Student Outcomes in Academic Community-Engaged STEM Projects with Multi-Dimensional Diversity

Dr. Danielle Wood, University of Notre Dame

Assistant Director for Community-Based Research and Impact.

Dr. Wood received her M.S.and Ph.D. from the University of Wisconsin-Madison and holds her B.S. from Purdue University. Her research interests include community engagement, asset-based community development, collective impact, and evaluation in complex settings.

Mrs. Alisa Zornig Gura, University of Notre Dame

Alisa Zornig Gura has served in various STEM community engagement roles with the University of Notre Dame since 2006 focusing on grant team management, program management, and project management as well as Broader Impacts for National Science Foundation proposals. She was the Executive Director of the Northern Indiana Regional Science and Engineering Fair from 2012 to 2016 and served on the Science Education Foundation of Indiana Board of Directors during that time. In addition, her committee work includes several initiatives to broaden participation of underrepresented groups in STEM. She holds a Bachelor of Science degree in Criminal Justice and a Master of Public Affairs degree with a concentration in Nonprofit Administration from Indiana University South Bend.

Dr. Jay B. Brockman, University of Notre Dame

Dr. Jay Brockman is the Associate Dean of Engineering for Experiential Learning and Community Engagement. He received his Ph.D. in Computer Engineering from Carnegie Mellon University and previously worked for Intel Corporation. He is also a founder of Emu Solutions, Inc., a startup company that is commercializing research in the area of high-performance computing.

Sam Alptekin

Student Outcomes in Academic Community Engaged STEM projects with Multi-Dimensional Diversity

Introduction

The United States lags behind most of the 72 developed countries in the 2015 international assessment of student STEM outcomes by the Organisation for Economic Co-operation and Development Programme for International Student Assessment (OECD PISA). It is also below the average in mathematics and lags behind 18 of the 35 member countries for the average science score (OECD, 2015). The demand for STEM skills in the United States workforce is not at just the baccalaureate or graduate degree level; STEM-trained workers are needed to perform in the 27% of STEM postsecondary jobs requiring competencies at the sub-baccalaureate level (postsecondary certificate, some college credit, or Associate degree level) (Carnevale, Smith, & Melton, 2011). Nonetheless, attrition is disproportionately high for women, African Americans, Latinos, and people from low-income families in STEM fields, leading to substantial research exploring why people leave the field (Seymour, 2000). In order for the United States to begin to meet STEM employment projections, educational institutions at all levels of workforce development need improved approaches to attract and retain diverse students in the STEM fields (Carnevale, Smith, & Melton, 2011; Gates Jr. & Mirkin, 2012 ; Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013).

In response to the need for a more diverse and prepared STEM workforce, the Bowman Creek Educational Ecosystem (BCe2) was developed for the purpose of attracting and retaining diversity into the STEM fields and building STEM literacy throughout the region while improving the quality of life in low-income neighborhoods. To address

STEM needs at various levels, BCe2 employs a concept known as multi-dimensional diversity, extending diversity into race, gender, and socio-economic status, including a diversity of student ages, education, and cultural backgrounds. The fundamental aim of BCe2 is to develop a system for STEM learning across different types of institutions that is woven into the cultural fabric of the region - creating a 'sticky environment' for STEM. As such, this effort seeks to impact attraction and retention *across* the STEM pipeline, but also attraction and retention of STEM professionals to the geographic region in which the students and institutions are making contributions. The National Science Foundation recognized the potential for BCe2 to engage underrepresented groups in STEM by funding research on the model through their Improving Undergraduate STEM Education program.

About the project

To achieve its aims of increasing representation in STEM fields and building STEM literacy throughout the region, the collaboration for BCe2 occurs across many institutions and types of partners, including area schools, government, community organizations, and a diversity of academic institutions. Although led by the College of Engineering at the University of Notre Dame, other local schools in the partnership are Indiana University at South Bend, Ivy Tech Community College, and the Engineering Magnet school in the local district (Riley High School). The strength of the BCe2 collaboration was recognized with the Indiana Department of Education's 2018 Award for Excellence in the Post-Secondary Education category.

Outcome aims for the student internship include: development of leadership skills, engagement with local community, and engagement with STEM content through authentic community projects. The aims also included changes in Accreditation Board for

Engineering and Technology (ABET) student outcomes that relate to 'workforce readiness' and '21st Century skills' such as the ability to function on multidisciplinary teams, the ability to communicate effectively, and the ability to design a system or process. The internships occur over 10 full-time weeks during the summer and interns are paid $10 per hour for their work.

Leadership development for BCe2 follows a servant-leader model with the intention of deepening experiential learning. It begins with a behavior model training – the Leadership Effectiveness Triangle of Awareness, Competence, and Commitment. Next, interns are trained in team-building and identifying problem-solving preferences. These skills are integral to understanding common frictions in teamwork as student teams engage the complexity of problem-solving for community issues. Following initial training, BCe2 interns engage in real-world community projects. In 2017, multi-dimensionally diverse teams tackled a variety of projects, such as Vacant Lot Optimization, Integrated Stormwater Management, Native Tree Nurseries, and Neighborhood Redevelopment. With support from three STEM teachers from Riley High School in South Bend, a full-time BCe2 Team Lead oversaw the development and progress on all the projects. Additionally, a group of over 20 mentors made up of working professionals from the local community volunteered to mentor the interns through a user-centered design approach to problem-solving.

The Bowman Creek Educational Ecosystem effort applies elements of the persistence framework (Graham et al., 2013) with early research and active learning in the community. Early experience in applications of STEM can also help build confidence and identity related to STEM. Forming identity in connection to a discipline is one of the strongest indicators of persistence in that discipline (Andersen & Ward, 2014) and active

learning can support diversity in sensemaking (Danielak, Gupta, & Elby, 2014). Challenging students to innovate and invent also increases engagement and retention while encouraging collaborative learning (Kennedy & Odell, 2014). By attending to critical qualities for an innovation ecosystem, which is characterized by a social, open, contextual, and tangible culture (Meinel & Leifer, 2014), BCe2 draws on what is known about fostering innovation design to establish team cultural norms and guide project development. The BCe2 model contributes two critical conceptual extensions: the role of multi-dimensional diversity in STEM learning and the interest in developing a geographically specific STEM workforce. It contributes to the development of these skills and dispositions within a multi-dimensionally diverse context, providing the conditions to add to our understanding of the benefits and challenges of even more 'behaviorally complex teams'(Zafft, Adams, & Matkin, 2009).

Methods

Selection

Student interns in this study were nominated through a referral process from faculty and teachers at partner institutions. Student selection occurred through an application, interview, and screening process, which included criteria to ensure that the intern cohort was built with an emphasis on diversity in age, education, socio-economic status, and racial and cultural backgrounds. The final 2017 cohort included 28 college/university and 2 high school students.

Data collection

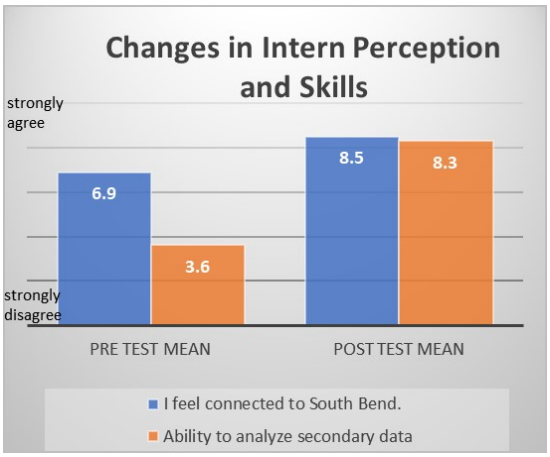
This inquiry used a concurrent mixed methods design, which included a nested quasi-experimental design with pre/post-testing to understand changes in student outcomes from the initiation of the internship to its end. The pre/post testing was delivered through a digital survey instrument using Qualtrics software and included quantitative Likert-type

scaling and qualitative open-ended questions. Other qualitative data was collected through reflections, interviews, and ethnographic observations. Qualitative data was used to provide context, augmentation, and nuance. Ethnographic observations provided insights to the learning environment, culture, and other socially constructed programmatic concerns. This study was submitted to and approved through the University of Notre Dame's Institutional Review Board.

Analysis and Findings

After data cleaning, quantitative information from surveys was analyzed using SPSS Statistics Software. Researchers conducted a paired-samples t-test on the pre/post data to identify differences shown in the survey data from the intervention, meaning the BCe2 internship. Despite challenges with the broad differences in the interns and different learning areas, there were some topics that highlighted growth areas for all interns. Two statements with Likert-type scale responses highlighted significant change that was common across the different subgroups in the internship. A paired-samples t-test was conducted to determine differences pre and post intervention in responses to the *ability to analyze secondary data*. There was a statistically significant increase in interns reporting using secondary data to address a community challenge from Time 1 (M=3.58, SD=3.403) to Time 2 (M=8.29, SD=1.578), $t(21) = -6.848$, $p<.001$ (two-tailed). The mean increase was 4.71 with a 95% confidence interval ranging from -6.14 to -3.28. The eta squared statistic (.69) indicated a large effect size. Both showed a statistically significant increase from the beginning of the internship to the end and had a large effect size.

A localized version of the survey instrument contained several questions specific to South Bend, thus providing information pertinent to developing a geographically specific



STEM workforce. A paired-samples t-test was conducted to determine differences pre and post intervention in Likert-type scale responses to the statement *I feel connected to South Bend.* There was a statistically significant increase in interns reporting feeling a connection to South Bend from Time 1 (M=6.94, SD=3.138) to Time 2 (M=8.48, SD=2.158), t(21) = -2.297, p=.03 (two-tailed). The mean increase was 1.54 with a 95% confidence interval ranging from -2.94 to -.142. The eta squared statistic (.21) indicated a large effect size.

Qualitative data from ethnographic observations and interviews was coded for consistent themes of interest according to underlying research questions. These included: attraction to STEM; attraction to the region; STEM skill-building; collaboration and soft skills; project planning and management; and governance and change. Narrative responses from the open-ended questions on the pre/post survey were coded for themes similarly. Interns most commonly indicated an increased attraction to the region and understanding of the benefits of diversity in collaborative project. Furthermore, several at-risk students indicated through survey or interview data that because of BCe2 (e.g. mentors, engaging learning environment) they intend to stay in their discipline.

Early findings suggest that the BCe2 strengthens STEM attraction and retention across the STEM pipeline, helping to build a workforce that will meet national STEM employment needs and projections. Moreover, findings also suggest that the model develops in students a sense of civic commitment and attachment to place that can encourage geographic diversity in how STEM talent is distributed. Together, the model

shows promise in human resource development, particularly when it is applied in areas where it is difficult to retain STEM-skilled workers.

Discussion and Next Steps

Early data from the BCe2 pilot related to attraction and retention of underrepresented students in STEM are encouraging; engaging diverse teams of interns in authentic community projects and exposing them to career possibilities helps interns to build technical skills and identify with STEM workforce opportunities. Preliminary findings from survey and interview data regarding *feeling a connection to the region* also provides pertinent information to regarding the potential for the BCe2 model to develop a geographically specific STEM workforce.

To more fully understand both the influences of context and how BCe2 impacts actual retention of students in STEM professions, further study is needed. To test the influences of context, pilot sites in additional communities with different types of institutional partners is needed (for example, a public lead institution situated in a large or small rather than medium-sized city). In addition, a longitudinal study that tracks participants into their early careers would be important to confirm the germination of the seeds planted by the BCe2 internship experience. Significant indicators of model and programmatic success would include sustainability of additional pilots in other locations, along with fields of employment at one, three, and five years after graduation, home and workplace geographic locations, and confidence in career preparedness specific to individuals who participated in the internship.

This work is supported by the National Science Foundation Informing Undergraduate STEM Education program under Grant No. 1612021. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Andersen, L., & Ward, T. J. (2014). Expectancy-value models for the STEM persistence plans of ninth-grade, high-ability Students: A comparison between black, hispanic, and white students. *Science Education, 98*(2), 216-242.

Carnevale, A. P., Smith, N., & Melton, M. (2011). STEM: Science Technology Engineering Mathematics. Center on Education and the Workforce: Georgetown University.

Danielak, B. A., Gupta, A., & Elby, A. (2014). Marginalized Identities of Sense-Makers: Reframing Engineering Student Retention. *Journal of Engineering Education, 103*(1), 8-44.

Gates Jr., S. J., & Mirkin, C. (2012 June 25). Encouraging STEM Students Is in the National Interest, *Chronicle of Higher Education*.

Graham, M. J., Frederick, J., Byars-Winston, A., Hunter, A.-B., & Handelsman, J. (2013). Increasing Persistence of College Students in STEM. *Science, 341*(6153), 1455-1456. doi: 10.1126/science.1240487

Kennedy, T., & Odell, M. (2014). Engaging Students in STEM Education. *Science Education International, 25*(3), 246-258.

Meinel, C., & Leifer, L. (2014). *Design Thinking Research: Building Innovation Ecosystems*.

OECD. (2015). PISA 2015 Results (Volume I): Organisation for Economic Co-operation and Development.

Seymour, E. (2000). *Talking about leaving: Why undergraduates leave the sciences*: Westview Press.

Zafft, C. R., Adams, S. G., & Matkin, G. S. (2009). Measuring Leadership in Self-Managed Teams Using the Competing Values Framework. *Journal of engineering education, 98*(3), 273-282.