Using Multi-Disciplinary Design Challenges to Enhance Self-Efficacy within a Summer STEM Outreach Program

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Abstract

Research regarding STEM programs has shown that participating in these programs leads to increased knowledge and retention of technological concepts [1]. Additionally, participating in STEM programs leads to increased self-confidence, satisfaction, and interest in engineering [2]. Current research focuses on whether participating in STEM programs increases self-efficacy [3]. However, several factors can influence the effectiveness of these programs. For example, motivation influences the degree to which participants are engaged with activities as does their background knowledge [4]. Additionally, program effectiveness is impacted by the limitations of the learning context itself such that participants will be unable to complete designs if expectations for the design exceed the constraints of their environment [4]. The program is designed to introduce and educate the participants in the various engineering disciplines offered at the collegiate level and culminates in a multi-disciplinary design challenge designed as a "collaborative-benefit" competition [5]. The program is meant to drive students toward collaboration and achievement of a shared goal.

The purpose of this study is to examine the effectiveness of an intensive, two-week project-based engineering program for high school students on self-efficacy and engineering identity in the participants. Results from this year's survey suggest that participating in the program increased high school students' perceived and actual knowledge of the engineering discipline. Completing the program also led to improvements in self-efficacy and increased interest in the field of engineering. This paper will discuss the process for developing design challenges for assessment of self-efficacy, assessment tools, and outcomes from the program delivery.

1. Introduction

Research regarding STEM programs has shown that participating in these programs leads to increased knowledge and retention of technological concepts [1]. Additionally, participating in STEM programs leads to increased self-confidence, satisfaction, and interest in engineering [2]. Current research tends to focus on whether participating in STEM programs increases self-efficacy [3]. However, there are several factors that can influence the effectiveness of these programs. For example, motivation influences the degree to which participants are engaged with activities as does their background knowledge [4]. Additionally, program effectiveness is impacted by the limitations of learning context itself such that participants will be unable to complete designs if the expectations for the design exceed the constraints of their environment [4].

Recent research in engineering education has shown that project-based learning classes can help to improve motivation of students, increase students' interest in engineering, and improve performance of engineering students [6]. Capstone-style design classes that give students the opportunity to develop a design-thinking approach to solving engineering problems. Brereton said, "Engineering fundamentals are learned through activities at the border that involve continually translating between hardware and abstract representation" [7]. It is with this in mind that the New Mexico Pre-Freshman Engineering Program (NM PREP) was molded into a project-based learning environment where students spend their time going back and forth between abstract ideas on a board and hands-on activities in an effort to build on the engineering fundamentals that could assist them in pursuing degrees and careers in STEM.

2. Methods

2.1 The Outreach Program [1]

NM PREP is a two-week program that takes place at New Mexico State University (NMSU). Throughout the program, students are introduced to the various engineering disciplines offered at the collegiate level. As such, this program is led by 11 engineering faculty members from the various engineering disciplines, each of whom delivered a pre-approved lesson relating to their current research. This structure gave students the opportunity to experience design-thinking as it relates to different engineering disciplines. Students also get to experience college life as they are housed in dorm rooms for the duration of the program. The program culminates in a multi-disciplinary design challenge designed as a “collaborative-benefit” competition which is meant to drive students toward collaboration and achievement of a shared goal [1].

2.2 Participants

Forty-eight high school students from across the state of New Mexico applied to participate in NM PREP. A committee comprised of 8 members rated the applications based on highest math and science classes completed, grades in all classes for the most recent semester, teacher recommendations, and merit of the student-written essay. After reviewing the applications, 47 students (62% male, 38% female) were selected to participate in the program. Of those that participated, 53% identified as Hispanic, 24% identified as Caucasian, and 23% identified as American Indian, Asian/Pacific Islander, African American, or Other.

2.3 Procedure

Prior to beginning the program, students were asked to complete a pre-survey. The survey consisted of a content assessment which asked students to define and identify various engineering concepts (such as the meaning of acceleration and velocity). Students were also asked about their degree of confidence regarding various subjects (e.g., “Algebra”), situations (e.g., “Building something from a drawing”), and skills (e.g., “Gathering the necessary information to solve a problem”). Additionally, students were asked about their engineering identity (e.g., “I think of myself as an engineer”), personal identity (e.g., “A person who is thrilled by discovering something new”), mindset (e.g., “Intelligence is something you are born with”), grit (e.g., “A person who thinks that intelligence is something you either have or you don’t”), and interest in engineering careers (e.g., “Industrial Engineer”). Following completion of the program, students were asked to complete a post-survey which was the same as the pre-survey with the exception that students were asked several open-ended questions about their participation in the program (e.g., “Would you like to participate in this program again”).

2.4 Development of Assessment tools

The Self-Efficacy Assessments were developed for the assessment of student self-efficacy, grit, mindset, and to gauge the efficacy and enjoyability of various aspects of the program. The self-efficacy questions were developed using questions from a tripartite model of self-efficacy focusing on confidence, identity and drive. The grit questions were developed based on Duckworth and colleagues’ [9] research focusing on perseverance and passion. The mindset questions were derived from Dweck’s research [10] regarding the comparison of fixed and growth mindsets.

The content exam was developed in-house based on the curriculum developed by NMSU professors and NM PREP Academy staff. More information about these assessment tools is available upon request through email at engr-nm@nmsu.edu.

3. Results

3.1 Content Assessment

Prior to completing NM PREP, participants got an average score of 68.87% on the content assessment (21.35/31 questions correct). Following the completion of NM PREP, participants got an average score of 72.26% on the content assessment (22.40/31 questions correct). While this difference in scores is not statistically significant (see Fig. 1), the results of the content assessment indicate that participants’ knowledge of engineering increased as a result of the program, $t(39) = -1.00$, $p = .33$, $d = 0.20$.

3.2 Confidence

After ($M = 2.58$, $SD = 0.60$) completing NM PREP, participants indicated that they felt significantly more confident about various subjects compared to before ($M = 2.28$, $SD = 0.58$), $t(42) = -4.48$, $p < .00$, $d = 0.51$ (see Fig. 2). Similarly, participants indicated that they felt significantly more confident about various situations after ($M = 3.06$, $SD = 0.45$) completing NM PREP compared to before ($M = 2.81$, $SD = 0.46$), $t(42) = -4.16$, $p < .00$, $d = 0.56$ (see Fig. 2). Participants also indicated that they felt significantly more confident about their skills after ($M = 3.07$, $SD = 0.52$) completing NM PREP compared to before ($M = 2.68$, $SD = 0.71$), $t(41) = -1.00$, $p < .00$, $d = 0.62$ (see Fig. 2). As such, participating in NM PREP improved participant’s confidence.

3.3 Identity

After ($M = 3.91$, $SD = 0.84$) completing NM PREP, participants indicated that they had a significantly stronger engineering identity compared to before ($M = 3.64$, $SD = 0.84$), $t(42) = -2.68$, $p = .01$, $d = 0.33$ (see Fig. 3). While participants also had a stronger personal identity after ($M = 3.49$, $SD = 0.49$) completing NM PREP compared to before ($M = 3.35$, $SD = 0.58$), the difference was not significant, $t(42) = -1.88$, $p = .06$, $d = 0.33$ (see Fig. 4). As such, participating in NM PREP had little influence on participants’ personal identity but it did improve their engineering identity.

3.4 Self-Efficacy

While participants had a stronger mindset after ($M = 2.65$, $SD = 0.60$) completing NM PREP compared to before ($M = 2.53$, $SD = 0.52$), the difference was not significant, $t(42) = -1.84$, $p = .07$, $d = 0.23$ (see Fig. 5). Similarly, while participants had a stronger sense of grit after ($M = 3.20$, $SD = 0.61$) completing NM PREP compared to before ($M = 3.08$, $SD = 0.55$), the difference was not significant, $t(42) =$

-1.17, *p* = .25, *d* = 0.21 (see Fig. 6). As such, participating in NM PREP had little influence on participants' self-efficacy.

4. Summary

4.1 Discussion

Results from this year's survey suggest that participating in the program increased high school students' perceived and actual knowledge of the engineering discipline. Completing the program also led to increased interested in the field of engineering and, although nonsignificant, improvements in self-efficacy. Further, high school students' confidence about engineering, engineering situations, and their ability to function as an engineer increased.

4.2 Considerations

The survey was independently developed within the NMSU College of Engineering, taking cues from educational research. There is a chance that some of the variability in the content assessment scores could be attributed to practice effects, though this probability has not been accounted for or examined. Further, the assessment tools and the academy itself are constantly being modified based on the data collected.

4.3 Future Work

Further exploration into the relationship between our design challenge and students' self-efficacy are planned for the next few years as a part of the NM PREP Academy curriculum. Additional components that will be examined in future programs will include data collection regarding grit and mindset of the students and changes therein. In addition to these results, there are plans to expand our scope of understanding the research team is looking to begin implementing the same self-efficacy survey to students in their freshman and senior years of an NMSU Engineering degree. Also included in this expansion will be the addition of a College Readiness Assessment (yet to be determined which one) for both the PREP students and the college students for a more thorough comparison.

References

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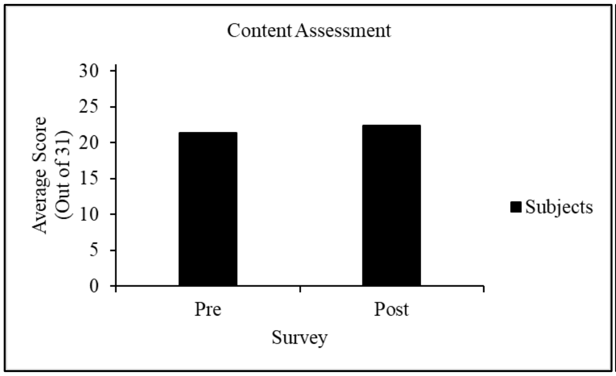

Fig. 1 Content Assessment

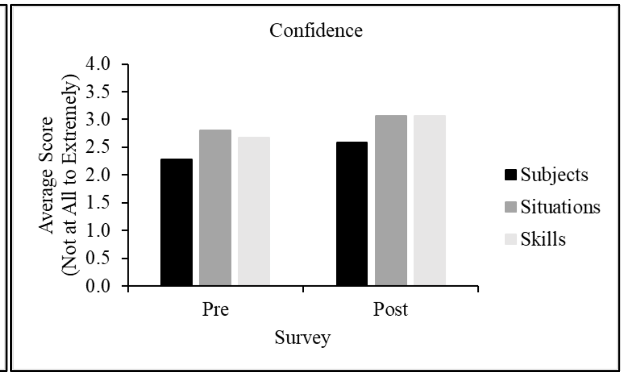

Fig. 2 Confidence

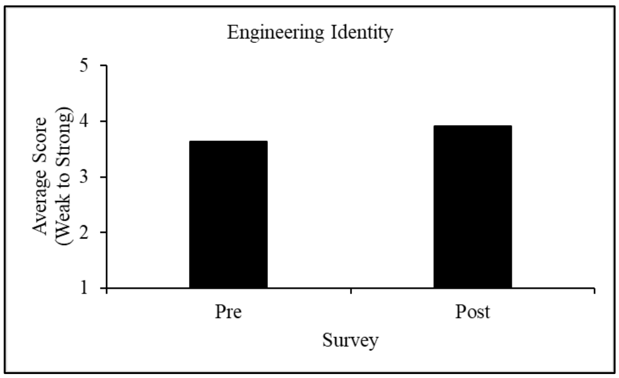

Fig. 3 Engineering Identity

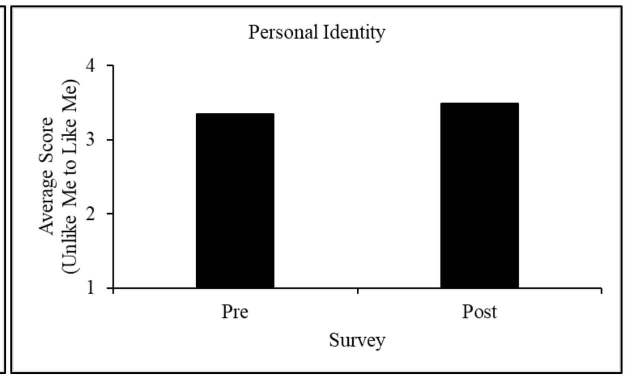

Fig. 4 Personal Identity

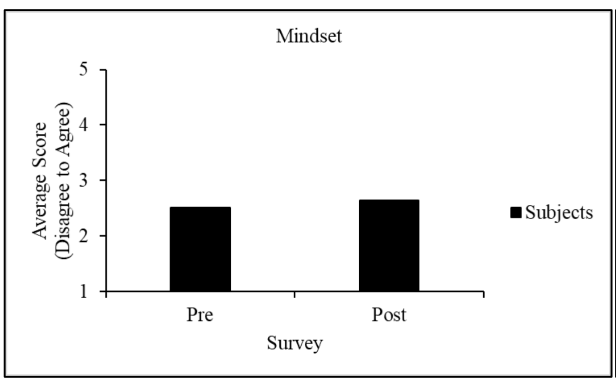

Fig. 5 Mindset

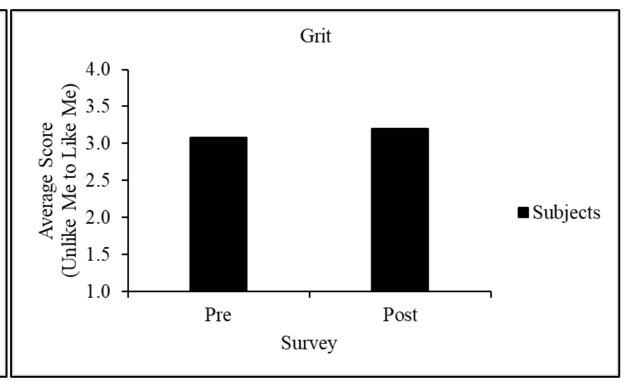

Fig. 6 Grit