Bulls-Engineering Youth Experience: promoting relationships, identity development, and empowerment for 1st year students through outreach

Jonathan E. Gaines, Ph.D., Victoria Bergman
The University of South Florida, gainesj@usf.edu, bergman1@mail.usf.edu

Abstract - **Bulls-Engineering Youth Experience Promoting Relationships, Identity Development, and Empowerment (Bulls-EYE PRIDE) is a 3-year engineering design based intervention program recently recommended for funded through the National Science Foundation's Broadening Participation in Engineering program. Project personnel train and hire engineering undergraduate students as mentors for local middle school youth. After training, mentors facilitate a 5-week summer intervention program for rising 7th and 8th graders, drawing from a community around USF that is primarily Black and Hispanic. Part one of the curriculum, Bulls-EYE Robotics, was created and piloted during the 2014-2015 academic year to target rising 7th graders with an emphasis on mechatronics and interpersonal relationships. Part two of the curriculum, Bulls-EYE Environment, was created and piloted during the 2015-2016 academic year to target rising 8th graders through environmental engineering, earth science, and community involvement. All activities are structured through the program's novel Plan, History, Act, Shift, Evaluate, Success (PHASES) design process. The program will reach 120 middle school youth and 60 mentors while adding a research component to measure participant engineering identity development over time. This paper presents the essential components of the Bulls-EYE PRIDE program while sharing reflections from some of the Bulls-EYE Mentors about their experiences facilitating the pilot programs.**

Index Terms – Engineering identity, Interdisciplinary engineering design, K-12, Outreach, Mentoring

MOTIVATION

A lack of sustained participation in engineering has been found to be partly due to poor engineering identity among underrepresented minorities (URM) [1]. Insufficient support systems, particularly during the summer months, also obstruct the development of promising URMs [2]. Approaches in the literature to make teaching, learning, and mentoring more culturally responsive [3] if applied to engineering design might lead to increased engineering identity, support, and consequently higher representation. Approaches leveraging the design process to increase engineering identity are needed especially if able to convert theory into practice.

In the effort to broaden participation in engineering, URMs benefit from learning environments where relevance, supportiveness, critical thinking, and inter/intra-personal skills are important [3]. Engineering design may be particularly important for learning involving URMs in that: (1) engineering can be introduced as a profession that helps the community, (2) design teams benefit from cultural diversity and are cooperative in nature, (3) engineering problems can be open-ended and rely on inquiry and critical thinking skills and (4) engineering design teams often support the development of critical life skills.

The values of culturally responsive engineering design might have an even more fundamental benefit to learning for URMs. Culturally responsive learning emphasizes “ethnic identity, cultural competence, academic skills, and community allegiance and service” (Gay, 2010, p. 203) as a holistic package. All of these traits can be reflected fairly organically in the engineering design process. Thus, a culturally responsive approach to engineering design may provide a counter-space for a more fruitful learning environment. The inquiry based nature of engineering design projects also lends itself to “topic-chaining” instruction which has been found to be particularly effective for URMs [4]-[8]. Topic chaining pertains to the need to build towards complex topics by relating previous learning experiences to future ones while also introducing relevant context.

INTRODUCTION

Bulls-EYE PRIDE aims to increase engineering identity by investing in participant life skills and technical skills. The program invites 40 middle school youth and 20 undergraduate students to campus for a 5-week summer camp meant to increase engineering identity of 3 target populations simultaneously:

- **URM Mentees:** URM middle school students from the surrounding area of USF that participate in Bulls-EYE Robotics and/or Bulls-EYE Environment as 6th, 7th, and/or 8th graders;
- **Engineering Mentors:** Undergraduate students that participate in the program in the early years of advancement in their engineering program in need of leadership development experience;

- **NMST Mentors:** URM Novice Math or Science Teachers that participate as experienced pre-service teachers or early in-service teachers with a need for professional development experience.

Each year, the program will select, train, and hire 20 mentors—a cohort of 15 Engineering Mentors and 5 Novice Math/Science (NMST) Mentors to facilitate the program's Bulls-EYE Robotics and Bulls-EYE Environment curricula. Mentors complete a 16-hour training on culturally responsive mentoring to prepare for work with mentees. Each intervention will have 7-8 Engineering Mentors, 2-3 NMST Mentors, and 20 mentees. The program will use a mixed methods approach to measure its impact on engineering identity and skills. An advisory board and independent evaluator will further evaluate the approach.

The program introduces the PHASES (Plan, History, Act, Score, Evaluate, Shift) design process as a vessel for the delivery of program content. PHASES connects middle school engineering Next Generation Science Standards (NGSS) through a systematic "topic-chaining" approach while providing opportunities for critical thinking, self-improvement, and community engagement. PHASES starts with a simple design process and adds additional steps as youth complete projects and become comfortable with learned skills. The approach combines Gay (2010) approach to culturally responsive learning and an amended version of Ulrich and Eppinger (2008) [9] 7 step design process. PHASES is unique because it emphasizes strong relationships through 1. traditional scaffolding to build upon simpler ideas, 2. storytelling through an interconnected narrative, and 3. relevance to the practical realities of participants. The PHASES structure, applied to informal learning environments for this project, is expected to also translate to more formal educational settings.

FIGURE 1
PHASES DESIGN PROCESS USED FOR PROJECTS IN BULLS-EYE PRIDE.

NGSS are featured one at a time as the design process becomes more complex. MS-ETS1-1 is featured in Phase 2 where "Plan-Act-Eval" is the design process for the first project. The step "History" is added to the design process in Phase 3 the following week to feature MS-ETS1-2. The next project is related to the first and requires understanding of competing designs from researching previous solutions. MS-ETS1-3 is then featured in Phase 4 as "Score" is introduced because specific characteristics of competing designs are analyzed with respect to design criteria towards a redesigned solution. Lastly, Phase 5 adds "Shift" to the design process to feature MS-ETS1-4 since the performance of the final design product will be tested and modified. As each week features a newly added design step, analogy to parallel life skill activities is used to provide soft skills and help give projects context and relevance.

Three research questions have been developed to assess the projects effectiveness:

1) Which components of the Bulls-EYE PRIDE program do stakeholders (Advisory Panel, mentors, and mentees), perceive as critical in engineering identity development?
2) How do Engineering Mentors' and URM Mentees' engineering identities develop in the Bulls-EYE PRIDE program over time?
3) To what extent and in what ways do NMST Mentors demonstrate increased understanding of engineering design and a willingness to incorporate aspects of engineering design in their classroom teaching? What are the challenges and supports that NMST Mentors face as they attempt to use aspects of engineering design in their classroom teaching in a culturally responsive manner?

Bulls-EYE TEST will use a conceptual framework comprised of the following dimensions:

- Intrinsic psychological and behavioral motivation to study engineering [10]-[11]
- Engineering knowledge, skills, and competencies [12]-[13]
- Presence of meaningful interpersonal relationships: This dimension will examine positive experiences with faculty, peers, mentors, and sponsors [14]-[16].
- Environmental and cultural influences of engineering identity development: This dimension will examine the following: cultural processes [17], engineering role modeling [18], sense of belonging [17], the outcomes from engaging in a "rites-of-passage" ceremony [14] [19], attributes specific to social identities (e.g., gender, race, ethnicity) [14]-[16], [18], fortified commitment to the community [18], nurturing of an engineering family or community [18].

Each component of Bulls-EYE PRIDE is structured in a way that simultaneously addresses each facet of this framework. Like Stevens et al. (2008) asserted, these dimensions are both distinct and interrelated.

MENTOR REFLECTIONS

The structure of the program was finalized through the program's two pilot programs conducted during the 2014-2015 and 2015-2016 academic years. Three of the authors of this paper served as mentors and have provided reflections on what the program meant to them. Victoria

Bergman, a senior undergraduate student that participated as a mentor for the 2nd pilot program provides a narrative.

"*Growing up my family would've never had the resources available to enroll me in a program such as BullsEYE which is why I think it is such a great way to give back to the local community and provide an environment that can help foster the potential many kids may not know they have*." – Victoria

"With BullsEYE undergraduates had the opportunity to lead a small team of middle schoolers in the ways of TETRIX Prime robotics along with the novice ideas behind the engineering and design aspects involved in making a cohesive robotic design. Not only was BullsEYE rewarding professionally, but it was also very rewarding personally for the mentors as well."

"With the first half of the BullsEYE curriculum geared towards building up critical thinking skills required for implementation and execution of a design TETRIX Prime robotics were used because they were ideal in the sense that it provided a standard base for which groups could start with while still allowing for each team to customize their robots as they saw fit based on the theme that year. With many of the mentees coming from nontraditional backgrounds, most of the children had never seen or heard of TETRIX Prime prior to BullsEYE which was where the mentors came in. With mentors only stepping in when necessary, mentees were able to develop critical thinking skills as evidenced by each group's customization and adaptation of their robots in accordance to their regular design, much like how an engineer out in the field would have to adapt his or her plan to changing circumstances. As the mentors saw introducing TETRIX Prime to these children came with a learning curve in the beginning but thanks to positive reinforcement and persistence the mentees got better over time"

"*I thought it was really cool to see your mentee get better and better with how to work the TETRIX Prime kits pieces; at the beginning of the program the kids had no idea how two beams were supposed to connect, but then towards the end when presented with the task of adapting their robots my group broke down what they were going to do step by step and executed their plan no problem.*" –Victoria

"Since the second half of the program was aimed towards interpersonal relationships between the mentees and the mentors a lot of the focus for the second half of the day was geared towards working on leadership skills as well as how to properly express and formulate one's thoughts. More often than not the traditional classroom settings these middle schoolers are in for their regular academic year does not offer the kind of opportunity for personal growth and improvement that only BullsEYE can provide. In the program because there doesn't exist the problem of a student only having their instructor's attention for a few brief moments of help before being left for another an issue, it allows for the mentees to really focus at the task at hand. As pointed out by a mentor, these were the conditions in which their [mentees] talents and potential flourished,

"*When BullsEYE began, one of my mentees was really shy and offered more assistance in helping out with small tasks related to building their group's robot but as the weeks went on they started to come out of their shell and become more confident and I thought that was cool how I saw them slowly become more outspoken as the weeks went on*"—Victoria

"By the end of the program, BullsEYE aimed to grow both the technical and interpersonal skills of all attendees. Providing the environment in which these relationships between middle schoolers and the undergraduates served as an unforgettable experience for these kids whose untapped potential for engineering and design could've gone by unnoticed for years in their classrooms." Victoria's narrative concluded with the following:"

"It goes without saying that BullsEYE was equally enriching for those who helped to run it as well since the mentors got a firsthand experience on what it really means to help shape the STEM of tomorrow." –Victoria

The narrative provided by Victoria demonstrates some of the strengths of the program and its ability to support the growth of both mentors and mentees.

CONCLUSION

Bulls-EYE Mentoring successfully piloted its curriculum and finalized its program structure during two pilot programs that culminated in two five week summer camps on the campus of the University of South Florida. These pilot programs hired a cohort of undergraduate students and invited approximately 30 middle school youth to campus each year. This culminated in the Bulls-EYE Mentoring program being recommended for funding through the National Science Foundation's Broadening Participation in Engineering program. The reflection provided from one of the program's mentors shows in what ways the program is effective in making an impact with both mentors and mentees. The program's research component will measure engineering identity development of mentors and mentees to measure program effectiveness.

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AUTHOR INFORMATION

Jonathan E. Gaines, Ph.D. Instructor II, The University of South Florida, gainesj@usf.edu

Victoria Bergman, Undergraduate Student, The University of South Florida, bergman1@mail.usf.edu

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