Improving the Engineering Pipeline Through University & Community-Developed Museum- Based Educational Kits

Dr. Stacey V Freeman, Boston University

Dr. Stacey Freeman is the Director of National Outreach for the College of Engineering at Boston University. In this role, she is responsible for planning, developing, and implementing outreach and diversity programs and initiatives to promote Engineering and increase the K-12 pipeline for women and underrepresented minority students. Specifically, she supervises staff and students to sustain and develop innovative and cutting edge approaches to K-12 STEM outreach, such as the Technology Innovation Scholars Program which is a professional development program for undergraduate students that provides them the opportunities to fulfill their role as "societal engineers" by connecting the College with K-12 communities throughout Boston and beyond.

Dr. Sandra Lina Rodegher, Boston University

Dr. Sandra Rodegher is the Manager for National Outreach Initiatives for the Office of Outreach and Diversity in Boston University's College of Engineering. In this role she seeks to develop mechanisms for engaging diverse populations and creating cultures of inclusion. She is also a Senior Sustainability Scientist and was previously a Senior Program Coordinator for Sustainability in Science Museums at Arizona State University (ASU). She holds a Ph.D. in Sustainability Science from ASU and an M.A. in Industrial and Organizational Psychology from the University of New Haven

Improving the Engineering Pipeline Through University & Community-Developed Museum-Based Educational Kits

Objectives or purposes

Museums provide much-needed opportunities for creative thinking, exploration, and STEM identity development. This paper describes the pilot testing a two-year NSF project in which researchers partnered with museums across the U.S. and internationally, to develop culturally-relevant, hands-on activities that are distributed to over 50 museums. The project goal is to help combat engineering pipeline challenges by providing K-12 students with activities to educate them about engineering so the students can see how their involvement in STEM careers could positively impact their communities. This paper focuses on the university-museum partnership model and its uniqueness in that all levels of the program implementation and evaluation involved direct input from the museum partners to ensure the educational kits are community-informed and socially-driven.

There are several goals associated with this project. For the purposes of this paper, we will focus on how this project model creates synergies within an interdisciplinary team of faculty, graduate students, and museum educators, to inform and assess culturally-relevant, hands-on, interactive activities focused on engineering broadly. Working closely with 10 museum partners and educators in Ontario, Portland, Los Angeles, Fort Lauderdale, Detroit, Miami, Ann Arbor, Boston and Buenos Aires, kits were tested, feedback was collected, and evaluation results were used to continuously iterate on the kits to ensure they work well in diverse settings.

Perspective(s) or theoretical framework

A national crisis will emerge if the United States cannot amplify the number and diversity of K-12 students who pursue degrees and careers in engineering. Many of society's challenges impact a broad spectrum of peoples, communities, and systems. Addressing these challenges require engagement of diverse ideas, perspectives, intellects, and goals. Although today more women than men are enrolling in college (National Center for Education Statistics, 2017), the number of women pursuing engineering remains flat (NCES, 2016; Yoder, 2012; Engineering Workforce Commission, 2013). Despite great efforts to diversify the STEM pipeline, too few students of color enter STEM careers. In 2011, only 6% of African Americans and 7% of Latinos held STEM jobs (Landivar, 2013), which is not representative of the overall population.

There are many factors that discourage underrepresented populations and women from pursuing STEM careers including a lack of positive role models (Carlone & Johnson, 2007), unwelcoming and uninviting atmosphere, and lack of relevancy (Chen & Soldner, 2013). Increasingly, students in U.S. high schools want to create a positive impact on the world. Further, many students do not understand how STEM fields are relevant to their lives. We do know that underrepresented students are attracted to majors that directly impact social issues (Carnevale et al., 2016). However, this project aims to help combat these challenges by providing K-12 students with activities to educate them about engineering solutions to culturally relevant challenges so the students can see how their involvement in STEM careers could positively impact their communities. This community and cultural connection can motivate and recruit girls and students of color into STEM (Griffin et al, 2010).

Improving the Engineering Pipeline Through University & Community-Developed Museum-Based Educational Kits

Informal Science Learning Benefits. Rather than competition for traditional schooling, informal science education organizations, such as museums, play a complementary role in enhancing students' interest and exposure to STEM learning. For example, field trips are a common intersection between informal science education and schools that most educators believe are worthwhile for student learning (Anderson, Kisiel, & Storksdieck, 2006; Cox-Peterson, Marsh, Kisiel, & Melber, 2003; Kisiel, 2005). Trips to places like science centers, natural history museums, zoos, etc. "have the potential to situate learning within a rich and appropriate context that provides opportunities to engage in many of the practices of science and…for K-12 education" (Falk, Osborne, & Dorph, 2014). Museums provide much-needed opportunities for creative thinking, exploration, and STEM identity development. Bell et al's. (2009) research posits the time spent outside of school in places like museums provide students with enhanced opportunities for engagement in Next Generation Science Standards (NGSS) within relevant contexts (Falk, Osborne, & Dorph, 2014).

Interdisciplinary Work. The interdisciplinary team of university researchers, in collaboration with informal science experts from exemplar museums, we are poised to create unique, diverse and culturally relevant activities to reach a broad and diverse audience. Further, the project allows students to practice real-world competency-building, especially communicating and interdisciplinary collaboration. This is particularly important, given that "science and engineering teams are increasingly multidisciplinary. Funding agencies have recognized that solving complex problems often requires teams from multiple disciplines" (Paletz & Schunn, 2010). Bringing divergent perspectives together creates a critical awareness, which helps people to understand and make sense of different types of knowledge. Through multidisciplinary group work, holistic thinking can develop and the group may consider other forms of knowledge and value outside perspectives (Borrego & Newswander, 2010).

<u>Methods, techniques, or modes of inquiry</u>

Project administrators led internal evaluation of the kit testing at several sites around the U.S. and also elicited feedback from museum professionals in Buenos Aires, and at an international conference in Copenhagen. The evaluation testing model included four main goals: 1) Identify aspects of activities that are unclear, difficult to implement, confusing, etc.; 2) test facilitation to ensure games function correctly; 3) determine if educational outcomes are clearly articulated through facilitation; 4) evaluate effectiveness/engagement with kids and adults. To meet these goals, researchers implemented a three-part evaluation model.

1) Learn: museum educators/facilitators learn the activities without any guidance. Then, briefly practice leading the rest of the group through the activity they each learned.
   Metric source: observation
2) Lead: museum educators/facilitators lead activities with group of children on the public floor of a museum for 1-2 hours.
   Metric source: observation
3) Reflect: museum educators/facilitators discuss their experience learning and leading activities

Improving the Engineering Pipeline Through University & Community-Developed Museum-Based Educational Kits

Metric: capturing report out/discussion

The full protocol was implemented in Ontario, Portland, Los Angeles, and Fort Lauderdale at three large museums that serve youth and families. An abridged protocol (which skipped step two) was also implemented in Detroit, Ann Arbor and Copehagen. Miami, Buenos Aires, and Boston partners participated in a deeper engagement wherein they were brought in at various stages during the development process.

Data sources, evidence, objects, or materials

The materials used in the data collection include the prototypes of the educational activities. Eight different activities were tested and include materials, such as game cards, dice, and timers. Most objects are paper-based cards with accompanying instructions about how the games/activities function. Museum educators were each given one or two activities to learn and share with their colleagues prior to testing them on the public floor of the museum. At two of the museums, the museum educators used click counters to keep track of the number of visitors at the tables and activities.

Researchers collected observational data and took hand-written notes while observing the above protocol. Hand-written notes were then transcribed and compiled. The researchers also took photographs of the museum educators' interacting with the materials on their own, and during the public floor testing with kids and adults.

Results and/or substantiated conclusions or warrants for arguments/point of view

Internal evaluation is ongoing and has revealed several important ways to improve the kit materials to ensure they are culturally-relevant, flexible and adaptable to multiple settings, and effective educational tools for the museums who will receive them.

Taking into consideration the test sites that used all three steps of the protocol (Ontario, Canada; Fort Lauderdale, FL; Los Angeles, CA; Portland, OR), approximately 150 students, parents and other adults participated in one or more of the activities. Beyond the museum visitors, 39 museum educators and public floor staff participated in the activities across all four sites. Although it is very difficult to collect observational data about race/ethnicity, there was diverse representation across the four sites. In Los Angeles, the researcher observed approximately 50% of the visitors were Latinx with significant African American and Asian Pacific Islander populations, as well. The other museum visitors appeared to be majority white/Caucasian. In terms of age, the majority of the youth participants ranged from ages 4 – 10. The researcher specifically asked parents/adults their children's' ages if it was difficult to guess. Each child was accompanied by one or more adult. Many of the parents assisted with the implementation of the activities and seemed quite engaged in the process. Several parents made comments about the utility of the activities, especially those related to engineering careers.

Although observing the table demonstrations was useful to see how easily the youth could understand the games, what the testing revealed was that the games, themselves, are functioning well. The greater issue is whether or not the facilitator guide and game/activity instructions are understandable for the museum educators. A great deal of time in stage one and stage three of testing was discussing the instructions with the educators. The majority of the activity guides/instructions needed significant revisions to ensure the game functioning and rules are understood. The recap time spent with the museum educators after they tested the activities was the most valuable because it gave the researchers a chance to reflect on the fact that the biggest issues with the activities aren't the activities but rather how the activities are described. Thus, the research team could spend more time refining the instructions and considering other ways the games/activities can be taught when the activities are distributed. Based on the feedback, the research team will spend more time creating stop animation videos to show how the games are played. Further, the facilitator guide and instructions have been completely overhauled to make them more easily understood.

Scientific or scholarly significance of the study or work

The broader goal of this project is to broaden the engineering education and engagement of K-6 grade students across the U.S. by leveraging existing university relationships with science museums through the development of hands-on activity kits. These activity kits will be deployed across the U.S. to introduce museum visitors to relevant research, while enhancing the capacity of science museums to educate their audiences about how engineering can solve real-world challenges. Through the creation of physical activities as well as professional development trainings for museum educators, science museums across the United States will be better equipped to communicate engineering concepts with diverse audiences.

Advancing Collaboration

Collective Impact. The project model is based on a collective impact model, strongly advocating for inclusion of multiple organizations across several disciplines to solve the increasingly complex social issues, including lack of diversity in the STEM pipeline. A collective and collaborative approach from multiple organizations across many different sectors has the best chance of improving these grand societal challenges.

By testing the prototypes of the activities with several different organizations across the U.S. and with some international partners, project administrators hope to ensure the activities are culturally-relevant, can be used in a variety of settings, and are easily adaptable across various contexts. This prototyping and evaluation process also built capacity in museum educators by providing them a unique professional development opportunity where they could share their expertise and see their feedback utilized to benefit the broader museum community. Community-informed and developed activities have the greatest chance to create positive impact. Not only will the museums involved in the piloting be more invested in the long-term viability of the activities, the university benefits by having much more personal and intimate relationships. The museums can advocate for the external university involvement while also ensuring the final products are ultimately useful to the university's stakeholders – in this case, museum educators and their visitors. This community-informed model takes into consideration all collaborators and ensures their voices and input are heard throughout the creative development process. Further, these partners will have longer-term opportunities to be involved in the professional development training and ultimate implementation of the activities. This model is one that values transformational partnerships rather than transactional partnerships. The initial testing proved the value in university-museum collaborations to ensure activities are rigorously tested prior to dissemination, leading to the best possible educational outcomes and long-term usage of the activities.

Improving the Engineering Pipeline Through University & Community-Developed Museum-Based Educational Kits

Reference

Anderson, D., Kisiel, J., & Storksdieck, M. (2006). Understanding teachers' perspectives on field trips: Discovering common ground in three countries. Curator, 4(3), 365-386.

Bell, P., Lewenstein, B., Shouse, A., & Feder, M. A. (2009). Learning sciences in informal environments: People, places and pursuits. Washington: National Academies Press

Borego, M. & Newswander, L.K. (2010). Definitions of interdisciplinary research: Toward graduate-level interdisciplinary learning objectives. *The Review of Higher Education,* 34 (1), 2010.

Carlone, H.B., Johnson, A. (2007). Understanding the science experiences of successful women of color: Science Identity as an analytic lens. *Journal of Research in Science Teaching,* 44 (8), 1187-1218.

Carnevale, A.P., Fasules, M.L., Porter, A., and Landis-Santos, J. (2016). African Americans: College majors and earnings. Washington, D.C.: Georgetown University Press, 2016. Report.

Chen, X. and Soldner, M. (2013). STEM attrition: College students' paths into and out of STEM fields statistical analysis report. Institute of Educational Sciences. National Center for Education Statistics. U.S. Department of Education. Retrieved June, 2018 from: https://nces.ed.gov/pubs2014/2014001rev.pdf

Cox-Petersen, A., Marsh, D. D., Kisiel, J., & Melber, L. M. (2003). An investigation of guided school tours, student learning, and science reform: Recommendations at a museum of natural history. *Journal of Research in Science Teaching*, *40*, 200–218.

Engineering Workforce Commission, Engineering & Technology Enrollments (2013). Undergraduate enrollment in engineering programs, by sex, enrollment status, race or ethnicity, and citizenship. Retrieved June, 2018 from https://www.nsf.gov/statistics/2017/nsf17310/static/data/tab2-10.pdf

Falk, J.H., Osborne, J., Dorph, R. (2014). Supporting the implementation of NGSS through research: Informal science education. *NARST,* Retrieved from: https://narst.org/ngsspapers/Informal_Science_Education_June2014.pdf

Griffin, K.A., Pérez, D., Holmes, A.P., & Mayo, C.E. (2010). Investing in the future: The importance of faculty mentoring in the development of students of color in STEM. New Directions for Institutional Research, 148, 95-103.

Honey, M. & Kanter, D.E. (2013) *Design, make, play: Growing the next generation of STEM Innovators*. New York, NY: Routledge.

Kania, J. & Kramer, M. (2011). Collective impact. *Stanford Social Innovation Review*. Winter 2011, 35 - 41.

King, Z (2017). 2016 sustainABLE kits: Public impacts evalution report. Department of Evaluation and Research in Learning, Science Museum of Minnesota

Kisiel, J. (2005). Understanding elementary teacher motivations for science fieldtrips. Science Education, 86(6), 936-955.

Landivar, L.C. (2013). Disparities in STEM employment by sex, race, and Hispanic origin. *American Community Survey Report.* Retried on June, 2018 from: https://www.census.gov/prod/2013pubs/acs-24.pdf

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *STEM: Good jobs now and for the future.* U.S. Department of Commerce. Washington, DC.

National Center for Education Statistics (NCES) (2016). Back to School Statistics. Fast Facts. Retrieved June, 2018 from https://nces.ed.gov/fastfacts/display.asp?id=372

Paletz, S.B.F., Schunn, C.D. (2010). A social-cognitive framework of multidisciplinary team innovation. *Topics in Cognitive Science*. 2 (1), 73-95.

Rodegher, S. L., Freeman, S.V. (2017). University-museum partnerships: Reflections on programmatic best practices for sustainability collaborations. *Journal of Sustainability Education*, 13 (March, 2017).

Sheridan, K.M., Halverson, E.R., Litts, B.K., Brahms, L., Jacobs-Priebe, L., Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. Harvard *Educational Review*, 84 (4), 505 – 531.

Yoder, B.L. (2012). Engineering by the numbers. *American Society for Engineering Education*. Retrieved June, 2018 from: https://www.asee.org/papers-and-publications/publications/collegeprofiles/15EngineeringbytheNumbersPart1.pdf