Exploring the Impact of University Engineering Role Models on Elementary Students (NSF ITEST Project)

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Abstract

Tufts University founded an outreach program in 2001 in response to Massachusetts' inclusion of engineering in the required K-12 science curricular framework. The 17-year-old STOMP program places over 60 undergraduate engineering students as engineering ambassadors into 30 local elementary classrooms each year to help teachers integrate hands-on engineering design projects into their classroom weekly during the academic year. Inspired by the National Science Foundation's GK-12 model, STOMP was created to provide role models and support engineering activities in local schools. A unique characteristic of the STOMP program is that of the 60 undergraduate participants each semester, 50-65% are female, providing participating elementary students with opportunities to interact with role models of all genders. STOMP is representative of efforts that are happening at over 100 university-based engineering outreach efforts across the United States. As this type of outreach continues to proliferate, thinking about ways to improve and leverage this vast resource is essential to improving its impact.

Role Models in Elementary Engineering Education (RMEE) is an NSF ITEST project, leveraging expertise at Tufts University and Indiana University, that works with the existing STOMP program to develop intervention elements that optimize how role models in engineering are prepared and integrated into elementary school classrooms to maximize their impact on students' engineering identity and career awareness. With a particular focus on girls, RMEE is studying the traits and mechanisms that elementary students utilize to identify and select or reject potential role models in engineering.

This paper and poster will share the intervention elements developed and research results to date. Intervention elements include engineering trading cards for engineering ambassadors, news articles on engineering, and in-class tactics for building relationships between ambassadors and elementary students. Research for the RMEE project has focused on analysis of survey data on elementary students' engineering identity, qualitative analysis of interviews with elementary students on engineering interest, and close analysis of classroom video to examine productive interactions between engineering ambassadors and elementary students. The results and products of the RMEE project will inform and enable engineering outreach providers in multiple settings to enhance their programs and impact.

Introduction

As part of nationwide efforts to attract youth to engineering study and careers, many universities utilize engineering students as engineering ambassadors and role models to precollege students [1]. However, there is limited understanding of how this dynamic works and there are few resources to support helping undergraduates develop in this role. The Role Models in Elementary Engineering Education project leverages an existing university-led, in-school engineering education outreach program to 1) Advance the understanding of the mechanisms by which elementary students, with a particular lens toward gender, interact with and identify university engineering student role models, and 2) Develop resources to support effective role model-student interactions that can be used by any university-based engineering outreach program. Tufts University's Center for Engineering Education and Outreach and Indiana University are collaborators on the project.

STOMP is an existing engineering outreach program in which pairs of undergraduate students facilitate weekly, hour-long engineering design challenges in elementary school classrooms throughout the academic year. Within the context of the STOMP outreach program, the research team collected video recordings of interactions among undergraduate engineering ambassadors and participating elementary students, developed interventions to strengthen role model connections between ambassadors and elementary students, developed interventions to strengthen connections between elementary students' interests and engineering, and developed interview and survey instruments to better understand students' engineering identity, engineering interest, and connections with potential role models.

This paper and poster will share our research findings, the novel research methodologies we have developed, and innovations in outreach programming and outreach ambassador training.

Research Findings
In the first two years of this three-year project, the research team has focused on three areas: surveys, interviews, and classroom video data. Next, we detail what we have learned in these three areas.

1. **Engineering identity and engineering interest surveys**

In order to effectively cultivate engineering identity and interest in engineering, researchers need tools to measure engineering identity and interest. To date, engineering identity and interest research predominantly has focused on the middle school level and beyond [2]. However, studies of science, mathematics, and general STEM (science, technology, engineering, and mathematics) interest and identity suggest that STEM interest and identity begin to develop as early as elementary school [3]–[10]. It is reasonable to believe that engineering-specific interest and identity development are at work in early and middle childhood as well. However, few tools exist to measure engineering identity and interest at the elementary school age.

This project developed a survey instrument to measure engineering identity and interest in children in grades 3-6 (ages 8 to 12 years). The survey was refined over three phases and tested with 492 students in grades 3-6 in diverse communities in two states in the United States. In all phases, we adapted existing validated instruments to make questions more readable for and relevant to elementary students. For engineering identity items, we drew on social identity theory [11]–[13] to select items which assess the *recognition*, *interest*, and *performance/competence* factors of identity. Based on literature review and participant responses, we added items to assess *outcome expectations* and *STEM fascination.* To assess engineering identity, we drew from the 16-item revised Engineering Identity Development Scale (EIDS) [14], the Engineering Interest and Attitudes Survey (EIA) [15], STEM Fascination and Competence/Self-efficacy Scales [16][17], the STEM Career Interest Survey (STEM-CIS) [18], the Modified Attitudes Toward Science Inventory (M-ATSI) [19], and the Persistence Research in Science & Engineering (PRiSE) [20].

Additionally, the survey instrument assesses engineering career interest through assessing the types of activities that students are interested in doing as part of a future career. The current survey includes items created by the research team or adapted from existing instruments [21], [22] designed to assess students' interests and career interests. These items represent STEM activities (including engineering-specific activities) and non-STEM activities. The current survey instrument consists of 54 items and utilizes a 4-point response scale (which improved response variance). Exploratory factor analyses (EFA) using Principal Components analysis and reliability analyses (Cronbach's alpha) were used to eliminate items and explore underlying factors.

Recent research indicates there are likely three components of one's engineering identity: *recognition, interest,* and *performance/competence* [23]. Our data yielded a 5-factor model which expanded on these three components. While we expected to find a factor that represented *recognition*, two factors emerged: *recognition by others* and *self-recognition*. This is consistent with work which suggests that recognition by others is important in developing a science identity, but also important is whether one views one's self as a science person (self-recognition) [11]. The *interest* factor captured an individual's enjoyment in doing engineering activities, while the *performance/competence* factor reflected students' ability when doing engineering activities. Both factors are similar to constructs found in the literature [11], [12], [24].

We found a fifth factor in our data that warrants additional research. This factor seems to represent *perceptions of difficulty in engineering*. The three items that load on this factor are negatively worded items (e.g., "I don't understand engineering"). While these items could reflect a negative perception related to the difficulty of engineering, it is possible that these items loaded on one factor simply due to the negative wording. In other words, if the items had been worded positively (e.g., "I understand engineering"), they might have loaded on another factor such as *performance/competence*. Negatively worded items have been found to be psychometrically problematic because of the added level of difficulty when answering them. Some researchers have found that negatively worded items create distinct, albeit artificial, factors [25]–[27].

2. Interviews

This project aims to understand what mediates elementary students' identification and selection of engineering role models. Although the undergraduate engineering ambassadors may attempt to position themselves as engineering role models for participating elementary students, ultimately, it is the elementary students who choose role models for themselves. To understand what these elementary students are noticing and finding appealing or unappealing about these potential engineering role models, we interviewed the elementary students at the end of each semester in the outreach program. Our semi-structured interview protocol includes questions about students' experiences with engineering and the engineering outreach program, students' career aspirations, students' role models, and students' perceived connections or affiliations with the engineering ambassadors.

To date, we have interviewed 199 participating elementary students and have analyzed subsets of these interviews. We present two findings from the interview data: *interactions between engineering ambassadors and students lay the groundwork for, but do not guarantee, role model* *uptake* and *many students in this study are amenable to an engineering career, but do not find an engineering career more attractive than other career interests*.

Interactions between engineering ambassadors and students lay the groundwork for, but do not guarantee, role model uptake.

Prior research suggests that in order for students to select engineering ambassadors as role models, the students must perceive the ambassadors as appealing and attainable examples of desired futures [28]–[33]. Review of 126 of the interviews indicates that in a few cases, students overtly identify the engineering ambassadors as role models. More often, however, students appear to identify the ambassadors as appealing people, but not necessarily as exemplars of a desired future career. Broadly, students identify the ambassadors as affirming, caring, inspiring, helpful, and knowledgeable. Although students identify the ambassadors as appealing, if these students do not also want to become engineers, they may not be positioned to select the ambassadors as engineering role models.

Many students in this study are amenable to an engineering career, but do not find an engineering career more attractive than other career interests.

To unpack the extent to which students in this study are considering engineering careers, we analyzed a subset of 56 interviews, focusing on students' responses to the questions *Have you thought about what you want to do or be when you grow up? What kind of job would you like to have and why? Do you think you could be an engineer? Why or why not?* Analysis to date supports prior research findings that elementary aged students are contemplating career interests and options [34], [35]; in this study, 82% of participants readily named at least one career of interest to them and several participants also identified contingency career plans. This analysis identified a group of students (66% of our sample) who have currently identified a career of interest other than engineering yet are open to an engineering career. We wish to keep engineering as a career as a possible future for these students. This work suggests that it may be fruitful for engineering educators to identify ways in which engineering activities intersect with students' interests, thereby helping engineering study and careers to resonate with these students.

3. Classroom video data

The video data collection for the project focuses on capturing the classroom activity that occurs when undergraduate engineering ambassadors interact with elementary students in their classrooms. Thus far in the project, we have used a combination of audio and video recording to capture the ambassador/student interactions in 13 classrooms. Engineering ambassadors wear voice recorders and lapel microphones to capture all of their utterances and a selection of video cameras are used to record the classroom activity. In select cases, we also record groups of students in the classroom in order to see their interactions with ambassadors in the context of their engineering design work and group dynamics.

Analysis to date has focused on identifying the types of interactions engineering ambassadors initiate and support in the classroom. We have explored open coding and *a priori* coding around engineering design to unpack the pedagogical goals that engineering ambassadors attend to in the classroom. Preliminary analysis of their discourse suggests engineering ambassadors attend to and support students' engineering design work, particularly around planning, testing, and improvement, by positioning themselves as a coach who asks questions and models practices.

Intervention Elements

We designed interventions intended to develop our undergraduate ambassadors as engineering role models for participating students. Leveraging research on role modeling and mentoring, we intended to strengthen undergraduates' ability to build relationships with students and share their own identities as multi-faceted individuals who are studying engineering.

1. **Trading Cards**

We created "trading cards" for engineering ambassadors to share with their students.

Fig. 1: Trading Cards for Engineering Ambassadors

These cards are similar to baseball cards or Pokémon cards; each card shows an ambassador's face and name on one side, and fun facts about them on the other side. These fun facts include the ambassador's favorite engineering class, most challenging class, and engineering superpower as well as non-engineering-related facts such as if they have pets, siblings, or hobbies. Ambassadors distribute the cards to their students so their students can learn more about them and have more opportunities to observe similarities between themselves and ambassadors, which supports building personal connections with the ambassadors.

2. **Engineering Ambassador Training**

To help engineering ambassadors position themselves as role models, we developed training materials that we use to help share research on role models and interest in engineering to highlight relevant actions for the ambassadors. For example, role model literature [29], [33], [36] highlights that role aspirants often choose role models who share affiliations and characteristics with them. Hence, we encourage ambassadors to share background and relevant interest information with students such as their shared status as students, their position in a family with siblings, or their love of animals or video games.

Novel Methodologies

We are developing two tools: (1) an engineering identity measurement tool that may also serve as an intervention tool and (2) a qualitative data collection and coding app intended to support live coding of classroom observations.

1. *Create an Engineer LEGO* activity

We created the *Create an Engineer LEGO* activity to gain understanding of elementary students' sense of themselves as engineers now and their beliefs about their potential to become engineers. *Create an Engineer* extends tools such as the Draw-a-Scientist (DAST) [37] and Draw-an-Engineer Tests (DAET) [38]. The DAST and DAET examine students' (mis)conceptions of scientists and engineers; however, they provide limited information about whether students can envision *themselves* as scientists or engineers now or in the future. We drew from constructionism [39] and the LEGO Serious Play (LSP) method [40] which posit that hands-on learning results in deeper understanding of the world and oneself in it. The LSP method is a process used to enhance innovation and business development; in this process, adults build metaphorical representations of their identity using LEGO bricks. We adapted this process to help understand 3rd-5th grade students' engineering identity. We chose to use LEGO bricks and craft materials because these materials are familiar to many students, yet easy for students to use even without prior experience. The activity allows us to explore students' creations of physical representations of themselves as engineers, including elements related to gender and physical characteristics (e.g., skin color, hair color and style), all of which students can customize using a variety of LEGO and craft material options.

In the activity, we prompt students to imagine themselves as an engineer and doing engineering. Student write or sketch or write notes, then use a curated collection of LEGO bricks to build a scene of themselves doing engineering. Initially, student created themselves using LEGO mini-figurines and their scene with LEGO bricks; in future iterations, students will create themselves with craft materials and their scene with LEGO bricks. At the end of the activity, students reflect on what they have created by verbally sharing their creation with others. While these reflections provide insight into students' beliefs about who can be an engineer and what engineers do, they also provide students with an opportunity to imagine and see themselves in the role of an engineer.

Preliminary analysis suggests that this activity has potential for not only exploring students' perceptions of engineers but also as a way for allowing students to imagine themselves in the role of an engineer. We continue to refine the activity.

2. CLOBS 2.0

The RMEE project has collected over 400 hours of classroom video data. Traditional methods of transcription and qualitative analysis have limited the quantity of data that can be analyzed. To facilitate additional analysis as well as better catalog the data, the team at Indiana University has worked on a new tool that can be used for live coding of classroom activity as well as on video recorded session. The **CL**assroom **OBS**ervation tool (Figure 2) allows for classroom events to be coded and time-stamped. Still under development, the tool includes an underlying interface that will allow researchers to customize the codes and many of the functions, making it useful far beyond the RMEE project. Currently available for Windows, the testing to date has been limited but plans are in place to continue to redesign the tool and to seek funding to port it to other platforms.

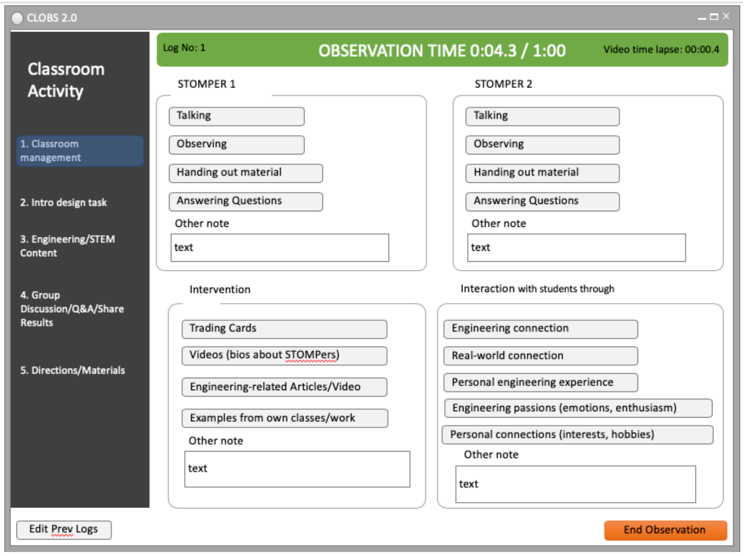

Fig. 2: CLOBS tool for coding live and video recorded classroom sessions

Next Steps

The Role Models in Elementary Engineering Education project is gearing up for its final year of data collection. Work is continuing on tool and intervention refinement to prepare for the comprehensive final year. We are testing new intervention elements (like engineering awards) to see how Engineering Ambassadors can recognize and celebrate individual students' abilities.

We are also working to consolidate resources the project has developed to be shared. STEMoutreachTools.org will host intervention elements as well as training elements with STEM outreach organizations and groups.

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References

[1] E. Iversen, "Engineering Outreach on Campus," Washington, DC, 2015.

[2] B. M. Capobianco, B. F. French, and H. A. Diefes-Dux, "Engineering Identity Development Among Pre-Adolescent Learners," *J. Eng. Educ.*, vol. 101, no. 4, pp. 698–716, 2012.

[3] L. Archer, J. DeWitt, and B. Wong, "Spheres of influence: what shapes young people's aspirations at age 12/13 and what are the implications for education policy?," *J. Educ. Policy*, vol. 29, no. 1, pp. 58-85, 2014.

[4] L. Archer, J. Dewitt, J. Osborne, J. Dillon, B. Willis, and B. Wong, "'Doing' science versus 'being' a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity," *Sci. Educ.*, vol. 94, no. 4, pp. 617-639, 2010.

[5] J. DeWitt, J. Osborne, L. Archer, J. Dillon, B. Willis, and B. Wong, "Young children's aspirations in science: The unequivocal, the uncertain and the unthinkable," *Int. J. Sci. Educ.*, vol. 35, no. 6, pp. 1037-1063, 2013.

[6] J. Dewitt and L. Archer, "Who aspires to a science career? A comparison of survey responses from primary and secondary school students," *Int. J. Sci. Educ.*, vol. 37, no. 13, pp. 2170-2192, 2015.

[7] R. H. Tai, C. Q. Liu, A. V. Maltese, and X. Fan, "Planning early for careers in science," *Science,* vol 312, no. 5777, pp. 1143-1144, 2006.

[8] A. V. Maltese and R. H. Tai, "Eyeballs in the fridge: Sources of early interest in science," *Int. J. Sci. Educ.*, vol. 32, no. 5, pp. 669-685, 2010.

[9] A. V. Maltese, C. S. Melki, and H. L. Wiebke, "The nature of experiences responsible for the generation and maintenance of interest in STEM," *Sci. Educ.*, vol. 98, no. 6, pp. 937-962, 2014.

[10] C. Murphy and J. Beggs, "Children's perceptions of school science A study of 8–11 year-old children indicates a progressive decline in their enjoyment of school science," *Sch. Sci. Rev.*, vol. 84, no. 308, pp. 109-116, 2003.

[11] H. B. Carlone and A. Johnson, "Understanding the science experiences of successful women of color: Science identity as an analytic lens," *J. Res. Sci. Teach.*, vol. 44, no. 8, pp. 1187-1218, 2007.

[12] Z. Hazari, G. Sonnert, P. M. Sadler, and M.-C. Shanahan, "Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study," *J. Res. Sci. Teach.*, vol. 47, no. 8, pp. 978-1003, 2010.

[13] A. Bandura, *Social Foundations of Thought and Action: A Social-Cognitive View*. Englewood Cliffs, NJ: Prentice Hall, 1986.

[14] B. M. Capobianco, E. D. Deemer, and C. Lin, "Analyzing predictors of children's formative engineering identity development.," *Int. J. Eng. Educ.*, vol. 33, no. 1, pp. 44-54, 2017.

[15] C. M. Higgins, M. Hertel, J.D. Shams, M.F. Lachapelle, and C.P. Cunningham, "NASA MISSION Grant: Engineering Adventures unit development (final report)," Boston, MA, 2015.

[16] R. Chen, Y.F., Cannaday, M.A., Schunn, C, Dorph, "Measures Technical Brief: Fascination in STEM," 2017. Available: activationlab.org/wp-content/uploads/2018/03/Fascination_STEM-Report_20170403.pdf.

[17] P. Chung, J., Cannday, M.A., Scunn, C., Dorph, R., Vincent-Ruz, "Measures Technical

Brief: Comptency Beliefs in Science," 2016. Available: activationlab.org/wp-content/uploads/2018/03/Competency-Beliefs-Report-3.2-20160331.pdf.
[18] M. W. Kier, M. R. Blanchard, J. W. Osborne, and J. L. Albert, "The development of the STEM career interest survey (STEM-CIS)," *Res. Sci. Educ.*, vol. 44, no. 3, pp. 461-481, 2014.
[19] M. H. Weinburgh and D. Steele, "The Modified Attitudes towards science inventory: developing an instrument to be used with fifth grade urban students," *J. Woman Minor. Sci. Eng.*, vol. 6, no. 1, pp. 87-94, 2000.
[20] Harvard-Smithsonian Center for Astrophysics, "Persistence Research in Science & Engineering Survey." [Online]. Available: https://www.cfa.harvard.edu/sed/projects/PRiSE_survey_proof.pdf.
[21] D. Rounds, J., Su, R., Lewis, P., Rivkin, "O*NET Interest Profiler Short Form psychometric characteristics: Summary," Washington, DC, 2010.
[22] P. Rounds, J., Ming, C.W.J., Cao, M., Song, C., Lewis, "Development of an O*NET Mini Interest Profiler (Mini-IP) for mobile devices: Psychometric characteristics," Washington, DC.
[23] A. Godwin, "The development of a measure of engineering identity." In *Proceedings of the American Society of Engineering Education Annual Conference and Exposition*, 2016.
[24] A. Godwin, G. Potvin, and Z. Hazari, "The development of critical engineering agency, identity, and the impact on engineering career choices." In *Proceedings of the American Society of Engineering Education Annual Conference and Exposition*, 2013.
[25] N. Schmitt and D. M. Stuits, "Factors defined by negatively keyed items: The result of careless respondents?," *Appl. Psychol. Meas.*, vol. 9, no. 4, pp. 367-373, 1985.
[26] S. D. Swain, D. Weathers, and R. W. Niedrich, "Assessing three sources of misresponse to reversed Likert items," *J. Mark. Res.*, vol. 45, no. 1, pp. 116-131, 2008.
[27] C. M. Woods, "Careless responding to reverse-worded items: Implications for confirmatory factor analysis," *J. Psychopathol. Behav. Assess.*, vol. 28, no. 3, p. 186, 2006.
[28] D. E. Betz and D. Sekaquaptewa, "My fair physicist? Feminine math and science role models demotivate young girls," *Soc. Psychol. Personal. Sci.*, vol. 3, no. 6, pp. 738–746, 2012.
[29] G. A. Buck, V. L. Plano Clark, D. Leslie-Pelecky, Y. Lu, and P. Cerda-Lizarraga, "Examining the cognitive processes used by adolescent girls and women scientists in identifying science role models: A feminist approach," *Sci. Educ.*, vol. 92, no. 4, pp. 688–707, 2008.
[30] P. Bricheno and M. Thornton, "Role model, hero or champion? Children's views concerning role models," *Educ. Res.*, vol. 49, no. 4, pp. 383-396, 2007.
[31] S. Cheryan, J. O. Siy, M. Vichayapai, B. J. Drury, and S. Kim, "Do female and male role models who embody stem stereotypes hinder women's anticipated success in stem?," *Social Psychological and Personality Science*, vol. 2, no. 6, pp. 656-664, 2011.
[32] S. Cheryan, A. Master, and A. N. Meltzoff, "Cultural stereotypes as gatekeepers: Increasing girls' interest in computer science and engineering by diversifying stereotypes," *Front. Psychol.*, vol. 6, no. 49, pp.1-8, 2015.
[33] N. Dasgupta, "Ingroup experts and peers as social vaccines who inoculate the self-concept: The stereotype inoculation model," *Psychol. Inq.*, vol. 22, no. 4, pp. 231-246, 2011.

[34] A. Nick Chambers, E. T. Kashefpakdel, J. Rehill, and C. Percy, "Drawing the future: Exploring the career aspirations of primary school children from around the world," January, 2018.

[35] R. W. Auger, A. E. Blackhurst, and K. H. Wahl, "The development of elementary-aged children's career aspirations and expectations.," *Prof. Sch. Couns.*, vol. 8, no. 4, pp. 322–329, 2005.

[36] T. Morgenroth, M. K. Ryan, and K. Peters, "The motivational theory of role modeling: How role models influence role aspirants' goals," *Rev. Gen. Psychol.*, vol. 19, no. 4, pp. 465-483, 2015.

[37] D.W. Chamber, "Stereotypic images of the scientist: The Draw-a-Scientist Test," *Science Education,* vol. 67, no. 2, pp. 255-265, 1983.

[38] M. Knight and C. Cunningham, "Draw an Engineer: Development of a tool to investigate students' ideas about engineers and engineering," in *Proceedings of the American Society for Engineering Education Annual Conference and Exposition*, 2004.

[39] I. Papert, S., Harel, "Situating constructionism," *Constructionism*, vol. 36, no. 2, pp. 1–11, 1991.

[40] E. Frick, S. Tardini, and L. Cantoni, "White paper on LEGO ® SERIOUS PLAY A state of the art of its applications in Europe," 2013.