Board 24: Promoting the Participation of Elementary School African Americans, Hispanics, and Girls in STEM by Expanding Summer Engineering Experiences

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Promoting the Participation of Elementary School African Americans, Hispanics, and Girls in STEM by Expanding Summer Engineering Experiences

Abstract

Promoting the participation of under-represented minorities in engineering is a national imperative. Focusing on elementary school students is critical for broadening participation in engineering, as many children form lasting beliefs about their STEM identities and STEM self-efficacy in elementary school. While there has been a recent surge in efforts to integrate engineering in curriculum in traditional school settings, out-of-school settings continue to play an important role in promoting equity in pre-college engineering experiences. Out-of-school settings in particular can be ideal for providing children with culturally-relevant engineering experiences. This project focuses on the National Society of Black Engineers (NSBE)'s Summer Engineering Experiences for Kids (SEEK) program. This multi-partner project allows us to expand and strengthen the experience, conduct research on the impact of the program, and conduct research on how such outreach programs might grow in sustainable manners. Our poster will present a summary of the large-scale data collection that occurred during the summer of 2018 at all 16 sites located across the US. We administered a variety of instruments to identify changes in the children's STEM-related outcomes over the course of the SEEK experience. To further operationalize the variation in organizational contexts across sites, we collected data from parents and mentors. In the poster we will share information about the instruments used for this study. Additionally, our poster will summarize the work that we have done to further strengthen the curricular and training aspects of SEEK.

Overview

Promoting the participation of under-represented minorities in engineering is a national imperative. Focusing on elementary school students is critical for broadening participation in engineering, as many children form lasting beliefs about their STEM identities and STEM self-efficacy by the time they reach middle school [1]. While there has been a recent surge in efforts to integrate engineering in curriculum in traditional school settings (e.g. [2-4]) through the Next Generation Science Standards), out-of-school settings continue to play an important role in promoting equity (e.g. [5-7]) and access [e.g. 8] in pre-college engineering experiences. Out-of-school settings in particular can be ideal for providing children and youth with culturally-relevant engineering experiences (e.g. [9-11]).

This project focuses on the National Society of Black Engineers (NSBE)'s Summer Engineering Experiences for Kids (SEEK) program. SEEK is a three-week summer program that engages 3rd-5th grade-aged children in hands-on, team-based engineering design projects led by "mentors" who facilitate the summer program and are typically undergraduate STEM students and in-service teachers. Since the program was first introduced in 2007, over 20,000 students have participated in SEEK. Based on early success of this program, NSF funded our multi-partner project to expand and strengthen the experience, conduct research on the impact of the program, and conduct research on how such outreach programs might grow in sustainable manners. Two objectives guide the research aspect of this project:

1. Evaluate SEEK's success at influencing STEM-related academic and career identity, conceptual knowledge, and interpersonal and intrapersonal skills.
2. Generate evidence and a greater understanding of organizational contextual factors that operate to enhance, moderate, or constrain SEEK's impact from site to site.

Data Collection Approaches

In previous publications we described our initial plans for data collection [12], [13]. This poster presents a summary of the large-scale data collection that occurred during the summer of 2018 at all 16 sites located across the US. We administered a variety of instruments (that have been vetted through peer-reviewed publication processes) to identify changes in the children's STEM-related outcomes over the course of the SEEK experience. We also collected background information with regard to socio-demographic characteristics, academic preparation, and personal and social experiences, which provide contextual information to help us understand differences between sites. To further operationalize the variation in organizational contexts across sites, we collected data from parents and mentors.

Data Collected from Children

The children who participated in the SEEK camps completed assessments at the beginning and end of the three-week day-camp experience. Approximately 1,650 children completed the pre-tests, 1,400 completed the post-tests, and of these, approximately 1,375 were matched cases (pre and post).

Specific instruments used include:
- The **Engineering Identity Development Scale (EIDS):** This instrument was developed by Capobiano and her colleagues [14] to determine how elementary school students develop their sense of identity within engineering. The instrument has established validity and reliability for academic and engineering career identity (two-factor solution) within the elementary school context and can be used within science and engineering education settings.
- **Youth Life Skills Inventory:** This instrument measures STEM-related interpersonal and intrapersonal skills, which the NSF ITEST program RFP identifies as being key student outcomes of projects funded by this program. It consists of five subscales that we will use in this project (Working with Groups; Understanding Self; Communicating; Making Decisions; Leadership). Development of the measure for students in grades 3–5 is described by Robinson and Zajiceks [15], which adapted the Leadership Skills Inventory [16].
- **Academic Motivation:** The MUSIC (eMpowerment, Usefulness, Success, Interest, and Caring) Model of Academic Motivation survey instrument was developed and validated for use within the elementary school context by Jones and Sigmon [17]. To demonstrate validity, the authors administered the instrument to 535 students from first to fifth grades.
- **Fit of Personal Interests** and **Perceptions of Engineering** [18] The F-PIPES instrument measures students' personal interest profiles and their perceptions of engineering (and allows researchers to investigate alignment between the two along six interest

dimensions—realistic, investigative, artistic, social, enterprising, and conventional – that are based in Hollands' Career Theory [19].

- **Conceptual Knowledge Questions:** Drawing from publicly available, released standardized tests questions, we developed a set of conceptual knowledge questions to measure students' understanding of grade-level-appropriate mathematics and science concepts. Approximately half of these items were common across all 16 sites while the other half of the items were identified based on the specific curriculum modules used at the site.
- **Design Process Knowledge Task:** The Design Process Knowledge Task was developed to measure elementary-school-aged children's understanding of the engineering design process [20]. Children are asked to critique another child's design process, commenting on what was good about the process and what could be improved. Responses to the task are coded for absence or presence of distinct design activities (e.g. Model It, Test, Improve) based on the model of the design process presented in the SEEK camp.

Data Collected from Parents and Mentors

Across all 16 sites, we also collected pre-SEEK survey data from 1,004 parents and post-SEEK survey data from 275 parents. We used the Parent Engineering Awareness Survey [21] as one portion of the survey completed by the parents. The Parent Engineering Awareness Survey asks parents to consider their own understanding of engineering and their ability to help their children learn about engineering; their attitudes towards pre-college engineering education; and the types of activities they engage in with their children at home related to engineering.

Across all 16 sites, we also collected 161 surveys from SEEK mentors and 25 surveys from SEEK site leaders. These surveys were created specifically for the SEEK camp. We also conducted interviews with 25 of the SEEK mentors. Mentors were interviewed during site visits to six SEEK camps across the country. An example of a question posed in the interview is: "What is your motivation for mentoring in the SEEK program?" [22]

Curriculum

Drawing on the observations of the 2017 SEEK camps, our own prior research, findings from the administration of the F-PIPES instrument, feedback from our Advisory Board, and other researchers' work, we reviewed the eight curriculum modules that were revised or created for use during the 2018 SEEK camps. We recommended changes to the ways that engineering was described in the modules and changes to add a social context to some of the engineering short challenges included in the curriculum. We also developed a model of the engineering design process that was aligned with the activities in the SEEK curriculum modules, aligned with the Next Generation Science Standards, and aligned with empirical research on engineering design processes [23]. We added cues throughout the curriculum modules to help the SEEK mentors and participants connect activities to the engineering design process and created classroom posters that communicate core messages about engineering and engineering design.

Mentor Training Materials

Based on the review of literature on mentoring we completed in the first year of the project, our observations of the 2017 SEEK camps, and feedback from our Advisory Board, we identified a set of topics for mentor training related to facilitating engineering activities. We organized the topics into three modules: Engineering Design; Engaging Students in Engineering; and Fostering Positive Collaborations in Teams. For each of these three modules, we created pre-work assignments that consisted of a combination of pre-reading (text we created to summarize relevant research literature), short videos, and on-line quizzes. The pre-work assignments were sent to the mentors in May 2018. We also created Tip Sheets to reflect (1) the topics emphasized in the pre-work assignments and (2) topics specific to each specific curriculum module.

Next Steps

At this time, we are analyzing data collected during the Summer 2018 SEEK camps and preparing to collect data in the 2019 SEEK camps. One analysis we recently completed focused on students' responses to the Working with Groups items on the Youth Life Skills Inventory, which allowed us to investigate children's perceptions of teamwork [24]. We are continuing to make revisions to the curriculum (a priority for this year is shortening the modules) and the mentor training (priorities for this year include helping mentors help children understand the differences between science and engineering, helping mentors identify and respond to problematic group dynamics, and growth mindset). We are also developing a protocol to interview SEEK campers to learn more about their experiences the SEEK program overall and the competitions that are held each Friday of the camp.

Future Work

Additional possible future opportunities include further consideration of the ways in which the curriculum, assessments, and mentor training can be connected to the youth participants' cultural practices, as well as to examine the experiences of the SEEK campers and SEEK mentors from a sociocultural perspective. For example, we might build on Christopher Wright's study of Black male youths' participation in a STEM program, where Wright explored the linguistic practice of signifying (where the youth used humor, teasing and wordplay) as the youth co-constructed their understanding of STEM concepts and established their own approach to collaborative critique [25]. If we examine the dynamics as teams of SEEK campers address their weekly design challenges, we may find similar linguistic practices and strategies.

A second opportunity for future research is to investigate the experiences of the Junior Mentors. To date our research on SEEK mentors has focused on the undergraduates and professionals who serve as mentors; however, high school students aged 14 to 17 years old are also engaged as Jr. Mentors. Just as we have investigated SEEK mentors' motivations for mentoring in the SEEK program, we might investigate Jr. Mentors' motivations. Tucker-Raymond, Lewis, Moses and Milner investigated a similar question in their study of high-school-aged youths' interests in teaching mathematics and computer science to younger children, noting that understanding these motivations is important as "young people are crucial to the fight for educational equity" [26, p. 1038]. We might anticipate that the SEEK Junior Mentors may be motivated to serve as mentors

for similar reasons that the youth from the Young People's Project wanted to teach mathematics and computer science – the opportunities for them to empower themselves (e.g. through new knowledge, skills and community connections), while also empowering others [26].

Acknowledgements

References

[1] Eccles, J. S., Wigfield, A., Harold, R. D. & Blumenfeld, P. (1993). Age and gender differences in children's achievement self-perceptions during the elementary school years. *Child Development*, 64, 830–847.

[2] Cunningham, C. M. (2009). Engineering is Elementary. *The Bridge, 30*(3), 11–17.

[3] Moore, T. J., & Tank, K. M. (2014). *Nature-inspired design: A PictureSTEM curriculum for elementary STEM learning.* Paper Presented at the 2014 Annual Meeting of the Association of Science Teacher Educators, San Antonio, TX.

[4] NGSS Lead States (2013). *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

[5] Calabrese Barton, A. Tan, E., & Greenberg, D. (2017). The Makerspace Movement: Sites of Possibilities for Equitable Opportunities to Engage Underrepresented Youth in STEM. *Teachers College Record*, 119(7).

[6] Calabrese Barton, A. & Tan, E. (2018). A longitudinal study of equity-oriented STEM-rich making among youth from historically marginalized communities. *American Education Research Journal*. DOI: 10.3102/0002831218758668

[7] Tucker-Raymond, E. & Gravel, B. (2019) *STEM Literacies in Makerspaces: Implications for Learning, Teaching, and Research*. New York, NY: Routledge

[8] Edwards, C., Lee, W.C., Knight, D.B., Reid, K., Fletcher, T., Meeropol, G. (2018). Maximizing Accessibility: Providing Summer Engineering Experiences for Racially, Ethnically, and Economically Underrepresented Youth. Collaborative Network for Engineering and Computing Diversity Conference, Crystal City, VA.

[9] Mercado Santiago, M. (2014). *Culturally responsive engineering education: A case study of a pre-college introductory engineering course at Tibetan Children's Village School of Selakui*. Dissertation.

[10] Ortiz, A. M., & Rodriguez Amaya, L., & Warshauer, H. K., & Torres, S. G., & Scanlon, E., & Pruett, M. (2017). They Choose to Attend Academic Summer Camps? A Mixed

Methods Study Exploring Motivation for, and the Impact of, an Academic Summer Pre-engineering Camp upon Middle School Students in a Latino Community. In the *Proceedings of the 2017 ASEE Annual Conference & Exposition*, Columbus, Ohio.

[11] Jordan, S. S., & Betoney, C. A., & Pangan, T. J. D., & Anderson, I., & Fernandez, J. A. (2018). Board 66: Results from the Implementation of Culturally-relevant Engineering Design Curriculum for the Navajo Nation and Future Directions. In the *Proceedings of the 2018 ASEE Annual Conference & Exposition*, Salt Lake City, Utah.

[12] Young, G.D., Knight, D., Lee, W.C., Cardella, M., Hynes M., Reid, K. and Fletcher, T. (2017). Leveraging a multi-partner approach to develop successful STEM outreach programs. *Proceedings - Frontiers in Education*, Indianapolis, IN.

[13] Knight, D.B., Lee, W.C., Cardella, M., Hynes, M., Young, G., Reid, K., & Edwards, C. (2018). Strengthening the STEM pipeline for elementary school African Americans, Hispanics, and girls by scaling up summer engineering experiences. *Proceedings of the 2018 Annual Conference of the American Society for Engineering Education*, Salt Lake City, UT.

[14] Capobianco, B.M., French, B. F. and Diefes-Dux, H. A. (2012). Engineering Identity Development Among Pre-Adolescent Learners. *Journal of Engineering Education*, 101: 698-716. doi:10.1002/j.2168-9830.2012.tb01125.x

[15] Robinson, C.W., & Zajicek, J.M. (2005). Growing minds: The effects of a one-year school garden program on six constructs of life skills of elementary school children. *HortTechnology*, *15*(3), 453-457.

[16] Townsend, C.D., & Carter, R.I. (1983). The relationship of participation in FFA activities and leadership, citizenship, and cooperation. *Journal of the American Association of Teacher Educators in Agricultural, 24*(1), 20-25.

[17] Hynes, M., Maxey, K. (2018). Investigating the Fit Between Students? Personal Interests and Their Perceptions of Engineering in a National Society of Black Engineers (NSBE) Pre-college Summer Workshop. *Proceedings of the 2018 American Society for Engineering Education Annual Conference and Exposition,* Salt Lake City, UT.

[18] Sigmon, M., & Jones, B. D. (2015). Creating a version of the MUSIC Model of Academic Motivation Inventory for elementary school children. Paper presented at the annual meeting of the *Eastern Educational Research Association*, Sarasota, Florida.

[19] Holland, J. L. (1997). *Making vocational choices: A theory of vocational personalities and work environments* (3rd ed.). Odessa, FL: Psychological Assessment Resources.

[20] Hsu, M.-C., Cardella, M. E., & Purzer, Ş. (2014). Assessing Design. In Ş. Purzer, J. Strobel, & M. E. Cardella (Eds.), *Engineering in Pre-College Settings: Synthesizing Research Policy, and Practices* (pp. 303–313). West Lafayette, IN.

[21] Yun, J., Cardella, M., Purzer, S., Hsu, M., & Chae, Y. (2010). Development of the Parents' Engineering Awareness Survey (PEAS) According to the Knowledge, Attitudes, and Behavior Framework. In the *Proceedings of the 2010 American Society of Engineering Education Annual Conference & Exposition*, June 2001, Louisville, KY.

[22] Lewis, R.S., Edwards, C., Lee, W.C., Knight, D.B., Maxey, K.R., Rush Leeker, J., Cardella, M.E., & Hynes, M. (2018). Examining the value of mentoring in youth engineering programs: What motivates a mentor to mentor?. Proceedings of the 48th Annual Frontiers In Education Conference, San Jose, CA.

[23] Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. In the *Journal of Engineering Education*. https://doi.org/10.1002/j.2168-9830.2007.tb00945.x

[24] Beauchamp, C., Edwards, C., Knight, D.B., Lee, W.C. (2019). Exploring student perceptions of teamwork in a summer outreach program. *Proceedings of the 2nd Annual Collaborative Network for Engineering and Computing Diversity Conference*, Arlington, VA.

[25] Wright, C. (2016). Constructing a collaborative critique-learning environment for exploring science through improvisational performance. *Urban Education*. doi:10.1177/0042085916646626

[26] Tucker-Raymond, E., Lewis, N., Moses, M. et al. (2016) Opting in and Creating Demand: Why Young People Choose to Teach Mathematics to Each Other. *Journal of Science Education & Technology*, 25 (6), 1025-1041. https://doi.org/10.1007/s10956-016-9638-0