Development of a Middle School Architectural Engineering Pilot Program (Work in Progress)

Introduction

STEM occupations are expected to grow in the next decade with much of the projected job growth predicted in architecture, engineering, and construction (AEC) occupations [1]. However, studies have shown that "an insufficient number of college students are pursuing degrees in engineering" [2], and "the number of underrepresented minority engineering graduates is not on pace to meet the shortfall" [3]. It is crucial to create inclusive educational programs in STEM to expose and connect with youths from underserved backgrounds to not only achieve innovation but also for more equitable educational outcomes. Buildings are used by all people, and as such all stakeholders can only be represented by a diverse workforce. This understanding of how engineering shapes the built environment is important to recognize and cultivate in young students; however, opportunities to engage in engineering in K-12 are often lacking or nonexistent for low-income students. In the pilot program discussed in this paper, the student participants and the counselors are part of a program called Talent Search, a program for low-income schools in Pennsylvania. Through collaboration with the Talent Search Program, challenges of participant recruitment and other common implementation problems can be avoided. The Talent Search Program is one of the Federal TRIO Programs dedicated to assisting low-income and/or first generation middle and high school students in furthering their education beyond high school. A majority of the students who participate in the targeted Talent Search programs are from demographic groups that are underrepresented in STEM.

This work in progress paper describes the development of the Middle School Architectural Engineering Pilot Program (MSAEPP) and the planned methods to measure the efficacy of the program in affecting middle school student's motivation in pursuing STEM careers as a part of a National Science Foundation Research Initiation in Engineering Formation (RIEF; 2106264) award. The study focuses on answering the research question: *"How does the combination of meaningful engineering learning, exposure to professional engineers, and career planning, focused on building industry engineering applications, increase identity-based motivation of students from low-income households and marginalized students in pursuing STEM careers?"* The MSAEPP consists of series of modules (Figure 1) designed to provide students the opportunities to explore perceptions of engineering and engineers, engage in meaningful engineering learning, and explore STEM careers while learning career planning and career exploration skills. Expanded descriptions of the modules are presented in Table 1. The MSAEPP is planned to be implemented through the Talent Search Programs at middle schools in Pennsylvania.

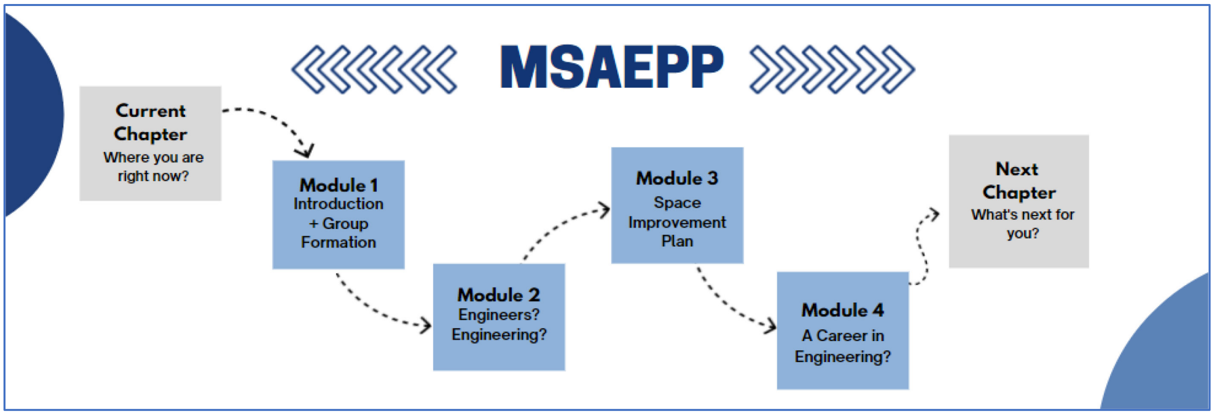

Figure 1. Flowchart of the modules

Theoretical Frameworks

We use two theoretical frameworks to develop and study the MSAEPP: Social Cognitive Career Theory (SCCT) [4] and Identity-Based Motivation (IBM) [5]. From SCCT, the core concept explored in this study is self-efficacy as this affects academic-career interest and future goal setting [4]. A strong sense of self-efficacy (an individual's belief in their capabilities) can be developed and strengthened through mastery experience and vicarious experience through social models [6, 4]. The three core components of IBM are action readiness (make strategies feel identity-congruent), psychological relevance (future is connected to the present; accessible identity matters for choice), and interpretation of experienced difficulty (facilitate interpretation of experienced difficulty as a signal of task importance) [7]. Oyserman suggested that an impactful intervention should "help students experience their future possible selves as psychologically relevant to the present, see strategies to attain that self as identity-congruent, and experience difficulties as energizing rather than undermining of goal-focused investment" [7, pp. 11]. The core concepts from SCCT and IBM are incorporated into the learning outcomes of the module activities. Modules are categorized into introduction, exposure to professional engineers, meaningful engineering learning and career development. Refer to Table 1 for the summary of modules, targeted constructs, and category of the activities.

Planned Methods

We are currently developing and adapting existing quantitative and qualitative measures to understand how the MSAEPP affects students' self-efficacy, identities, and motivations towards STEM careers. Our initial measures are mapped to each module and described in more detail below (Figure 2).

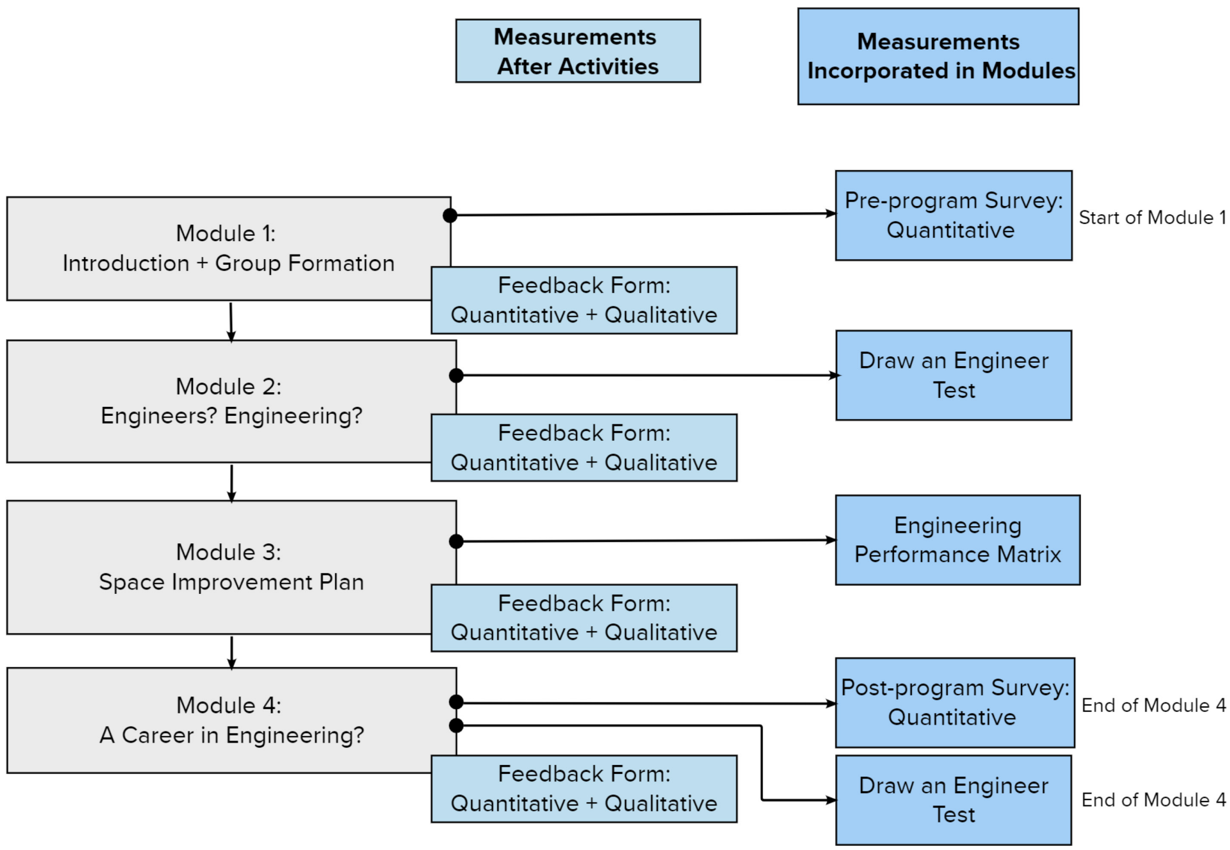

Figure 2. Proposed research methods for understanding the impact of the MSAEPP on learners.

Draw an Engineer Tool (DAET)

The Draw an Engineer Test (DAET) is both a written and drawn activity that elicits stereotypes students may have regarding engineering and being an engineer [8]. We will use this measure at the beginning and the end of MSAEPP to understand the starting perceptions of students (Module 2) and how those perceptions are affected by the pilot program (end of module 4). We will conduct a rubric and thematic analysis of the written and drawn responses. Data measured from both pre- and post-implementation could be compared and analyzed using inductive coding and using comparative analysis for the two sets of results.

Engineering Performance Matrix (EPM)

The Engineering Performance Matrix (EPM), obtained from the Framework for P-12 Engineering Learning [9], will be used to measure student's engineering literacy development in the program (i.e., meaningful engineering learning experiences). Engineering literacy consists of three dimensions which are Engineering Habits of Mind, Engineering Practices, Engineering Knowledge. The three dimensions contain core and sub-concepts and the activities in Module 3 will target specific engineering literacy concepts. The Engineering Performance Matrix will be used to measure students' development progress of the targeted engineering literacy core and sub-concepts. Additionally, the EPM could also be used to inform us on the students' self-efficacy; a positive performance could correlate with an increase in self-efficacy.

IBM and STEM Career Intentions

To measure the success of the intervention strategy in increasing engineering identity and motivation to pursue STEM careers, a multi-methods approach will be implemented through pre- and post-surveys and activity feedback forms.

Pre- and Post-Surveys

Pre- and post-intervention quantitative data will be gathered via modifying the STEM Survey, an existing instrument developed by two of the advisory board members, Adam Maltese and Merredith Portsmore, through NSF ITEST grant 1657509. This instrument was adapted from the 16-item revised Engineering Identity Development Scale (EIDS) [10], the Engineering Interest and Attitudes Survey (EIA) [11], STEM Fascination and Competence/Self-efficacy Scales [12], the STEM Career Interest Survey (STEM-CIS) [13], the Modified Attitudes Toward Science Inventory (M-ATSI) [14], the Persistence Research in Science & Engineering (PRiSE) [15], and Engineering Role Identity Measure [16]. This survey was developed for upper elementary and middle school students and measures STEM identity, STEM career interests, and the perceptions of role models. The survey instrument consists of 54 items and utilizes a 4-point response scale. Additionally, we will develop and test new survey items consistent with IBM constructs specifically for middle school students. Together, the modified STEM Survey will assess the students' engineering career interest, which is affected by self-efficacy, while the new IBM survey will supplement the current gap in measurement tools for IBM assessment of middle school students to better understand how students engage with engineering topics and perceive engineering for action readiness, psychological relevance, and interpretation of difficulty.

A positive increase in the Likert-scale scores would demonstrate that this program had some influence on students' goals, identities, and beliefs. These data will be analyzed using a paired t-test to determine if significant changes emerge as a result of the program activities with an planned alpha of 0.05. We will also examine the practical significance of these changes through effect sizes (i.e., Cohen's d). Multiple regression modeling will also be used to understand if changes in STEM identity are related to race, gender, year in school, and years in the programs (as well as the interaction effects of these groups) to understand how well the engineering activities worked for particular groups of students.

Feedback Forms

We will collect qualitative and quantitative data via a feedback form adopted from Pathways to Success Through Identity-Based Motivation [7, pp. 188]. It contains questions that measure which activities are successful at affecting the targeted identity-based motivation and self-efficacy constructs after the conclusion of each module. It will also contain open-ended questions to gather students' feedback and opinions about the modules and activities.

These data will be analyzed using a direct qualitative content analysis. Directed content analysis works with previously formulated, theoretically derived aspects of analysis by connecting them with the textual data. The goal of a directed approach to content analysis is to validate or conceptually extend a theoretical framework or theory [17, 18, 19]. Thus, this approach is particularly apropos for understanding how identity-based motivation functions in a K-12 engineering outreach context. This process involves both deductive coding based on the theoretical framework as well as inductive coding for emergent themes [18].

Throughout our study in both the making and handling of data, we will engage in validation questions to ensure the quality of the data [20].

Conclusion

Meaningful data will be collected to provide insight on the efficacy of the pilot program and how to better improve the program for future implementations. In addition, as part of the MSAEPP, a tool is planned to be developed to measure middle school identity-based motivation.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 2106264. Any opinions, findings, and conclusions are recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. Additional Support has been provided by an internal seed grant from the Penn State College of Engineering.

Module		Summary of Modules	Category	Activity		SCCT		IBM		
						Self-efficacy				
						Mastery	**Vicarious**	**Psychological Relevance**	**Action Readiness**	**Interpretation of Experienced Difficulty**
1	Introduction + Group Formation	Get to know the pilot program. Meet your fellow peers! Prepare yourself with the tools and skills for the pilot program.	Introduction	A.1	Introduction to MSAEPP					
				A.2	Pre-pilot program measurement					
				A.3	Group formation + icebreaker					
2	Engineers & Engineering	Explore perceptions and knowledge about engineering and engineers. Meet engineers from the industry. They will be your guide for your project.		A.1	Draw an Engineer Test (DAET)			Y		
				A.2	DAET Class discussion			Y		
				A.3	Create questions - Ask an engineer				Y	
			Exposure to professional engineers	A.4	Panel discussion with engineers		Y	Y	Y	Y
3	Space Improvement Plan	Propose a space improvement plan for your school! Practice engineering! Learn engineering specific content and transferable skills.	Meaningful engineering learning	A.1	Project introduction				Y	
				A.2	Project preliminary brainstorming	Y		Y	Y	Y
				A.3	Space research	Y			Y	Y
				A.4	Preliminary design	Y			Y	Y
				A.5	Design iteration	Y			Y	Y
				A.6	Finalize proposal and presentation slides	Y			Y	Y
				A.7	Final presentation				Y	Y
4	Career planning + exploration	Visit the engineer's office! Learn career planning strategies. Explore career pathways in STEM.	Exposure to professional engineers	A.1	One day as an engineer		Y	Y	Y	
			Career development	A.2	Learn to create a career plan			Y	Y	
				A.3	What do I know about myself?			Y	Y	
				A.4	STEM career pathways?			Y	Y	

Table 1 – Summary of categorized modules with activities and targeted constructs

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