Investigation of High School Pathways into Engineering (work in progress)

Dr. Carla B. Zoltowski, Purdue University, West Lafayette

Carla B. Zoltowski, Ph.D., is Co-Director of the EPICS Program at Purdue University. She received her B.S. and M.S. in electrical engineering and Ph.D. in engineering education, all from Purdue University. She has served as a lecturer in Purdue's School of Electrical and Computer Engineering. Dr. Zoltowski's academic and research interests include human-centered design learning and assessment, service-learning, ethical reasoning development and assessment, leadership, and assistive technology.

Dr. Marisa Exter, Purdue University

Marisa Exter is an Assistant Professor of Learning Design and Technology in the department of Curriculum and Instruction at Purdue University. Her cross-disciplinary background includes degrees in Computer Science and Instructional Systems Technology. Marisa Exter's research aims to provide recommendations to improve or enhance design and technology programs. Some of her previous research has focused on software designers' formal and non-formal educational experiences and use of precedent materials, and experienced instructional designers' beliefs about design character. These studies have highlighted the importance of cross-disciplinary skills and student engagement in large-scale, real-world projects.

She has been working with the EPICS (Engineering Projects in Community Service) High team to understand whether participating in service-learning engineering projects at the high-school level increases student knowledge about and interest in working in the field of engineering.

Dr. Monica E Cardella, Purdue University, West Lafayette

Monica E. Cardella is an Associate Professor of Engineering Education at Purdue University and the Director of Informal Learning Environments Research for INSPIRE (the Institute for P-12 Engineering Research and Learning). She has a BSc in Mathematics from the University of Puget Sound and an MS and PhD in Industrial Engineering from the University of Washington. Her research focuses on: parents' roles in engineering education; engineering learning in informal environments; engineering design education; and mathematical thinking.

Mr. Todd P. Shuba, Purdue University, West Lafayette

Todd Shuba is a Master's student in Education with a concentration in Educational Psychology at Purdue University. He is also a Graduate Research Assistant with the Engineering Projects in Community Service (EPICS) High School Program. His research interests include transfer of learning, collaborative learning, and student achievement and motivation. He holds a Bachelor of Science in Interdisciplinary Engineering with a concentration in Environmental and Ecological Engineering and a minor in Mechanical Engineering from Purdue.

Ji Hyun Yu, Purdue University, West Lafayette
Miss Mindy Hart, EPICS
Dr. William C. Oakes, Purdue University, West Lafayette

William (Bill) Oakes is the Director of the EPICS Program and Professor at Purdue University. He is one of the founding faculty members in the School of Engineering Education with courtesy appointments in Mechanical, Environmental and Ecological Engineering as well as Curriculum and Instruction in the College of Education. He has received numerous awards for his efforts at Purdue including being elected as a fellow of the Teaching Academy and listed in the Book of Great Teachers. He was the first engineer to receive the U.S. Campus Compact Thomas Ehrlich Faculty Award for Service-Learning. He was a co-recipient of the U.S. National Academy of Engineering's Bernard Gordon Prize for Innovation in Engineering and Technology Education and the recipient of the ASEE Chester Carlson Award for Innovation in Engineering Education. He is a fellow of ASEE and the National Society of Professional Engineers (NSPE).

Investigation of High School Pathways into Engineering (work in progress)

Abstract

A significant effort has aimed at increasing the number and diversity of students in pathways to engineering careers. This paper describes an effort to address these goals by adapting EPICS, a nationally recognized project-based, service-learning university program, to the high school and middle school environments. Preliminary data from 60 high schools in 11 states with over 2200 students indicates that this program is having an impact on students' interest in and their views of engineering. However, students' academic and career choices are influenced by a number of factors. Building on previous studies which have investigated pathways to and through engineering, this study uses Social Cognitive Career Theory to explore students' experiences in the program, and how these experiences impact pathways into engineering. This work-in-progress paper describes the development and piloting of a survey instrument, which can be given to students before and after they participate in the program.

Introduction

Meeting global challenges requires a technical workforce that is both diverse and highly trained. A significant effort has aimed at increasing the number and diversity of practicing engineers over the last two decades, but little progress has been made. One promising approach is the EPICS High Program, which engages high school and middle school students in engineering projects that meet a need within their own community. The approach of introducing students to engineering through community-based service-learning projects explicitly links engineering to meeting human needs, and may attract students who would otherwise not feel a personal connection with engineering. This approach is consistent the 2008 NAE report, *Changing the Conversation*[1]; aligns with the service-learning and diversity literature[2-4]; and provides social context, emphasis on general educational goals including communication, cooperative and interdisciplinary approaches, and problems with a "holistic, global scope."[5-7]   Many disciplines have reported positive impacts of service-learning with respect to interest, motivation, student satisfaction, personal success, desire, faculty-student interaction, and retention of students [8-19]. Service-learning has also been shown to improve learning outcomes[20].

Preliminary data from the EPICS High Program are promising, including demographics that are nearly gender-balanced and ethnically diverse and an increase in students' expressed interest in STEM fields[21]. However, as a number of studies that have investigated pathways both into and through engineering[22-25] have shown, students' academic and career choices are influenced by a number of other factors. The instrument piloted in this study will be used to investigate the impact of EPICS High participation within the larger context of other impacts on students' lives.

Understanding Factors that Impact Students' Pathways to Engineering

The pilot is part of a larger study to explore high school students' experiences in the program and how they impact pathways into engineering using a mixed-methods approach grounded in Social Cognitive Career Theory (SCCT)[26]. SCCT has its roots in Bandura's Social Cognitive Theory (1997, 2001)[27-28], which posits that personal characteristics, behaviors, and environment all play

important roles in an individual's academic and career choices. These choices are influenced by three main factors: **self-efficacy**, **outcome expectations**, and **personal interests**. Brown and Lent (1996)[29] found that people choose not to follow certain career paths because of faulty beliefs they may hold about their own self-efficacy or faulty outcome expectations about academic endeavors and/or careers, and that modifying self-efficacy and outcome expectations can help people reconsider career pathways. We used the SCCT framework to create our own model to allow us to explore the relationship between the SCCT factors, participation in EPICS High, contextual supports and barriers, and student's interests and goals (see Figure 1). This model guided the development of a survey instrument to be used as a pre-/and post-participation survey, which has been adapted from existing validated instruments[1,25,30-31] (see Appendix A).

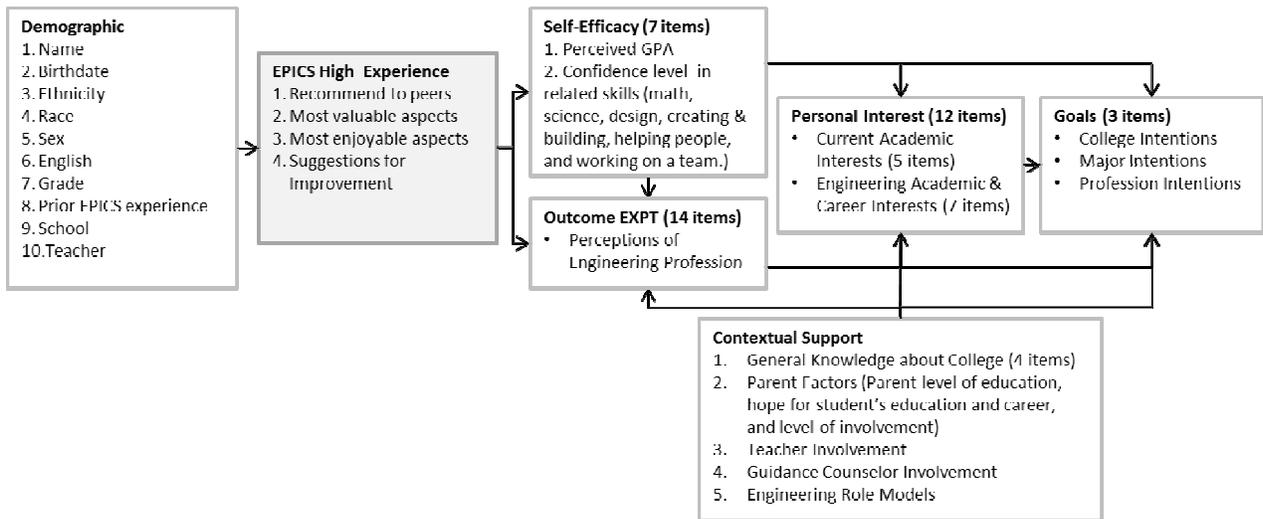Figure 1. Application of SCCT model for our study

Fall 2013 Pilot

The questionnaire was piloted (as a post-participation survey) at five diverse schools in Fall 2013(see table below). Data was analyzed only for students who had completed assent and consent forms that were collected and returned by the teachers.

	Geographic Location	Setting	School Type	N
School 1	Midwest	Suburban	Private, Christian high-school	4
School 2	Midwest	Urban	College preparatory public high-school	11
School 3	Northeast	Urban	All-girls college preparatory, private Catholic high-school	6
School 4	West Coast	Urban	Public middle-school	3
School 5	Southwest	Urban	All-girls college-preparatory, private Catholic high-school	21

Participants

Of the 45 who completed the questionnaire, 93% are high-school students, 7% are from middle-school, and 49% have had previous experience in EPICS. 60% are female, reflecting two all-girls schools. The group as a whole have well-educated parents, with the highest level of education

completed of a parent or guardian was a graduate degree for 51% and a college degree of some type for 27% of the students. However, half of public school students indicated either that their parents had not completed any college or that they did not know what level their parents had completed. Sixty percent are white, 20% African American, 16% Asian, and 13% Native American or from the Pacific Islands (students were directed to "pick all that apply"). Thirteen percent indicated they are Hispanic or Latino, and 9% have a first language other than English.

Self-Efficacy and Personal Interest

Students generally consider themselves good in school, with 76% indicating that they considered themselves "an A student" and 24% "a B student". In order to understand both students' self-efficacy and interests in engineering-related skills and activities, they were asked about what they like to do, and what they feel they are good at (see Figure 2). When used as a pre-/and post-test, this question will allow us to determine whether students' self-efficacy changes after their time in the EPICS High Program.
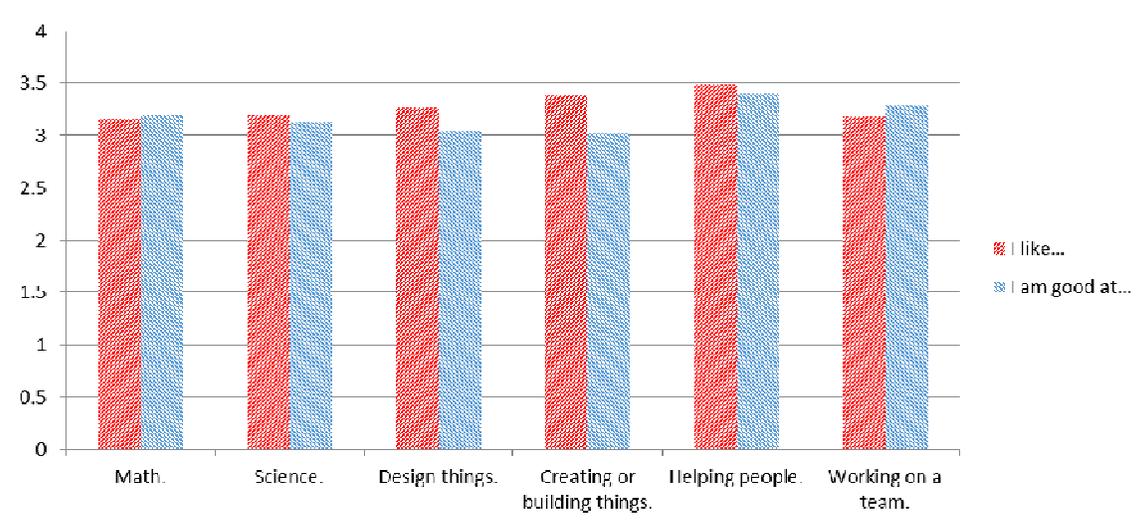

Figure 2. Current Academic Interest & Self-Efficacy *(Strongly disagree =1; Strongly Agree=4)*

Contextual Supports

As shown in Figure 3, students indicated that their decisions on whether to go to college are most influenced by their parents (76%), followed by friends (22%), teachers and guidance counselors (20%), and then grandparents (16%) and siblings (13%). An additional five individuals (11%) wrote in "myself" as a primary influence. Nearly all students indicated that their parents expected them to get a college degree (47%) or continue further to an advanced degree (49%). When asked what career their parents wanted them to pursue, students gave a range of answers – but 53% indicated that engineer was at least one of the options. When asked how many times they have been told that they should be an engineer, 52% of the participants responded two or more times, while 32% indicated zero. Sixty-two percent indicated they knew two or more engineers, while only 7% said they did not know any engineers. Students generally indicated satisfaction with the amount of involvement their parents had in their decisions about college (with 73% indicating they were "ok with level of involvement" and 16% wishing they had

more), but indicated they would like more involvement from their teachers (29%) and guidance counselors (36%). Although the majority of students indicated they know what they need to do to get into college (56% strongly agree, 31% agree) and what courses they need to take in high-school to get into college (51% strongly agree, 38% agree), about a quarter of students indicated they were not well informed about college admissions procedures and financial aid.

Outcome Expectations

Students' understandings of what is involved in working in engineering fields were measured by their response to a number of statements about engineers and engineering. As shown in Figures 4 and 5, students have a broad understanding of what engineers do after participating in EPICS.
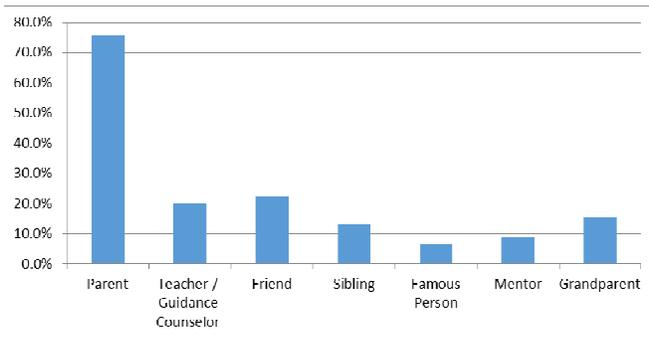

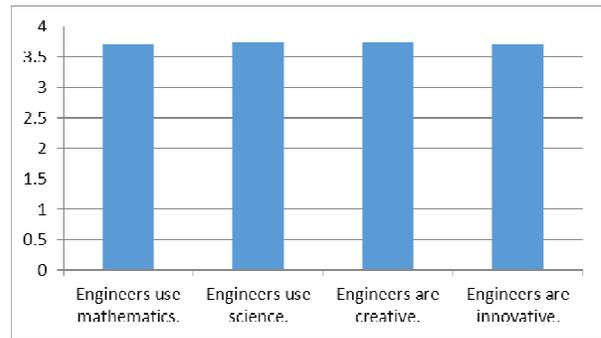Figure 3. Influencial Individuals on College Choices (Choose all that Apply)

Figure 4. Outcome Expectations: Students' Perceptions of Engineering Skills (Strongly disagree =1; Strongly Agree=4)
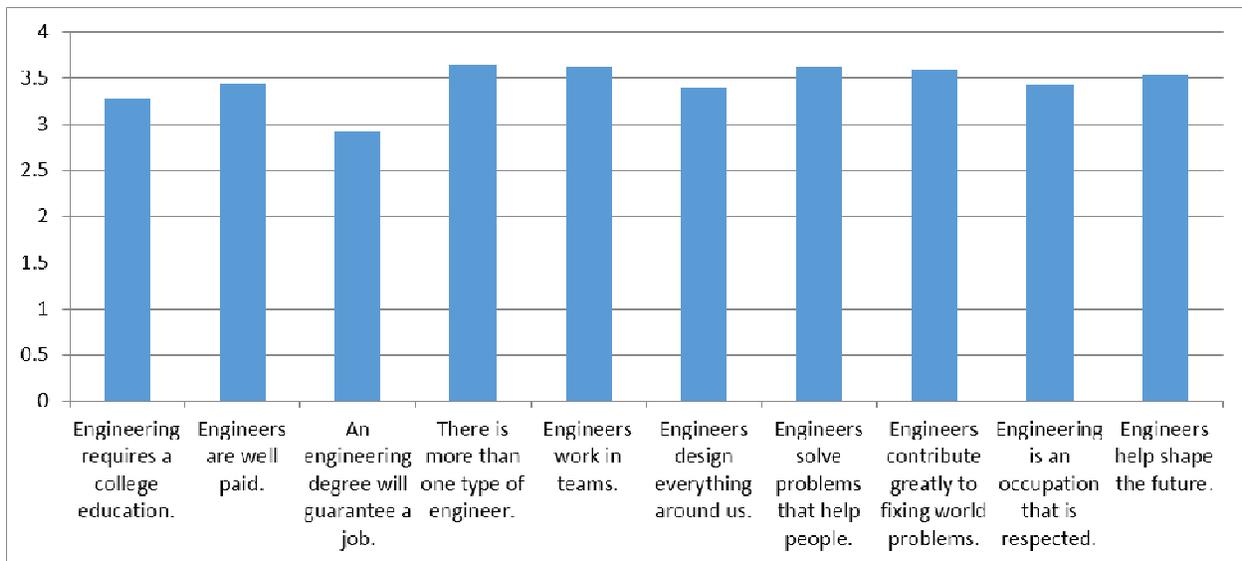

Figure 5. Outcome Expectations: Students' Perceptions of Engineering Careers (Strongly disagree =1; Strongly Agree=4)

Goals

Nearly all students intend to go to college (91% strongly agree and 4% agree), and a majority indicate they are likely to pursue a degree in engineering (38% strongly agree, 38% agree). In open-ended responses, those intending to pursue a degree in engineering expressed an interest in a specific engineering discipline, while others indicated that they enjoyed math, science or

"building things", and saw engineering as a way to use those skills. Others indicated that they liked helping people or being innovative or creative. More pragmatic responses cited good job prospects and family expectations. Students who indicated they do not intend to pursue a degree in engineering either had other specific goals or areas of passion, indicated they felt they were not enough at math or creative enough, or indicated that they do not like building things or other perceived aspects of engineering.

Responses to the EPICS High Program

When asked whether they would recommend EPICS to a friend, 89% agreed or strongly agreed. In open-ended comments, students indicated a range of benefits from participating in the program, including developing teamwork, problem solving, creativity, organizational and leadership skills and how to be "business appropriate", and the sense that they could make a difference through community service. Students most enjoyed being on a team, building things, helping people, making a difference, and building friendships. Suggestions for improvement generally focused on organizational and pedagogical aspects of the class.

Limitations

Because no pre-survey was used in this pilot, we cannot discuss change in student responses based on EPICS participation. The initial schools were selected for ease of administration and willingness of the teachers to have students take the pilot instrument. Therefore, we may have over-representation of some demographics. For example, 60% of participants who completed the survey come from two private, religious, all-girls schools, and three of the schools, which include 84% of the participants, identify themselves as "college preparatory". Although the resulting demographics of the pilot schools are not necessarily proportional to those of the EPICS High Program as a whole, they do represent a diverse set of schools that demonstrate the survey instrument would work well across the program. The numbers of participants in the pilot was not large but the data is encouraging to continue a larger scale implementation.

Conclusion

The information collected in the pilot gives us an interesting picture of the participating students in six schools, as well as allowing us to refine our process for recruitment and engagement with the schools in conducting this study. Further validation of the pre- and post-test procedure will be completed in the spring semester before the instrument is finalized for the entire program. Results from the instrument across the entire program will be reported in future papers.

There is an enormous opportunity to engage pre-college students in activities that use engineering to improve the quality of life of people in their communities. Research and early data indicate that EPICS participation may engage more diverse students in engineering. In addition, it can help improve their communities for all citizens. The dynamics of student development are complex. As this and other programs develop, assessment instruments such as the one piloted in this study will help us to better understand all of the factors surrounding students' perceptions of themselves and decisions about going into engineering, which can in turn help inform us about better ways to assist these students.

References

1. National Academy of Engineering. (2008). *Changing the conversation: Messages for improving public understanding of engineering*. Washington, DC: National Academies Press.
2. Matyas, M. L. & Malcolm, S. (1991). *Investing in human potential: Science and engineering at the crossroads*. Washington, DC: AAAS.
3. Oakes, J., Gamoran, A., & Page, R. N. (1992). Curriculum differentiation: Opportunities, outcomes, and meanings. In P. W. Jackson (Ed.), *Handbook of research on curriculum* (pp. 570-608). New York: Macmillan.
4. Lima, M. (2000). Service-learning: A unique perspective on engineering education. In E. Tsang (Ed.), *Projects that matter: Concepts and models for service learning in engineering* (pp. 109-117). Washington, DC: American Association for Higher Education.
5. Noddings, N. (1992). Gender and curriculum. In P. W. Jackson (Ed.), *Handbook of research on curriculum* (pp. 659-684). New York: Macmillan.
6. Rosser, S. V. (1990). *Female-friendly science*. Elmsford, NY: Pergamon Press.
7. Rosser, S. V. (1995). *Teaching the majority: Breaking the gender barrier in science, mathematics, and engineering*. New York: Teachers College Press.
8. Markus, G. B., Howard, J. P. F., & King, D. C. (1993). Integrating community service and classroom instruction enhances learning: Results from an experiment. *Educational Evaluation and Policy Analysis*, *15*, 410-419.
9. Batchelder, T. H. & Root, S. (1994). Effects of an undergraduate program to integrate academic learning and service: Cognitive, prosocial cognitive, and identity outcomes. *Journal of Adolescence*, *17*, 341-355.
10. Giles, D. E. & Eyler, J. (1994). The impact of a college community service laboratory on students' personal, social, and cognitive outcomes. *Journal of Adolescence*, *17*, 327-339.
11. Astin, A. W. & Sax, L. J. (1998). How undergraduates are affected by service participation. *Journal of College Student Development*, *39*, 251-262.
12. Astin, A. W., Vogelgesang, L. J., Ikeda, E. K., & Yee, J. A. (2000). *How service-learning affects students*. Los Angeles: Higher Education Research Institute.
13. Muthiah, R. N., Hatcher, J., & Bringle, R. G. (2001). The role of service-learning on retention of students: A multi-campus study of service-learning. *Proceedings of the International Conference on Advances in Service-Learning Research*. Berkeley, CA: International Association for Research on Service-learning and Community Engagement.
14. Skeers, M. H. & Aragon, E. (2002). Combining active learning with service-learning: A student-driven demonstration project. *Journal of Chemical Education*, *79*, 462-464.
15. Vogelgesang, L. J., Ikeda, E. K., Gilmartin, S. K., & Keup, J. R. (2002). Service-learning and the first year experience: Outcomes related to learning and persistence. In E. Zlotkowski (Ed.), *Service-learning and the first-year experience: Preparing students for personal success and civic responsibility* (pp. 15-26). Columbia, SC: University of South Carolina.
16. Zlotkowski, E. (Ed.) (2002). Service-learning and the first-year experience: Preparing students for personal success and civic responsibility. Columbia, SC: University of South Carolina.
17. Gallini, S. M. & Moely, B. E. (2003). Service-learning and engagement, academic challenge, and retention. Michigan Journal of Community Service Learning, 10(1), 5-14
18. Oakes, W. C. & Thompson, M. (2004). Integration of service learning into a freshman engineering course. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*. Salt Lake City: American Society for Engineering Education.

19. Keup, J. R. (2005). The impact of curricular interventions on intended second year enrollment. *Journal of College Student Retention*, *7*(1), 61-89.

20. Eyler, J. & Giles Jr., D. E. (1999). *Where's the learning in service learning?* San Francisco: Jossey-Bass.

21. Oakes, W. C., Dexter, P., Hunter, J., Baygents, J. C., & Thompson, M. G. (2012). Early engineering through service-learning: Adapting a university model to high school. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*. San Antonio, TX: American Society for Engineering Education.

22. Sheppard, Matusovich, Atman, Streveler, Miller. "Engineering Pathways Study: Work in Progress: Engineering Pathways Study: The College-Career Transition", 10/01/2010-09/30/2011, "Frontiers in Engineering Conference", "Fall 2011 conference"

23. Atman, C. J., Sheppard, S. D., Turns, J., Adams, R. S., Fleming, L. N., Stevens, R., Streveler, R. A., Smith, K. A., Miller, R. L., Leifer, L. J., Yasuhara, K., & Lund, D. (2010). *Enabling engineering student success: The final report for the Center for the Advancement of Engineering Education.* San Rafael, CA: Morgan and Claypool Publishers.

24. Sheppard, S., Atman, C., Stevens, R., & Fleming, L. (2004). Studying engineering student experience: Design of a longitudinal study. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*. Salt Lake City: American Society for Engineering Education.

25. Cardella, M. E., Wolsky, M., Paulsen, C. A., & Jones, T. R. (2013). Informal pathways to engineering. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*. Atlanta: American Society for Engineering Education.

26. Lent, R., Brown, S., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, *45*(1), 79-122.

27. Bandura, A. (1997). *Self-efficacy: The exercise of control.* Englewood Cliffs, NJ: Prentice Hall.

28. Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, *52*, 1-26.

29. Brown, S. & Lent, R. (1996). A social cognitive framework for career choice counseling. *The Career Development Quarterly*, *44*, 355-367.

30. Capobianco, B. M., French, B. F., & Diefes-Dux, H. A. (2012). Engineering identity development among pre-adolescent learners. *Journal of Engineering Education*, *101*(4), 698-716.

31. Besterfield-Sacre, M. E., Atman, C. J., & Shuman, L. J. (1998). Engineering student attitudes assessment. *Journal of Engineering Education*, *87*(2), 133-141.

Appendix A

Construct	Instrument	Item
Self-Efficacy (7 items)	*new*	1. I consider myself to be a(n) A/B/C/D/F student.
	Informal Pathways to Engineering[25]	2. I am good at math. 3. I am good at science. 4. I am good at designing things. 5. I am good at creating or building things. 6. I am good at helping people. 7. I am good at working with others on a team.
Outcome Expectations (14 items)	Engineering Identity Development Scale[30]	1. Engineers use mathematics. 2. Engineers use science. 3. Engineers work in teams. 4. There is more than one type of engineer. 5. Engineers design everything around us. 6. Engineers solve problems that help people.
	Pittsburgh Freshman Engineering Attitudes Survey[31]	7. Engineers are creative. 8. Engineers are innovative. 9. Engineers are well paid. 10. An engineering degree will guarantee a job. 11. Engineering is an occupation that is respected. 12. Engineers have contributed greatly to fixing problems in the world.
	new	13. Engineering requires a college education.
	NAE Messaging for Engineers[1]	14. Engineers help shape the future.
Personal Interests: Current Academic Interests (6 items)	Informal Pathways to Engineering[25]	1. I like to learn about math. 2. I like to learn about science. 3. I like to design things. 4. I like to create or build things. 5. I like to help people. 6. I like to work with others on a team.
Personal Interests: Engineering Academic and Career Interests (7 items)	Informal Pathways to Engineering[25]	1. I would like a job where I can design, create, or build things. 2. I would like a job where I help people. 3. I would like a job where I design, create, or build machines that help people walk. 4. I would like a job where I design, create, or build new medicines. 5. I would like a job where I design, create, or build cars. 6. I would like a job where I design, create, or build technology to protect the environment. 7. I would like a job where I design, create, or build computer applications.

Goals (3 items)	*new*	1. I am likely to go to college. 2. I am likely to major in engineering. 3. I want to be an engineer.
Context: Parent/School Supportiveness (12 items)	*new*	1. What's the highest level of education that your parents or guardians completed? 2. How many engineers do you know? 3. How many times have you been told that you should be an engineer? 4. What career do you think that your parents or guardians want you to pursue? 5. My parents or guardians expect me to earn <degree>. 6. Who has the most influence on your decision whether or not to go to college? 7. My teachers talk about me going to college. 8. How satisfied are you with your teachers' level of involvement in decisions about college? 9. My guidance counselors talk about me going to college. 10. How satisfied are you with your guidance counselors' level of involvement in decisions about college? 11. My parents or guardians talk about me going to college. 12. How satisfied are you with your parents' or guardians' level of involvement in decisions about college?
Context: General Knowledge about College (4 items)	*new*	1. I feel that I know about college admission procedures (for example, application timeline and entrance requirements). 2. I feel that I know about financial aid for college (for example, grants, loans, and scholarships). 3. I feel that I know what I need to do to get into college (for example, academic requirements). 4. I feel that I know about the types of courses I need to take in high school to prepare for college.