongingness (ß=.55, $p<.001$)
- Encouragement (ß=.56, $p<.001$)

This suggests that students' motivations to pursue additional STEM education and/or careers is contingent on the degree to which the program was able to (a) improve their sense of belonging in STEM and (b) provide encouragement for attaining a STEM degree. This finding corroborates previous research which indicates that STEM persistence increases as students experience a greater sense of belonging and general social support from mentors and colleagues (London et al. 2011).

Quantitative data analysis was limited in that the response rate for the student surveys was not 100%. (Response rate was roughly 85% across all items and multiple administrations of the survey.) Thus, responses might demonstrate a bias towards the positive, as students who felt less compelled to respond to the program survey were often those who had left the program (and usually the institution). Additionally, due to the low sample size, we must use caution when interpreting the results of the regression analysis. Correlations among constructs suggest that multicollinearity may have impacted the results of the regression. To mitigate the effects of multicollinearity, each predictor variable in the regression model was standardized (e.g., converted to a z-score). Furthermore, the results provided in the current report are preliminary and should be replicated using a larger sample size. It is also important to note that disaggregation of data by gender or race/ethnicity did not reveal significant differences among the participating groups of students.

Qualitative Findings

During annual interviews, students were asked about their experiences in program activities, and how they thought these experiences affected them. In particular, we explored which facets of the program led to increased STEM identity and encouragement. Students explained that the volunteer work they did to meet their civic engagement requirements helped them in many ways. Specifically, they were able to solidify their STEM content knowledge and improve their communication and leadership skills:

> *Being part of [tutoring]… helps you refresh your mind. When you are helping them it helps you refresh your mind. You refresh communication skills.*
>
> *It improves your leadership skills. One thing that I've learned is that you're more involved in the community and you're more exposed to the problems of the community. I think that it really improves your communication skills, your leadership, and it helps you learn more about your community.*

TABLE 3.
Comparison of Outcomes for Program and Non-program STEM Students at Institution

	GSU-PC STEM Students Entering 2011-2012	STEP program students entering 2011-2015	STEP program students entering 2011-2015 who completed at least 10 hours of civic engagement per semester
Enrollment by FTE	4402	214	116
Graduates within 2 years - Associate's degree	154 (3%)	47 (22%)	34 (29%)
Transfers within 2 years to a 4-year institution	542 (12%)	48 (22%)	50 (43%)

Participants also felt that civic engagement motivated them to work harder in STEM and gave them a broader perspective on their futures.

> *It opens your mind up to all that's out here. It's opened my mind to what's out there and made me think that I want to help people. It's an unselfish thing.*

> *Even being around the other members, outside of class, you get to know them—being around people that are really smart, makes me want to be really smart.*

> *You become more motivated. You want to learn as much as you can. You want to help as much as you can. You want to put things out there so that people can learn from you.*

> *It's not about improving myself, but improving other people's lives. I started thinking about non-profits. I started thinking about things that I didn't think about before.*

In short, students explained that participation in civic engagement improved their STEM and soft skills and motivated them to consider a broader range of career options. Their sense of identity as part of a STEM community was solidified through exchanges with their peers as well as with those they were helping.

In order to examine the effect of programmatic activities on actual persistence, we tracked transfer and graduation rates of the scholars, and compared those to non-participant STEM students. Table 3 indicates that program participants were more than twice as likely to complete their program of study and /or transfer to a four-year institution to pursue a STEM degree. Furthermore, STEP students who completed at least 10 hours per semester of civic engagement activities were even more likely to graduate and/or transfer (Table 3).

Discussion

The culture that students encounter when studying STEM has an effect on their interest, self-concept, sense of connectedness, and persistence in STEM. Students who persist often have to draw upon personal, cultural, and co-curricular resources to counter messages about the nature of ability and stereotypes that they encounter in interactions with faculty and that are embedded in organizational norms and practices.

Interventions aimed at improving participant identity and belonging have been shown to enhance achievement and persistence (Cohen & Garcia 2008). Not surprisingly, students in highly evaluative environments (such as STEM courses) are sensitive to stereotype threat when facing difficult coursework and feedback, suggesting that it is particularly important to focus on improving STEM identity in an effort to increase student success (Cohen & Steele 2002).

Despite limitations of the study discussed in the results section, we found that an increase in STEM identity and belongingness and encouragement predicted an increase in intent to persist, and that actual persistence was improved with civic engagement. We posit that opportunities to guide others through tutoring and other civic engagement activities enhanced STEM identity, as scholars explained to us during interviews. In concurrence with STEM achievement, improved identity and belongingness in STEM led to a substantially higher likelihood of graduation and or transfer, as evidenced by participant graduation and transfer rates in comparison to those of non-participant STEM students at the institution. Participating students still face a number of challenges, as do their non-participating counterparts; though the overall graduation and transfer rate for participants is still alarmingly low, the trend towards success is encouraging and suggests that interventions aimed at increasing STEM identity through civic engagement will increase overall STEM diversity in academe and the workforce

About the Authors

Dr. Pamela M. Leggett-Robinson is the Science Department associate chair and an associate professor of chemistry on the Decatur campus of Georgia State University-Perimeter College. Dr. Leggett-Robinson has served as a program director for several NSF and NIH initiatives and is currently the principal investigator of Georgia State University-Perimeter College's NSF STEP grant. Her research and scientific presentations focus on natural product chemistry, surface chemistry, and student support programs in STEM education. She holds a BS in Chemistry from Georgia State University, an MS in Bio-Inorganic Chemistry from Tennessee Technological University, and a PhD in Physical Organic Chemistry from Georgia State University. As corresponding author, Dr. Leggett-Robinson can be reached at pleggett1@gsu.edu.

Mrs. Naranja Davis is the NSF GSU-PC STEP coordinator. She has worked as a coordinator on several other NSF STEM initiatives over the past 10 years and is experienced in student data systems. Ms. Davis has a BS in Communication with a minor in Public Relations.

Dr. Brandi Villa did her graduate research in areas of applied and environmental microbiology as well as program evaluation of a science education outreach organization. She has been a science educator at middle school, high school, and undergraduate levels for more than a decade and thus brings an educator and researcher's perspective to the design and implementation of education research and program evaluation. In addition to her passion for all aspects of STEM education, Dr. Villa particularly enjoys challenges related to evaluation design, reporting, and data visualization.

References

American Association of Community Colleges (AACC). (2011). Fast facts, 2011. Washington, DC: American Association of Community Colleges.

American Association of Community Colleges (AACC). (2014). Fact Sheet. Washington, DC: American Association of Community Colleges.

Bai, H., Wang, L., Pan, W., & Frey, M. (2009). Measuring mathematics anxiety: Psychometric analysis of a bi-dimensional affective scale. Journal of Instructional Psychology, 36(3), 185–193.

Bandura, A. (1997). Self-efficacy: The exercise of control. New York: W.H. Freeman and Company.

Baumeister, R. F., & Leary, M. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. Psychological Bulletin, 117(3), 497–529.

Britz, M. W., Dixon, J., & McLaughlin, T. F. (1989). The effects of peer tutoring on mathematics performance: A recent review. B.C.J. Special Education, 13,17–33.

Cabrera, A. F., Nora, A., Terenzini, P. T., Pascarella, E. T., & Hagedorn, L. S. (1999). Campus racial climate and the adjustment of students to college: A comparison between white students and African-American students. Journal of Higher Education, 70, 134–160.

Chen, X. (2009). Students who study science, technology, engineering, and mathematics (STEM) in postsecondary education. Washington DC: U.S. Department of Education, National Center for Education Statistics, Institute of Education Sciences. Retrieved January 31, 2018 from https://nces.ed.gov/pubs2009/2009161.pdf.

Chen, X. (2013). STEM attrition: college students' paths into and out of STEM fields (NCES 2014-001). Washington DC: U.S. Department of Education, National Center for Education Statistics, Institute of Education Sciences. Retrieved January 31, 2018 from https://nces.ed.gov/pubs2014/2014001rev.pdf.

Cohen, G. L., & Garcia, J. (2008). Identity, belonging and achievement: a model, interventions, implications. Current Directions in Psychological Science, 17, 365–369.

Cohen, G. L., & Steele, C. M. (2002). A barrier of mistrust: How negative stereotypes affect cross-race mentoring. In J. Aronson (Ed.), Improving academic achievement: Impact of psychological factors on education. San Diego, CA: Academic Press.

Cohen, P. A., Kulik, J. A., & Kulik, C. C. (1982). Educational outcomes of tutoring: A meta-analysis of findings. American Educational Research Journal, 19, 237–248.

Dovidio, J. F., Major, B., & Crocker, J. (2000). Stigma: Introduction and overview. In T. F. Heatherton (Ed.), The Social Psychology of Stigma (pp. 1–28). New York: Guilford Press.

Early, J. W. (1998). The impact of peer tutoring on self-esteem and Texas Assessment of Academic Skills mathematics performance of tenth grade students. Unpublished doctoral dissertation, Texas A&M University, College Station, TX.

Eccles, J., Wigfield, A., & Schiefele, U. (1998). Motivation to succeed. In W. Damon (Series Ed.) and N. Eisenberg (Volume Ed.), Handbook of Child Psychology. Vol. 3: Social, Emotional, and Personality Development (5th ed., pp. 1017–1095). New York: Wiley.

Fredricks, J. A., Blumenfeld, P. C., Friedel, J., & Paris, A. (2005). School engagement. In K. A. Moore and L. Lippman (Eds.), Conceptualizing and measuring indicators of positive development: what do children need to flourish? New York: Kluwer Academic/Plenum Press.

Glynn, S. M., & Koballa, T. R., Jr. (2006). Motivation to learn college science. In J. J. Mintzes & W. H. Leonard (Eds.), Handbook of college science teaching. Arlington, VA: National Science Teachers Association Press.

Good, C. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. Journal of Personality and Social Psychology, 102(4), 700–717.

Griffith, A. L. (2010). Persistence of women and minorities in STEM field majors: Is it the school that matters? Retrieved January 31, 2018 from http://digitalcommons.ilr.cornell.edu/workingpapers/122/

Hanover Research (2014). Encouraging Students to Embrace STEM programs. Retrieved January 31, 2018 from http://mygaen.org/research/Encouraging%20Students%20to%20Embrace%20STEM%20Programs.pdf.

Howard, G. S. (1980). Response-shift bias: A problem in evaluating interventions with

pre/post self-reports. Evaluation Review, 4(1), 93–106.

Huang,G., Taddese, N., & Walter, E. (2000). Entry and persistence of women and minorities in college science and engineering education (NCES 2000–601). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Hug, S., Thiry, H., & Tedford, P. (2011, March). Learning to love computer science: Peer leaders gain teaching skill, communicative ability, and content knowledge in the CS classroom. SIGCSE: Proceedings of the 42nd ACM Technical Symposium on Computer Science Education, Dallas, TX (pp. 201–206).

Johnson, D. R. (2012). Campus racial climate perceptions and overall sense of belonging among racially diverse women in STEM majors. Journal of College Student Development, 53(2), 336–346.

Kiyama, J. M. (2014). Structured opportunities: Exploring the social and academic benefits for peer mentors in retention programs. Journal of College Student Retention: Research, Theory, & Practice, 15, 489–514.

Kiyama, J. M., Luca, S. G., Raucci, M., & Crump-Owens, S. (2014). A cycle of retention: Peer mentors' accounts of active engagement and agency. College Student Affairs Journal. 32, 81–95.

Leonowich-Graham, P., & Condly, S. (2010). Encouragement may be the missing link in the pursuit of CS / IT Majors. Fall 2010 Mid-Atlantic ASEE Conference, Villanova University. Retrieved January 31, 2018 from https://www.asee.org/documents/sections/middle-atlantic/fall-2010/01-Encouragement-May-Be-the-Missing-Link-in-the-Pursuit-of-CS-I.pdf.

Li, X. (2007). Characteristics of minority-serving institutions and minority undergraduates enrolled in these institutions (NCES 2008-156). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

London, B., Rosenthal, L., Levy, S., & Lobel, M. (2011). The influences of perceived identity compatibility and social support on women in nontraditional fields during the college transition. Basic and Applied Social Psychology, 33, 304–321.

Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2009) Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering student self- efficacy. Journal of Engineering Education ,98(1), 27–38.

Monte, A. E., Sleeman, K. A., & Hein, G. L. (2007, October). Does peer mentoring increase retention of the mentor? 37th ASEE/IEEE Frontiers in Education Conference. Milwaukee, WI.

Mullin, C. M. (2012, February). Why access matters: The community college student body (Policy Brief 2012-01PBL). Washington, DC: American Association of Community Colleges

National Academies of Sciences, Engineering, and Medicine (NASEM). (2016). Barriers and opportunities for 2-year and 4-year STEM degrees: Systemic change to support students' diverse pathways. Washington, DC: National Academies Press.

National Research Council (NRC). (2000). How people learn: Brain, mind, experience, and school.. Expanded Edition. Washington, DC: National Academies Press.

National Research Council (NRC). (2009). Learning Science in Informal Environments: People, Places, and Pursuits. Washington, DC: The National Academies Press.

National Research Council (NRC). (2012). Community colleges in the evolving stem education landscape: Summary of a summit. Washington, DC: National Academies Press.

Ong, M. (2001). Playing with in/visibility: How minority women gain power from the margins of science culture. Women in Higher Education, 10/11, 4–44.

Palmer, R. T., Maramba, D. C., & Dancy, T. E. (2011). A qualitative investigation of actors promoting the retention and persistence of students of color in STEM. Journal of Negro Education, 80(4), 491–504.

Pérez, P., & Ceja, M. (2009). Best practices and outcomes in transfer to universities. Journal of Hispanic Higher Education. 9(1), 6–21.

Pérez, T., Cromley, J. G., and Kaplan, A. (2014). The role of identity development, values, and costs in college STEM retention. Journal of Educational Psychology, 106(1), 315–329.

Pratt, C., McGuigan, W., & Katzev, A. (2000). Measuring program outcomes: Using retrospective pretest methodology. American Journal of Evaluation, 21(3), 34–349.

President's Council of Advisors for Science and Technology (PCAST). (2012). Report to the President: Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Washington, DC: Executive Office of the President.

Provasnik, S., & Planty, M. (2008). Community colleges: Special supplement to the Condition of Education 2008 (NCES 2008-033). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Reid, L. D., & Radhakrishnan, P. (2003). How race still matters: The relation between race and general campus climate. Cultural Diversity and Ethnic Minority Psychology, 9, 263–275.

Snyder, C. R., & Lopez, S. J. (Eds.) (2002). Handbook of positive psychology. Oxford: Oxford University Press.

Starobin, S. & Laanan, F. S. (2008). Broadening female participation in science, technology, engineering, and mathematics: Experiences at community colleges. New Directions for Community Colleges, 142, 37–46.

Tocker, Y. (2010). Non-ability correlates of the science/math trait complex: Searching for personality characteristics and revising vocational interests. Doctoral dissertation: Georgia Institute of Technology, Atlanta, GA.

Tsapogas, J. (2004). The role of community colleges in the education of recent science and engineering graduates (InfoBrief 04-315.) Arlington, VA: Division of Science Resources Statistics, National Science Foundation.

Walton, G. M., & Cohen, G. L. (2007). A question of belonging: Race, social fit, and achievement. Journal of Personality and Social Psychology, 92(1), 82–96.

A Multitier Approach to Integrating STEM Education into a Local Elementary School

DIANA SAMAROO
New York City College of Technology,
Graduate Center of City University of New York

SERVENA NARINE
P.S. 307 Daniel Hale Williams School

AREEBA IQBAL AND KAYLA NATAL
New York City College of Technology

MELANIE VILLATORO
New York City College of Technology

Abstract

The targeting of elementary school students early in their education with exposure to the different Science, Technology, Engineering and Mathematics (STEM) fields will provide them future access to college offerings and career possibilities. Faculty and students from New York City College of Technology worked with young students at a local elementary school, creating and implementing programs that will help to strengthen the nation's STEM workforce and to prepare students to be productive citizens with a strong sense of self.

Introduction

The New York City College of Technology (informally known as "City Tech") partnership with P.S. 307 Daniel Hale Williams School began in 2014. The partnership aimed to promote A Better Educated City; an investment in STEM, and our nation's future. New York City College of Technology is part of the City University of New York (CUNY) system. Daniel Hale Williams is an elementary school serving students in Pre-K through Grade 5, which became a science and technology-themed magnet school for STEM Studies after being a recipient of a grant from the federal Magnet Schools Assistance Program. For the 2017-2018 academic year, 373 students are enrolled at Daniel Hale, where 57% are male students and 43% female students. The race/ethnicity reported by the school includes a 56% Black and 27% Hispanic student population. With a similar male to female ratio of undergraduate students, City Tech reports 30% Black and 33% Hispanic (New York City College of Technology 2017). The large underrepresented population at both schools made the partnership an ideal fit. Initially, college students were hired as interns through the CUNY Service Corps program. The CUNY Service Corps organizes students and faculty across the institution to work on projects that benefit the residents and communities of New York City. These projects aim to advance the "civic, economic and environmental sustainability" of the city (City University of New York [CUNY] 2018). At the core of the Service Corps, launched in 2013 as a response to Hurricane Sandy, is civic-engagement, which aligns with the values of SENCER. Students are paid as interns to work in civic-related jobs in community organizations (CUNY 2018). During the 2014–2015 academic year, two CUNY students worked to develop and implement an Educational Outreach Program that provided students in grades 1–5 with exposure to Science, Technology, Engineering, and Mathematics (STEM) in their elementary school classrooms. To sustain the program beyond the 2014–2015 academic year, the Black Male Initiative, Emerging Scholars, and Perkins Peer Advisement programs at City Tech continued to support the outreach project. Since the program's inception, a number of City Tech undergraduate students have served as mentors to the elementary school students and have worked with faculty at City Tech and key staff at the local elementary school. The goal of this collaboration, which has spanned a number of years, was to engage college students, elementary school students, college faculty, elementary teachers, and the families of the elementary students in a STEM outreach initiative.

Why is it important to integrate STEM education into the elementary school curriculum?

Many recent studies indicate that the gap in the STEM workforce will continue to widen unless more students decide to enter the STEM fields (Brophy et al. 2008; Brown 2012; Johnson 2013). According to the U.S. Department of Commerce, STEM occupations are growing at 17%, while others are growing at 9.8% (Langdon et al. 2011). To succeed in society today, we should encourage students to solve problems, develop their capabilities in STEM, and become tomorrow's scientists, inventors, and leaders (Science Pioneers 2017). Exposure to STEM careers at the elementary school level enhances student learning, encourages creativity, and entices curiosity. The National Academy of Engineering and the National Research Council list some benefits of incorporating engineering in K–12 schools: improved achievement in mathematics and science, increased awareness of engineering, understanding and being able to do engineering design, and increased technological literacy (Katehi, Pearson, & Feder 2009). With these studies as a rationale, we developed a multitier approach to integrate STEM into a Pre-K–5 (elementary) school.

Methods

The awareness of STEM-related careers was presented to the participating staff, students and families through in-class lesson plans, afterschool programs, and family workshops. Most of the projects centered on science and civil engineering to draw from the strength of the faculty involved. The engineering design process was included in the activities. Students were encouraged to (a) identify the problem, (b) brainstorm solutions, (c) try a design, (d) test, (e) identify strengths and weaknesses, and (f) try again. In order to promote skills associated with a well-rounded scientist and engineer, the activities integrated concepts of cost, schedule, and communication. The majority of the activities (in-class lessons, afterschool program and family workshops) were held at the local elementary school. College students and faculty met and communicated regularly with the staff at the elementary school to plan all activities. We present below the project design of this multitier approach to the community.

In-class Lessons

The in-class lessons centered on the NYC Scope and Sequence for Science and the Next Generation Science Standards (NGSS). The science focus included the following two topics: The Five Dancing Spheres (biosphere, lithosphere, geosphere, cryosphere, and hydrosphere) and Weathering and Erosion. In each unit, students in

FIGURE 1:

In-class lesson plans developed by the faculty, STEM specialists, and undergraduates.

Lesson 1: What Is the Cryosphere?

LEARNING OBJECTIVES

Students will be able to:

- Define cryosphere.
- Explain how the cryosphere is an essential part of the earth system.
- List examples related to the cryosphere (ice caps, etc.).

OUTLINE

Introduction (5 min)

- Students will have time to introduce themselves and create name tags.
- Interns will introduce themselves through power point slides.

Engineering Background (10 min)

Cryosphere Lesson (15 min)

- Define cryosphere
- Show examples that can relate to the cryosphere.

Activity (cryosphere vocabulary words) (15 min)

- Students will be given pictures and asked to match them with their definitions based on their prior knowledge.
- Introduce the activity for next lesson and expand how igloos are related to structural engineering.

Homework (5 min)

- Look up a video on how to build an igloo so that they will be prepared for next class.

Lesson 2: Making an Igloo

LEARNING OBJECTIVES

Students will be able to:

- Define cryosphere.
- Explain how the cryosphere is an essential part of the earth system.
- List examples related to the cryosphere (ice caps, etc.).

OUTLINE

Introduction (10 min)

- Interns and Students will reintroduce themselves.
- Students will be shown the PowerPoint from lesson 1 to familiarize themselves with the cryosphere.
- Discuss the homework on how to build an igloo.

Activity (30 min)

- Students will be given materials to create their own igloo and shown examples of structures made of ice.
- http://www.cbsnews.com/news/a-frozen-flashy-city-arises-from-the-ice-in-china/
- https://www.youtube.com/watch?v=7OUtNkVXelk
- Leave 5 minutes so students can walk around to look at other student's creations.

Homework (10 min)

- Introduce hydrosphere and ask the students to think of examples related to its concept.

FIGURE 2:
In-class lesson plans developed by the faculty, STEM specialists, and undergraduates.

Lesson 5: What Is the Atmoshpere?

LEARNING OBJECTIVES

Students will be able to:

- Define the Atmosphere.
- Explain how the Atmosphere is an essential part of the earth system.
- List different forms of air and relate it to the Atmosphere (wind, storm, hurricane, etc.).

OUTLINE

Introduction (5 min)

- Students will be asked to give some examples of the Atmosphere.

Atmosphere Lesson (25 min)

- Define Atmosphere and give some examples.
- Introduce the different layers of the atmosphere and their properties.
- Show how Atmosphere in the form of wind has helped human beings since the dawn of civilization as a source of renewal energy.
- https://www.youtube.com/watch?v=niZ_cvu9Fts

Activity (atmosphere vocabulary words) (15 min)

- Students will be given pictures and asked to match them with their definitions based on their prior knowledge.
- Introduce the activity for next lesson and summarize how engineers use Atmosphere to generate green energy.

Homework (5 min)

- Introduce students about wind turbine and how to make their own using paper and a ruler.

Lesson 6: Making a Wind Turbine.

LEARNING OBJECTIVES

Students will be able to:

- Define the Atmosphere.
- Explain how the Atmosphere is an essential part of the earth system.
- List different forms of air and relate it to the Atmosphere (wind, storm, hurricane, etc.).

OUTLINE

Introduction (15 min)

- Students will be shown the PowerPoint from lesson 5 to familiarize themselves with the Atmosphere.
- Students will share with their group members and the class the materials they have for the activity.

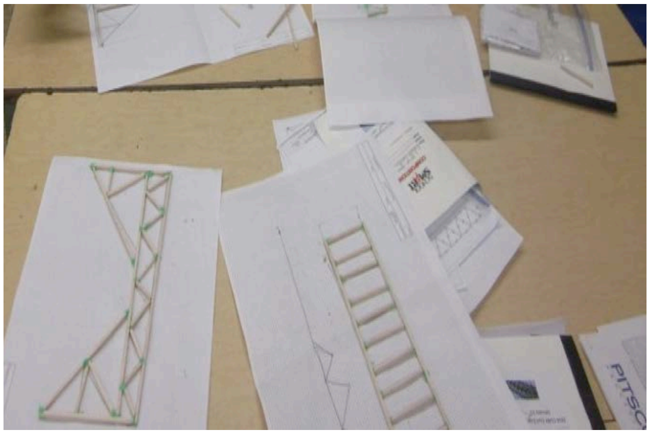
Activity (30 min)

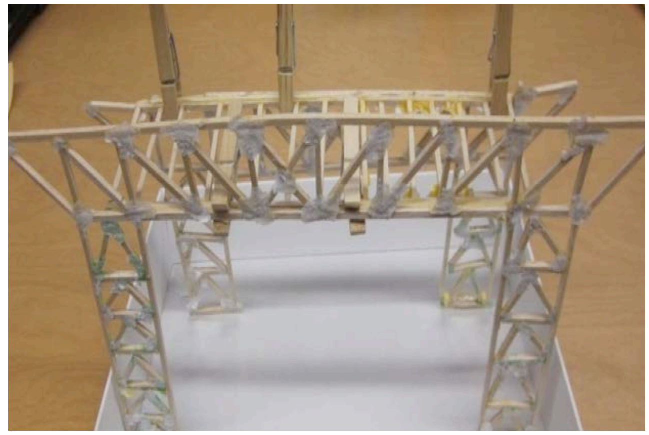
- Students will use the materials supplied to them to make a wind turbine. Any ideas students come up with will be included into the project.

Homework (5 min)

- Introduce Biosphere and ask the students to think of examples related to its concept.

FIGURE 3 represents balsa wood bridges/replicas being built from sketches.





grades 3 and 4 explored these science fields and created models to represent and display their learning. The civil engineering focus included the following in-class lesson topics: What is Engineering, Types of Engineering, Structures and Functions, Teams behind Construction, Construction Drawings, and Sustainability. The goal of the in-class lessons was to enhance the existing science curriculum with real-world applications and hands-on projects to help the students better understand the science curriculum. The commitment and participation of teachers from the elementary school were critical to the success of the program. The teachers and undergraduate students met regularly to plan, reflect, and ensure a smooth link between the NGSS curriculum and the in-class lesson topics. The teachers provided insight on teaching techniques for elementary school-age children and diverse learning styles. The undergraduate students worked closely with the teachers and tailored their lessons and activities to the children in the classroom.

The lesson plans for The Five Dancing Spheres curriculum (Figures 1 and 2) at the elementary school is only one example of the approach that we implemented. Each lesson included a visual aspect (examples), vocabulary activity, homework, and a hands-on activity.

Afterschool Programs

The afterschool programs reflected the model used in two local design competitions: West Point Bridge Design and Future City. These competitions are aimed at middle school students to promote interest in civil engineering careers. These projects required students to model the Engineering Design Process. Students used software programs to design their projects, create physical models, and prepare oral presentations. Even though students did not participate in the competitions, they were encouraged to be problem solvers and engineers. Students were encouraged to design, test, and revise their ideas. This provided a great opportunity for students to use their math, science, and technology skills while working with the engineering design process to come up with various solutions.

Engineering concepts such as force and equilibrium were incorporated through the Bridge Design project. Students used the Bridge Design software to design their bridges and simulate the testing of the bridge. Bridge Designer is a zero-cost educational software intended to provide middle school and high school students with a real-world overview of engineering through the design of a steel highway bridge (Ressler 2013). These elementary students were introduced to concepts of tensile and compressive force. Students created a virtual bridge and a replica model of their virtual bridge using balsa wood (Figure 3). Each material had a cost assigned to it, and students worked to make the strongest and most affordable bridge.

Similarly, concepts such as city planning and sustainable design were taught through the city design project. Future City is a project-based learning program where students in 6th, 7th, and 8th grade imagine, research, design, and build cities of the future (National Engineers Week Future City Competition 2017). Our afterschool partnership brought this project to the elementary students at P.S. 307, and they successfully created their own virtual city using the Sim City software. Students made blueprints of their cities and created a replica model showing a block of their cities using all recyclable materials. In preparing a blueprint, students visualize and sketch their design. Transferring the design from paper to three dimensions helped the students make a connection from 2-D to 3-D, promoting spatial thinking. Spatial thinking has been identified as an important trait for STEM careers (Wai, Lubinski, & Benbow 2009). "Fostering spatial thinking and mathematics learning in elementary school could contribute to a downstream ripple effect, improving students' interest and success in STEM subjects throughout their education and into their careers" (Burte et al. 2017).

The process of calculating total cost introduced the idea of budgets and the importance of adhering to a budget. Students also had to adhere to a schedule, as they were limited in the amount of time they could work on each portion of the project. Students presented their projects at the end of each program.

Family STEM Workshops

Recognizing the importance of family involvement in a child's success, the program included interactive STEM workshops and field trips for families that increased their awareness of STEM-related careers. Survey and program assessment data informed planning for the next project year. Topics in the family STEM workshops included, but were not limited to Civil Engineering, Chemistry, Mechanical Engineering, Architectural Engineering, and Computer Systems Technology. One local field trip included the SONY Wonder Technology Lab in New York City.

Some of the activities that were introduced at the workshops were (a) Spooky Materials Testing experiment which included a Mechanical Engineering focus; (b) building a home for turkeys with a Civil Engineering focus; (c) dissolving M&Ms and making slime with Chemistry; (d) learning coding with puzzles with a Computer Engineering focus; and (e) the design and creation of an architectural building model with Architectural Engineering as the focus.

The Spooky Materials Testing experiment (Schooling a Monkey 2018) introduced stress concepts to the elementary students by applying the different types of stresses (tensile, compressive, shear) to different types of candy and comparing the results of the tests on each candy. Students then made connections as to which type of candy, based on the stress concept, would be best for building.

Building a home for a turkey (Preschool STEAM n.d.) introduced the structural concepts and material cost to the students. The goal was to contain the holiday turkeys in a structurally sound and cost-efficient space. There were time limits and cost constraints that the students had to comply with. Students were also given a range of materials, each with a certain cost assigned.

Dissolving M&Ms (American Chemical Society 2018) and making slime (STEAM Powered Family 2018) introduced the concept of chemical experimentation and observation. In both activities, students were able to combine substances and observe the outcomes, which were colorful, fun, and thought provoking. With the help of parents, the students poured rubbing alcohol, water, and oil onto a plate of M&Ms and saw the dissolving effects the different solutions had on the M&Ms. The slime-making activity reinforced the concept of how observations are important in chemical processes.

Learning coding with puzzles introduced the algorithmic concept of coding patterns to the students (Institute of Electrical and Electronics Engineers 2018). This was accomplished through a brief introduction of how to follow steps using "coding language" and a visual puzzle activity that involved critical thinking. The students were then encouraged to "walk out" their coded steps on a large grid that closely followed the worksheet they worked on. As a next step, students and their families applied the skills they had learned to the online software in code.org.

By designing and creating an architectural building model, students were able to see the problem-solving and aesthetic skills it takes to become an architect. Students were given a laser-cut bendable paper set to create 3D models of their structure. Each student received the same pieces, but each individual was able to create entirely different structures by arranging the structure to their liking.

Results and Discussion

The faculty at New York City College of Technology recruited undergraduate students enrolled in the departments of Biological Sciences, Chemistry, and Civil Engineering Technology to serve as mentors, which included a pool of about 750 students. Throughout the years, several programs have provided support to the college students involved in this endeavor. These included the CUNY Service Corps, Emerging Scholars, Perkins Peer Advisement, and the Black Male Initiative programs, all of which have recognized the value of the STEM Outreach program. The success of the partnership and the collaboration of college faculty and students at City Tech has opened the eyes, minds, and future career potential of the elementary students at P.S. 307 Daniel Hale Williams School. It reinforced the need for STEM education in underrepresented learners. The partnership has increased exposure at the elementary school to STEM topics and courses taught at the college level. The outcomes as shown have been favorable and shared with the community at large via showcase presentations, school displays, and conference presentations, and at the college's annual poster session.

Success(es)

Our success included presenting activities seen as academically challenging (geared only to junior high, high school, or college students) to the elementary school students at P.S. 307, in a way that led to both success and enjoyment for the students. Furthermore, these students were able to figure out what STEM topics they enjoyed by trying many different discipline-oriented workshops. By including the parents in our workshops, we were able to inform them about various fields of engineering, next step school options for their elementary child, and career opportunities. Elementary school students were able to successfully implement the information they were learning through interactive hands-on STEM activities.

Impact on Undergraduate Students

There is a large body of evidence of the positive impact of undergraduate research on college students (Lopatto 2010; Russell, Hancock, & McCullough 2007). George Kuh (2008) also points to high-impact practices such as engagement beyond classroom (internships) and community-based learning that promote student engagement. The STEM outreach that we have described demonstrates that working with community partners such as the elementary school represents a valuable community-based project. The CUNY Service Corps indicate that undergraduates gain "workplace skills and abilities; personal development; civic engagement and social issues awareness" (CUNY 2017). The undergraduate students developed the curriculum under the guidance of the faculty and elementary school teachers. Additionally, the students gained valuable experience for the real world, including organization and communication and presentation skills.

Conclusion

This work brings to the forefront a collaboration that engaged faculty, undergraduates and elementary school students and teachers in a STEM outreach project. The project, which aimed to promote A Better Educated City, has increased awareness of STEM careers among families at the elementary school. Students were engaged in hands-on activities while learning elementary concepts related to STEM. Exposing elementary school students to science and engineering concepts can motivate them to solve various problems more effectively. "Quality STEM education is vital for the future success of students. Integrated STEM education is one way to make learning more connected and relevant for students" (Stohlmann, Moore, & Roehrig 2012, 28). Engineering is traditionally not a subject that is taught in elementary schools. However, it is a powerful method of teaching and motivating students in STEM-related fields. "Research indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners" (Furner & Kumar 2007, 186). Adding science, and more importantly, engineering as a part of the elementary school curriculum can be an effective way for students to strengthen their science, mathematics, and technological skills.

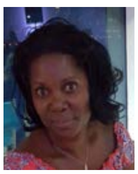
Acknowledgements

Professors Samaroo and Villatoro thank the following programs for supporting the various undergraduate students involved in this project over the years: Perkins Peer Advisement, Black Male Initiative and Emerging Scholars programs at New York City College of Technology, and the CUNY Service Corps. The authors thank the principals and teachers at Daniel Hale Williams School for opening their classrooms to this project throughout the years. We also acknowledge the faculty from the City Tech who participated in the Family STEM Workshops and the following undergraduates who have contributed to this project: Ramon Romero, Ngima Sherpa, Joyce Tam, Abigail Doris, Dante Francis and Jesam Usani.

About the Authors

Areeba Iqbal earned her Associate in Applied Science in Civil Engineering from New York City College of Technology. She is currently pursuing a Bachelor of Science in Civil Engineering from Manhattan College.

Kayla Natal is currently a student at New York City College of Technology, pursuing a Bachelor's degree in Mechanical Engineering. She also works as a Coordinator for the Peer Advisement Program. Kayla hopes to further her education and pursue a career in Industrial Design.



Servena Narine is a licensed and certified NYC Board of Education teacher. She currently works at Daniel Hale Williams Public School 307 Magnet School for STEM Studies. She has been an educator at P.S. 307 for 22 years. Over the course of her career, she has served as a classroom teacher (Grades Pre-K, 1, 2 and 3), mathematics coach, technology teacher, magnet resource specialist, and mentor. No matter the position, role or duties, she enjoys each, in addition to working with staff, students, parents, and partnerships. She brings to her work a focused and organized structure which has benefited her and the school over the years.

Melanie Villatoro is an assistant professor in the Department of Construction Management and Civil Engineering Technology. She teaches a variety of courses in the civil engineering major including statics, strength of materials, concrete, steel, soil mechanics, and foundations. Prof. Villatoro's approach to teaching builds on developing rapport with her students. She is highly effective in the classroom and as an advisor and mentor. She is passionate about student retention and performance, as well as STEM Outreach from the elementary to the high school level.

Diana Samaroo is an associate professor and chair of Chemistry Department at New York City College of Technology in Brooklyn, New York. Her pedagogical research is in the area of peer-led team learning in Chemistry and integrating research into the curriculum. With a background in biochemistry, her research interests are in the area of drug discovery, therapeutics, and nanomaterials. She has successfully mentored students through the Louis Stokes Alliance for Minority Participation and the Black Male Initiative and serves on the college's Undergraduate Research Committee.

References

American Chemical Society. (2018). *Dissolving M&Ms*. Retrieved February 5, 2018 from https://www.acs.org/content/acs/en/education/whatischemistry/adventures-in-chemistry/experiments/dissolving-m-ms.html.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education*, *97*(3), 369–387.

Brown, J. (2012). The current status of STEM education research. *Journal of STEM Education: Innovations & Research*, *13*(5), 7–11. Available from Academic Search Complete, Ipswich, MA. Accessed October 9, 2017.

Burte, H., Gardony, ,Hutton, , & Taylor, . (2017). Think3d!: Improving mathematics learning through embodied spatial training. *Cognitive Research: Principles and Implications*, *2*(13), 1–18.

City University of New York. (2018). CUNY Service Corps. Retrieved February 5, 2018 from http://www1.cuny.edu/sites/servicecorps/.

Furner, M. J., & Kumar, . (2007). The mathematics and science integration argument: A stand for teacher education. *Eurasia Journal of Mathematics, Science & Technology Education*, *3*(3), 185–189.

Institute of Electrical and Electronics Engineers. (2018) *Try Engineering*. Retrieved February 7, 2018 from http://tryengineering.org.

Johnson, C. C. 2013. Conceptualizing integrated STEM education. *School Science and Mathematics*, *113*(8), 367–368.

Katehi, L., Pearson, G., & Feder, M. (2009). The status and nature of K-12 engineering education in the United States. *The Bridge on K-12 Engineering Education*, *39*(3). Retrieved February 5, 2018 from https://www.nae.edu/19582/Bridge/16145/16161.aspx.

Kuh, G. D. (2008). *High-impact educational practices: What they are, who has access to them, and why they matter*. Washington, DC: Association of American Colleges and Universities.

Langdon, D., McKittrick, G., Beede, D., Khan, B, & Doms, M. (2011). *STEM: Good jobs now and for the future*. U.S. Department of Commerce, Economics and Statistics Administration. Retrieved February 7, 2018 from http://www.esa.doc.gov/sites/default/files/stemfinalyjuly14_1.pdf.

Lopatto, D. (2010). Undergraduate research as a high-impact student experience. *Peer Review 12*(2). Retrieved February 7, 2018 from https://www.aacu.org/peerreview/2010/spring.

National Engineers Week Future City Competition. (2017). *Future City Competition*. Retrieved February 5, 2018 from https://futurecity.org.

New York City College of Technology, City University of New York. (2017). *Fact Sheet 2017–2018*. Retrieved February 5, 2018 from http://www.citytech.cuny.edu/about-us/docs/facts.pdf.

Preschool STEAM. (n.d.). *Easy turkey preschool STEM activities*. Retrieved February 7, 2018 from https://preschoolsteam.com/thanksgiving-preschool-stem-activities/.

Ressler, Stephen. (2013). *The Bridge Designer Software*. Retrieved February 7, 2018 from http://stephenjressler.com/wpbd/.

Russell S. H., Hancock , & McCullough, J. (2007). The pipeline. Benefits of undergraduate research experiences. *Science, 316*(5824), 548–549.

Schooling a Monkey. (2018). *Hands-on teaching ideas*. Retrieved February 7, 2018 from http://www.schoolingamonkey.com/engineering-activities-for-kids/.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated stem education. *Journal of Pre-College Engineering Education Research* (*J-PEER*), *2*(1), 28–34.

STEAM Powered Family. (2018). *Slime STEM Activities – Learning with slime, STEM and fun!* Retrieved February 7, 2018 from https://www.steampoweredfamily.com/activities/slime-stem-activities-learning-with-slime-stem-and-fun/.

Science Pioneers. (2017). *Why STEM education is important for everyone*. http://www.sciencepioneers.org/parents/why-stem-is-important-to-everyone.

Ressler, Stephen. (2013). *The Bridge Designer Software*. Retrieved February 7, 2018 from http://stephenjressler.com/wpbd/.

Wai, J., Lubinski, D. & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*(4), 817–835.

Building a Greenhouse in a Community Farm: Urban Science and Community Democracy

JEFF SECOR
Prospect Heights Community Farm

Abstract

A greenhouse program in a community garden in Brooklyn, New York, is developed for year-round urban farming. The program exercises technical skills to design and build the greenhouse, and also exercises community democracy skills to address interpersonal issues such as land usage in over-crowded spaces and volunteer organization operations. We describe here the planning and construction of the greenhouse and also the process of community group discussion, debate, and voting in a volunteer run community garden.

Introduction

The urban environment of New York City (NYC) offers an endless supply of sensory and cultural experiences, but it does not offer much by way of open green spaces, and even less access to healthy, locally sourced food. Community gardens are green spaces in which the residents enjoy, steward, and cultivate a small plot of soil in the city. There are more than 900 community gardens across the five boroughs (Design for Public Space 2014), each one with a unique governance and farming mission. Organic farming for food production and education is vital, especially in urban environments where the availability and desire for whole food based diets are rare.

The community garden discussed in this report is located in Northern Brooklyn and occupies the land of three adjoining building lots. The garden has nearly one hundred members, operates a public compost collection system, and has over 1300 square feet of organic vegetable growing space. Until recently, the winter all but stopped our farming activities except for the use of small cold frames to grow greens and seedlings through the colder months. The next step in the garden's mission to grow food and educate the community was to establish a year-round gardening program in a greenhouse. This project report describes the obvious and non-obvious parts of the project that were important to ensure a successful outcome, including grant writing, technical design and construction, and, most importantly, community democracy.

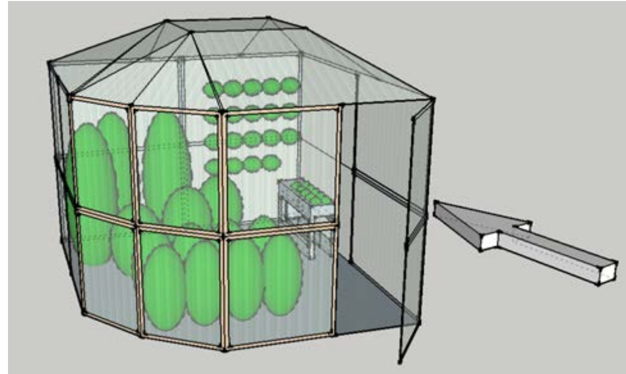


FIG. 1:
Original proposal for the greenhouse with an arrow pointing north. The vertical space in the greenhouse is utilized for maximum space efficiency. The rounded corners create a softer visual effect, but the final construction was a square greenhouse.

Planning Stages

The greenhouse development was funded by a generous grant from Citizens Committee of New York City. The grant mission statement was to develop a year-round farming space so that seedlings could be grown in the early spring for farm use and public sale, and to offer an educational and public laboratory space for anyone interested in greenhouse growing. The grant was written by three garden members during the winter of 2016 and notice of the $2300 award was given in the spring of 2017.

It is becoming increasingly important, especially in NYC, to justify the use of land space and grant money. There are many groups developing new metrics to understand and measure the impact of their community projects (Design for Public Space 2014). The metrics to measure the outcomes of the greenhouse are

1. Count of seedlings grown that are distributed to the farm
2. Revenue from greenhouse-grown seedlings at public plant sales
3. Record of crop yields from greenhouse-grown plants
4. Record of events and number of garden members working in the greenhouse.

The grant application included a proposed location of the greenhouse with adequate sun in the winter months, since a greenhouse relies on the sun for passive heating. From an aesthetic viewpoint, it is important to place the greenhouse in a position that does not obtrude on the visual experience of the garden. To accommodate these requirements, a south-facing space was chosen on the edge of the farm area, which is visually buffered by surrounding trees to the north. The greenhouse construction must also follow all zoning laws. This type of greenhouse would be considered a noncommercial greenhouse (Rules of the City of New York). In addition, the construction must follow building codes, including the roof loads for snow (Department of Buildings, New York City).

The average price per square foot of Brooklyn real estate is approximately $750 (www.trulia.com). This expense creates a huge pressure on the utilization of open spaces. Allocating eight square feet (worth approximately $48,000) for a greenhouse is thus a difficult decision. Even though the dollar value is not an actual cost, it does reflect the challenges confronted when proposing to use shared open space.

Community Democracy

Our community garden is a democratic organization comprised of community volunteers, and the deliberations to build the greenhouse presented a very valuable and in-depth exercise of community democracy. The ages of the participants ranged from children to senior citizens, and the team was comprised of architects, scientists, lawyers, artists, teachers, and corporate workers with varying skill levels specific to greenhouse construction. Some members supported the construction of the greenhouse, whereas other members were opposed to the project. Ideally, a rational and scientific approach can be a valuable strategy for moving forward while acknowledging the input of all members.

FIG. 2:
Josh, Traci, and Nathalie preparing the ground and the foundation timbers.

The primary question to address was whether or not to add an additional structure in the garden, because the surrounding urban environment is made of human made structures with small amounts of green space. To address this concern, the design of the greenhouse was modified to minimize the total vertical height by making a gable roof instead of a simpler shed roof. A slope is needed for snow and rain runoff, and an angled roof also provides increased light transmission. Additionally, we noted that a Spiraea shrub on the east side and overarching trees on the north of the greenhouse will visually buffer the structure in the summer months. Garden members stressed that a greenhouse structure is visually transparent, and that it is also a natural garden structure with visual vegetation inside.

Aside from the overall visual design of the garden space, we needed to consider sunlight exposure of the greenhouse and the shadows that it casts. A suggestion was made to place the greenhouse in a corner of the garden, but it was not clear how much sunshine the greenhouse would receive during the winter. The greenhouse requires direct sunlight in the winter months, so a suitable location must be far from tall fences or neighboring buildings. The sun's angle in the winter sky was an important detail to consider when locating the greenhouse. Areas receiving sun in the summer or fall months may not be illuminated in the winter due to neighboring buildings. To address these questions, a sun study was performed to determine the shadows cast by neighboring buildings in the winter months. The results of this study showed that the greenhouse would be in the winter shade if it were located in the back corner of the garden, because of the adjacent buildings and fences. It was also questioned if the greenhouse itself would cast shade on any plants behind the structure. However, this issue is not a serious concern, because the greenhouse is constructed with transparent polycarbonate panels that are 80% transmissive, which means that 64% of incident light can pass through two walls to the plants behind the structure. The final site was chosen as far from southern buildings as possible, and in a position with trees behind so that it would not cast shade on small plants.

Another concern raised was the potential effects of a non-natural structure on pollinating insects. This is a very important issue, because pollinating insects are critical to the natural cycles of a plant ecosystem. We were fortunate that our grant coordinator from Citizens Committee had firsthand knowledge about pollinating insects in urban environments, and she informed us that pollinating insects navigate by sunlight, shade patterns, and color. The transparent panels are expected to have minimal effect on their natural pollinating courses in the warmer months.

Finally, since a greenhouse creates an ideal environment for the growth of plants, it is also conducive to the growth of fungi, pests, and plant pathogens. The interior of the greenhouse remains constantly moist and stays warm. Without electrical fans, the air is stagnant and promotes fungal and bacterial growth. A modern technology solution to this problem is temperature activated vents that mitigate the problem of overheating and can provide air current channels through the structure. These automatic vents do not require electricity and are passively operated by temperature-sensitive wax-filled pistons attached to the windows. It is also necessary to remove any dead plant material as soon as possible to minimize fungal growth. In addition, there are several organic essential oils such as neem, cedar, and citrus that are being tried as fungal deterrents. It is important to address this issue because a disease or pest that grows in the greenhouse might spread into the farm. The community farm is crowded, just like the rest of the city, so plant or airborne diseases and pests can spread quickly. It is critical that the greenhouse be operated with the best scientific practices possible to ensure the well-being of the rest of the communal farm space.

There were three meetings of the general membership, each lasting an hour, to discuss the greenhouse. The garden organization has chosen to operate with a loose interpretation of Robert's Rules of Order. At the second meeting of discussions, a motion was made to implement the greenhouse. Among the 26 members present, the votes cast were 13 ayes, 10 nays, and 3 abstentions. According to our implementation of Robert's Rules, any decision is based on the majority of voters present and not on a simple majority of votes. Consequently, the motion did not pass because 14 aye votes were requited for a majority of voters present (abstention votes act as a nay when a majority is defined in this way). The close count of the vote prompted advocates of the greenhouse to propose a revised plan that was scaled down in size as a concession to the opposition concerned with land usage. A new motion was presented the following month and the votes cast were 17 aye and 10 nay with no abstentions. This vote passed the motion so that the greenhouse project could be implemented.

Splitting a community is problematic, both emotionally and politically. Most projects in these types of organizations are of smaller scale with smaller impact, and they move forward with near unanimous support. Overall, the fundamental challenge is to separate the science-based concerns versus emotional concerns and address each appropriately. Emotional resistance can sometimes be overcome by providing a scientific explanation. In other cases, science-based criticisms can lead to very constructive discussions; we can use science to support our ideas but must acknowledge that science can also oppose them. For example, some who were opposed to the project identified specific plant pathogens and microclimate issues that occur in a greenhouse, and this was one of the most important issues to address. Also, the concern to minimize the visual impact while maximizing sunlight exposure led us to a very informative sun study of our garden. This respect for science and rational discussion is critical in our current society, and forward progress can be made by focusing on tangible and rational methods.

Future Plans

All the work described above generated an 8-ft square greenhouse. The future work requires designing the interior space to be most space efficient and to the liking of the members. Initial ideas are to run multiple levels of shelving around the walls to maintain the maximum possible floor space for mobility. However, plants along the south-facing wall will block the sun, and so the density of shelves and plants on the south wall should be carefully considered. An irrigation system is being planned that will take roof runoff into gutters that feed directly into drip irrigation for plants in the greenhouse. The greenhouse will require regular maintenance throughout the year to keep plants watered and to deter infections. Other programs in the garden have been successful in sustaining a group of dedicated workers and a publicly available sign-up schedule, and we hope to replicate the successful model already in place in our garden. Also in progress is a process to plan and coordinate volunteer work. We intend to use the space for projects, instead of allocating space to individual members.as is the case in the rest of the garden. We hope that this will be a more equitable method of sharing the space.

Conclusions

An 8-ft square polycarbonate greenhouse was constructed in a community garden in Brooklyn, NY. This process was completely developed and executed by community volunteers. We have detailed the democratic discussions and scientific arguments needed to move forward through a system of community democracy to achieve success. We found that discussions among a large group of emotionally invested community members can be navigated by applying specific scientific principles in a democratic and objective manner. We hope that this project report can be of use to other community groups looking to undertake complex projects in a diverse community.

Acknowledgements

The author wishes to thank Citizens Committee for New York City for the generous grant and the entire garden membership of Prospect Heights Community Farm for working through this complex project to a successful completion.

About the Author

Jeff Secor has been a resident of Brooklyn for 10 years and a member of PHCF for nine of those years. He was a freelance gardener around Brooklyn during his graduate studies at the City College of

New York. He holds a Ph.D. in physics from CUNY with a specialty in spectroscopy, photosynthesis, and carbon quantum dots. He currently teaches physics at a private school in New York City and teaches workshops on winter gardening structures such as cold frames and greenhouses. Contact jeffsecor@gmail.com

References

Department of Buildings, New York City. Building Code, Loads, Title 27, Subchapter 9..

Design Trust for Public Space (2014). Five Borough Farm II: Growing the Benefits of Urban Agriculture in New York City.

Rules of the City of New York. Noncommercial Greenhouses Accessory to Residential Uses as a Permitted Obstruction in Required Rear Yards or Rear Yard Equivalents, Chapter 23-0.

APPENDIX

Construction Details for the Greenhouse

The materials for constructing the greenhouse are listed in Table 1. The greenhouse framing material was chosen to be cedar wood since it is an excellent exterior wood for greenhouse framing. It lasts through years of weather exposure and acts as its own insect repellent. Cedar wood is also locally available and within the budget of the greenhouse. The transparent covering is made of 6 mm-thick twin wall polycarbonate (PC) greenhouse panels. PC greenhouse panels are a relatively new material. The insulating R value of 1.54 for polycarbonate compares very well to the R value of 1.72 for a ¼-in. spaced double pane window. It is lightweight (a few pounds per 4 ft ×8 ft panel) and has no risk of breaking into sharp pieces as glass could. It should be noted that the PC panels have a slight blurring effect and are not as visually clear as glass. The PC panels are specified to pass 80% of the sun spectrum that is useful for photosynthesis (400–700 nm).

Local building codes were consulted to ensure compliance with applicable laws. The building codes in NYC are available online through the Department of Buildings. In NYC, this type of greenhouse would be considered a noncommercial greenhouse (Rules of the City of New York). This ordinance requires that the greenhouse be more 3 ft from the lot line. The roof was designed to conform to roof load specifications of 30 lb per square foot of horizontal extent (Department of Buildings, New York City). In general, the square foot of horizontal extent is 1 square foot multiplied by the cosine of the roof pitch. Finally, the PC manufacturer's specifications determined the required roof framing spacing to support the necessary roof load and resulted in roof purlins spaced 24 in. apart.

The greenhouse will be a warm and moist space in the winter, and the surrounding urban environment contains rodents. Galvanized wire mesh should be placed on the subground as a barrier to prevent rodents burrowing into the greenhouse. During the summer the greenhouse can easily rise above 100 °F. The windows for the greenhouse are fitted with automatic wax hinges which actuate according to the interior temperature to prevent excessive heating and promote air circulation in the warmer months. Two vents are placed on the roof panels, and one vent is placed closer to the ground to achieve a chimney effect.

The greenhouse construction was completed in three phases: (a) site preparation, (b) framing construction, and (c) installation of the PC panels. Site preparation is the most physically intensive phase. The existing plants and garden soil were removed in order to level the foundation soil and to make room for the 6

TABLE 1: MATERIALS FOR GREENHOUSE CONSTRUCTION

Item	Quantity	Price ($)	Total cost ($)
6mm polycarbonate sheet, 4 ft x 8 ft	11	50.68	557.48
2x4x8 cedar stud	41	13.6	557.60
2x4x10 cedar stud	1	17	17.00
2x6x8 cedar ridge board	1	26	26.00
6x6x8 foundation lumber	4	22.57	90.28
automatic wax hinge	2	63	126.00
metal mesh	1	45.94	45.94
door hinge	3	5	15.00
1/2" x 3 ft. rebar	8	3.5	28.00
screws and washers	50	1.00	50.00
foil tape	1	7.98	7.98
10" lag bolt	4	4.70	18.80
stainless stell rafter tie	12	2.54	30.48

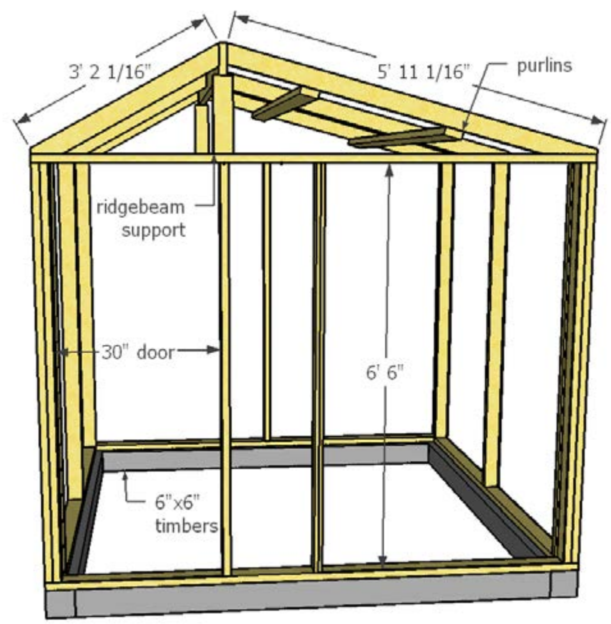


FIG. 3:
Cedar framing details. The door is framed at 30 in. wide. The ends of two side walls have a double stud, resulting in three studs in each corner of the structure. The lengths for the roof framing were a result of the 8-ft. span and minimizing scrap from the roof of the PC panels.

in. x 6 in. foundation timbers. The area was compacted with a 10-in. hand tamper. We chose not to pour a concrete foundation in order to minimize the impact on the natural area and to minimize the eventual work of removing the greenhouse. Once the timbers were leveled in an 8 ft x 8 ft square arrangement, they were bolted together in the corners with 10-in. galvanized lag bolts, and each timber was anchored in place with two rebar "L" shapes inserted 3 ft below ground level. This part of the project took approximately three days over two weekends.

The second phase was constructing the framing. The wall panels were built first using 3-in. coated decking screws. A group of a dozen members, including a 12-year-old boy, assembled the wall panels, thereby gaining first-hand experience with framing squares, drill bits, circular saws, and with creating a level work space in a community garden. Afterwards, another group of members templated the roof boards using a speed square and a circular saw. In order to provide additional support, stainless steel rafter ties connect the wall framing to the roof boards. (Stainless steel does not interact with cedar wood.) The frame was attached to the foundation using 4½-inch stainless steel screws and washers. The entirety of the framing work required five days over three weekends.

Finally, the double walled PC panels were installed. The PC panels can be cut by an electric circular saw. A saw blade with fine teeth must be used when cutting the PC to prevent plastic shrapnel and rough edges. The tops of the PC were sealed with metal foil tape to prevent water from entering the channels. The PC panels were attached directly to the cedar framing using 1 ½- in. dip coated screws with 1-in. neoprene washers. The neoprene washers are common applications where a soft washer is needed in order to prevent cracks and punctures in the panels. It is important not to use galvanized screws as they will cause rust bleeding with the cedar. The framing geometry is made so that all of the panels end on a cedar framing stud. This makes for a more stable structure and also reduces thermal leakage. A door was cut from one of the wall panels and hung on zinc plated hinges. The hinges were installed on the outside of the panel, not in contact with the framing, so there is no danger of galvanic interaction between zinc and cedar.

FIG. 4:
Anna, Traci, Greg, Melissa, and Josh inside the greenhouse frame, working together on the details of the roof framing.

FIG. 5:
Completed greenhouse with polycarbonate panels. The Spiraea bush in the forefront will grow many times in size. The blue Atlas cedar is behind the greenhouse on the north side.