2018 ASEE Annual Conference & Exposition
June 24–27, 2018
Salt Palace Convention Center
Salt Lake City, UT

Paper ID #21193

CAREER: Actualizing Latent Diversity: Building Innovation through Engineering Students' Identity Development

Dr. Allison Godwin, Purdue University, West Lafayette (College of Engineering)

Allison Godwin, Ph.D. is an Assistant Professor of Engineering Education at Purdue University. Her research focuses what factors influence diverse students to choose engineering and stay in engineering through their careers and how different experiences within the practice and culture of engineering foster or hinder belongingness and identity development. Dr. Godwin graduated from Clemson University with a B.S. in Chemical Engineering and Ph.D. in Engineering and Science Education. Her research earned her a National Science Foundation CAREER Award focused on characterizing latent diversity, which includes diverse attitudes, mindsets, and approaches to learning, to understand engineering students' identity development. She is the recipient of a 2014 American Society for Engineering Education (ASEE) Educational Research and Methods Division Apprentice Faculty Grant. She has also been recognized for the synergy of research and teaching as an invited participant of the 2016 National Academy of Engineering Frontiers of Engineering Education Symposium and 2016 New Faculty Fellow for the Frontiers in Engineering Education Annual Conference. She also was an NSF Graduate Research Fellow for her work on female empowerment in engineering which won the National Association for Research in Science Teaching 2015 Outstanding Doctoral Research Award.

Dina Verdín, Purdue University, West Lafayette (College of Engineering)

Dina Verdín is a Ph.D. candidate in Engineering Education and M.S. student in Industrial Engineering at Purdue University. She completed her undergraduate degree in Industrial and Systems Engineering at San José State University. Dina is a 2016 National Science Foundation Graduate Research Fellow and a 2016 Ford Foundation Honorable Mention Her research interest focuses on first-generation college students focusing on engineering identity development, negotiating multiple identities, and ultimately changing deficit base paradigms by providing asset base perspectives for understanding this community.

Ms. Brianna Shani Benedict, Purdue University

Brianna Benedict is a Graduate Research Assistant in the School of Engineering Education at Purdue University. She completed her Bachelor's and Master's of Science in Industrial and Systems Engineering at North Carolina Agricultural & Technical State University. Her research interest focuses on interdisciplinary students' identity development, belongingness in engineering, and recognition.

Rachel Ann Baker
Thaddeus J. Milton, Purdue University

Thaddeus is a junior majoring in Civil Engineering with a concentration in Transportation at Purdue University. He works with Dr. Godwin and her team in the UPRISE Research Department analyzing code and interview transcript, creating academic posters, and providing valuable insight to research papers. Thaddeus is also an executive board member to both the Black Student Union here at Purdue.

Mr. Joshua T. Yeggy

CAREER: Actualizing Latent Diversity: Building Innovation through Engineering Students' Identity Development – An Executive Summary

Introduction

Innovation is the key to economic growth and prosperity, and engineering is a critical driver in industrial innovation [1]. Many companies are discovering that more diverse approaches to problem solving contribute to product innovation, global competence, and other successful corporate outcomes [2]–[5]. The National Academy of Engineering's vision for the Engineer of 2020 states that while engineers will be "grounded in basic mathematics and science," they will also "expand their vision of design through a solid grounding in the humanities, social sciences, and economics," and emphasize "creative processes that will allow for effective development and application of next-generation technologies to problems of the future" [6, p. 49]. The engineer will be required to have the

> ingenuity of Lillian Gilbreth, the problem-solving capabilities of Gordon Moore, the scientific insight of Albert Einstein, the creativity of Pablo Picasso, the determination of the Wright brothers, the leadership abilities of Bill Gates, the conscience of Eleanor Roosevelt, the vision of Martin Luther King Jr., and the curiosity and wonder of our grandchildren [6, p. 57].

To accomplish the vision of engineering graduates set forth by the National Academy of Engineering will require engineering educators to understand, capitalize, and continue to foster diverse ways of thinking and innovative mindsets. However, a significant gap exists in our ability to measure, support, and connect how students develop as engineers with innovation.

Project Overview

The project CAREER: Actualizing Latent Diversity: Building Innovation through Engineering Students' Identity Development (NSF# 1554057) proposes to fill this gap by understanding engineering students' latent diversity. Latent diversity is defined as the differences in students' underlying attributes and characteristics that can be used for innovation but may not be readily recognized or visible in the engineering classroom. By offering a new vision for how we operationalize latent diversity and support students within engineering, this work has the potential to transform how engineering educators teach and develop innovative engineering students.

Students enter engineering with a variety of beliefs, and mindsets that are often homogenized in becoming "an engineer." Our current educational practices develop students with more similar engineering mindsets than different, which is problematic for innovation [7], [8]. Also, this process alienates many students, and the engineering profession loses innovation and talent if these latently diverse students leave engineering [7], [9], [10]. Therefore, this CAREER project addresses the following research questions,

1) What kinds of diversity in thought, innovation mindsets, and attitudes are present in engineering students?

2) How do undergraduate students with latent diversity form engineering identities within an engineering community of practice over time?
3) What support, both inside and outside of the classroom, can be provided to promote inclusion of students with latent diversity in engineering?

Recognizing and understanding this form of diversity can promote a more inclusive environment in engineering and recruit, educate, retain, and graduate more innovative and diverse engineers. Additionally, the outcomes of this work will help create more inclusive college classrooms that accept a wider set of students and produce engineers who can adopt various perspectives for innovative problem solutions. This research is important because it has implications for developing an engineering workforce rich in talent and capable of adapting to the changing engineering landscape. By characterizing latent diversity on a national scale and understanding how that diversity influences students' pathways through (and potentially out of) engineering, we can provide evidence-based ways to betters support and educate these students in engineering.

This executive summary describes the first phase of our research. We have developed a comprehensive survey of students' latent attributes developed from an extensive literature review as well as pilot interviews with students. Thirty-four ABET accredited institutions with a common first-semester engineering course were recruited to participate in this study. This recruitment was done via a random stratified list of institutions based on engineering undergraduate enrollment to ensure representation from small (7,750 or fewer), medium (7,751 to 23,050), and large (23,051 or more) institutions and prevent overrepresentation from a few large institutions in the sample or numerous small institutions [11]. The instructors at these institutions have estimated that they will distribute the paper-and-pencil survey to approximately 4,000 students. Surveys were distributed to students' Introductory Engineering course in the Fall 2017 semester. The number of responses in this sample is the first of their kind to characterize the breadth of student attitudes, mindsets, and beliefs in identity, motivation, epistemic beliefs, agency, masculine social norms, innovation self-efficacy, and other constructs on a national scale. The timing of this data collection is important as it will provide an understanding of students' "incoming" attitudes before they have had a sufficient time and number of experiences to develop their attitudes within the college.

Developing a Survey to Characterize Latent Diversity

On the survey, we measured multiple aspects of students' mindsets and affective states using established instruments and newly developed questions from pilot interviews with 12 diverse students. These students were purposefully sampled to maximize demographic diversity including gender identity, race, ethnicity, sexual orientation, students with disabilities, and first-generation college students. We measured engineering identity, motivation, epistemic beliefs (students' perceptions of engineering as a discipline), personality, and self-efficacy for innovation to name some of the constructs. We also measured students' career intentions on this survey. Below, we describe the different dimensions that we measured on the survey and that we believe from prior literature and hypothesis generation with students to contribute to our characterization of latent diversity. This list is not comprehensive, but does represent the wide range of constructs used to measure latent diversity in our work.

STEM Role Identity Constructs

Authoring a role identity as an engineer, physics person, and mathematics person relies on a student's development of their beliefs in three interrelated constructs: *interest* in the subject; beliefs that others see them as the kind of people that can do STEM (*recognition*); and beliefs about their ability to do well and understand content in their courses (*performance/competence*) [12], [13]. Items measuring STEM identities that have been rigorously tested for validity in multiple nationally representative studies (FICSMath [14], PRiSE [15], SaGE [16]) were used in this survey. Students were asked to rate the extent to which they agree or disagree with statements pertaining to engineering identity, physics identity, and mathematics identity using a 7-point anchored numeric scale from 0- "Strongly Disagree" to 6- "Strongly agree." For example, students responded to the question to measure their interest in a subject, "I am interested in learning more about (subject)." Students recognition beliefs were measured by answering questions like, "My instructors see me as a (math or physics) person (or engineer)." Students responded to questions about their performance/competence beliefs answering questions like, "I am confident that I can understand (subject) in class." The full set of items used is documented in prior work [17].

Motivation

The motivation questionnaire used in this survey is the Adaptation of Learning Self-Regulation Questionnaire (SRQ-L) [18]. In self-determination theory, motivation is related to important behavioral (e.g., persistence, future intentions) outcomes [19]–[21]. The SRQ-L measures why people learn in particular contexts using two subscales of Controlled Regulation (i.e., external or introjected) and Autonomous Regulation (i.e., identified regulation or intrinsic motivation). This instrument was adapted to an engineering class context. Students were asked to answer questions pertaining to their motivation for completing their assignments, engaging in college coursework, asking questions in class, and motivation for attending college using a 7-point anchored numeric scale from 0 - "Not true at all" to 6 – "Very true." Example questions of reasons for particular actions included, "Because I enjoy doing my homework," "Because I enjoy being actively engaged," "Because I enjoy asking hard questions," and "Because I enjoy succeeding in college."

Epistemic Beliefs

A student's way of knowing (i.e., epistemic beliefs) is based on how they actualize truth in a body of knowledge such as engineering. Epistemic beliefs influence how students learn and develop problem-solving strategies [22], [23]. The Engineering Related Beliefs Questionnaire (ERBQ) was developed to measure epistemic beliefs of engineering students but has since then been revised to improve internal consistency within the constructs based on content and face validity findings [22]. Faber and Benson [24] identified two constructs of epistemic beliefs that are relevant for engineering students—*certainty* and *source* of engineering knowledge. Students expressed both their certainty of engineering knowledge and source of engineering knowledge beliefs using a 7-point anchored numeric scale from 0- "Not at all" to 6- "Very much so."

Certainty of engineering knowledge involves the nature of knowledge and is assessed to understand to what extent students believe knowledge is absolute to emergent [22], [25], [26]. Students responded to questions like the following, "If my experience conflicts with the 'big ideas' in a textbook, the textbook is probably right," and "Engineers can solve engineering problems by just following a step-by-step procedure."

Source of engineering knowledge involves the process of knowing and is assessed to understand to what extent students believe they should obtain knowledge from an instructor (or expert) in comparison to developing their own understanding independent of an instructor [22], [25], [26]. For example, "The best way to develop engineering knowledge is from an expert's teachings."

Big-Five Personality

The Big-Five Personality Inventory short scale [27] is commonly used to assess an individual's personality. Early psychology work began to explore personality across several factors that have now been clustered into five dimensions—Extroversion is associated with being sociable; Agreeableness is associated with being cooperative; Openness is associated with flexibility and growth; Neuroticism is associated with a lack of emotional stability; and Conscientiousness is associated with self-discipline and organization [28], [29]. Recent research has found significant correlations between these traits and student retention in engineering [30]. Students were asked to express how accurately statements pertaining to the five personality traits described them using a 7-point anchored numeric scale from 0- "Very inaccurately" to 6- "Very accurately." Some example items include phrases to describe themselves, "Am the life of the party" (extroversion), "Sympathize with others' feelings" (agreeableness), "Have a vivid imagination" (openness), "Get stressed out easily" (neuroticism), and "Leave my belongings around" (conscientiousness).

Innovation Self-Efficacy

Innovation self-efficacy refers to "engineering students' confidence in their ability to be innovative" [20, p. 3]. Dyer and colleagues [32] framed innovation as four interrelated behavioral skills that build associational thinking: (1) questioning—inquiring about new knowledge or new information; (2) observing—noticing connections or lack thereof; (3) experimenting—trying new experiences and "tak[ing] apart products and processes in search of new data"; and 4) networking—interacting with people from diverse backgrounds and diverse perspectives to expand their own knowledge base, as well as a cognitive skill. Associational thinking is when students make connections across diverse areas knowledge and ideas through questioning, observing, experimenting and networking [32], [33]. Students were asked to think about how confident they are in their abilities to question, observe, experiment, network, and use associational thinking on a 7-point anchored numeric scale from 0- "Not confident" to 6- "Extremely confident." Example questions for each of the behavioral aspects include, "Ask a lot of questions" (questioning), "Generate new ideas by observing the world" (observing), "Experiment as a way to understand how things work" (experimenting), "Build a network of people whom I trust to bring new perspectives" (networking), and "Connect ideas from different areas" (associational thinking).

Future Work

We have begun digitizing the paper-and-pencil national surveys. Once this process is complete, the data will be mapped to understand the underlying profiles of students in engineering. The mapping process will be accomplished using Topological Data Analysis (TDA), an advanced clustering technique. TDA is a powerful set of methods that can be used to understand the emergent patterns and insights from complex data rather than pre-supposed groupings. This approach is similar to various cluster analysis techniques but is more numerically robust and relies on fewer assumptions about the data being analyzed [34]–[36]. The approach also allows for the reduction of complex, highly-dimensional data to better understand subtle patterns that remain hidden in other statistical techniques. Students will be selected from the various emergent groups and longitudinally interviewed over the next 3.5 years of their undergraduate education to understand how latent diversity influences students' pathways in engineering and may be better supported for future innovations.

Impact of the Proposed Work

The impact of this work is a change in the way diversity is conceptualized and supported in engineering. Through new understandings of students' mindsets, beliefs, and potential for innovation (i.e., latent diversity), the next generation of innovative thinkers with new and creative ideas can be fostered and actualized. The results of this work will directly affect thousands of undergraduate students through evidence-based pedagogies as well as the way engineering educators and co-curricular support programs provide opportunities for individual learning that celebrates latently diverse students' contributions to engineering. This work also has the potential to improve visible diversity with engineering as well by making engineering more inclusive and supportive of individuals. Results of this work connect with ABET criteria and National Academy of Engineering goals for developing the next generation of engineers, NSF's mission to support diverse groups, and the need for more engineers that think differently to address the global challenges facing engineering in the next century.

Acknowledgements

This work was funded by a National Science Foundation EEC CAREER grant (1554057). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

References

[1] M. C. Thursby, "The Importance of Engineering: Education, Employment, and Innovation," *The Bridge*, vol. 44, no. 3, pp. 5–10, 2014.
[2] J. Miller, "The Science and Engineering Workforce: Realizing Americas Potential," *Natl. Sci. Board Natl. Sci. Found. Rep. NSB*, pp. 03–69, 2003.
[3] D. E. Chubin, G. S. May, and E. L. Babco, "Diversifying the engineering workforce," *J. Eng. Educ.*, vol. 94, no. 1, pp. 73–86, 2005.
[4] W. Wulf, "Diversity in Engineering," *The Bridge*, vol. 28, no. 4, 1998.
[5] J. L. Keith, D. B. Ayer, E. Rees, D. V. Freda, J. K. Lowe, and J. Day, "Brief of Amici Curiae Massachusetts Institute of Technology, Leland Stanford Junior University, EI Du Pont de Nemours and Company, International Business Machines Corp., National Academy of

Sciences, National Academy of Engineering, National Action Council for Minorities in Engineering, Inc., in Support of Respondents in the Supreme Court of the United States (Grutter v. Bollinger and Gratz v. Bollinger)," *Grutter V Bollinger Al*, no. 02-241, 2003.

[6] U. S. National Academy of Engineering, *The engineer of 2020: visions of engineering in the new century*. National Academies Press Washington, DC, 2004.

[7] M. Lumsdaine and E. Lumsdaine, "Thinking preferences of engineering students: Implications for curriculum restructuring," *J. Eng. Educ.*, vol. 84, no. 2, pp. 193–204, 1995.

[8] P. R. Becher and Paul, *Academic Tribes And Territories: Intellectual Enquiry and the Culture of Disciplines*. McGraw-Hill Education (UK), 2001.

[9] E. Seymour and N. M. Hewitt, *Talking About Leaving: Why Undergraduates Leave the Sciences. Boulder, Colorado*. Westview Press, 1997.

[10] B. N. Geisinger and D. R. Raman, "Why they leave: Understanding student attrition from engineering majors," *Int. J. Eng. Educ.*, vol. 29, no. 4, p. 914, 2013.

[11] U.S. Department of Education, & Institute of Education Sciences National Center for Education Statistics, "IPEDS: Integrated Postsecondary Education Data System," Washington, D.C.

[12] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Understanding engineering identity through structural equation modeling," in *Frontiers in Education Conference, 2013 IEEE*, 2013, pp. 50–56.

[13] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice," *J. Eng. Educ.*, vol. 105, no. 2, pp. 312–340, 2016.

[14] J. Cribbs, Z. Hazari, P. M. Sadler, and G. Sonnert, "Development of an explanatory framework for mathematics identity," in *Psychology of Mathematics Education-North American (PME-NA) Chapter Conference*, 2012.

[15] 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.

[16] L. Klotz, G. Potvin, A. Godwin, J. Cribbs, Z. Hazari, and N. Barclay, "Sustainability as a route to broadening participation in engineering," *J. Eng. Educ.*, vol. 103, no. 1, pp. 137–153, 2014.

[17] A. Godwin, "The Development of a Measure of Engineering Identity," in *ASEE Annual Conference & Exposition*, 2016.

[18] E. L. Deci and R. M. Ryan, "Theory," Self-Determination Theory. [Online]. Available: http://selfdeterminationtheory.org/. [Accessed: 2018].

[19] R. M. Ryan and E. L. Deci, "Intrinsic and extrinsic motivations: Classic definitions and new directions," *Contemp. Educ. Psychol.*, vol. 25, no. 1, pp. 54–67, 2000.

[20] R. J. Vallerand, "Toward a hierarchical model of intrinsic and extrinsic motivation," *Adv. Exp. Soc. Psychol.*, vol. 29, pp. 271–360, 1997.

[21] R. J. Vallerand and C. F. Ratelle, "Intrinsic and extrinsic motivation: A hierarchical model," *Handb. Self-Determ. Res.*, vol. 128, pp. 37–63, 2002.

[22] C. Faber, P. Vargas, and L. Benson, "Measuring engineering epistemic beliefs in undergraduate engineering students," in *Frontiers in Education Conference (FIE), 2016 IEEE*, 2016, pp. 1–7.

[23] J. H. Yu and J. Strobel, “A First Step in the Instrument Development of Engineering-related Beliefs Questionnaire,” in *2012 ASEE Annual Conference & Exposition*, San Antonio, Texas, 2012.
[24] C. Faber and L. C. Benson, “Engineering Students’ Epistemic Cognition in the Context of Problem Solving,” *J. Eng. Educ.*, vol. 106, no. 4, pp. 677–709, 2017.
[25] M. Schommer, “Effects of beliefs about the nature of knowledge on comprehension.,” *J. Educ. Psychol.*, vol. 82, no. 3, p. 498, 1990.
[26] D. Tolhurst, “The influence of learning environments on students’ epistemological beliefs and learning outcomes,” *Teach. High. Educ.*, vol. 12, no. 2, pp. 219–233, 2007.
[27] L. R. Goldberg, “The development of markers for the Big-Five factor structure.,” *Psychol. Assess.*, vol. 4, no. 1, p. 26, 1992.
[28] M. R. Leary and R. H. Hoyle, *Handbook of individual differences in social behavior*. Guilford Press, 2009.
[29] G. R. VandenBos, *APA dictionary of psychology*. American Psychological Association, 2007.
[30] C. W. Hall *et al.*, “Aptitude and personality traits in retention of engineering students,” *J. Eng. Educ.*, vol. 104, no. 2, pp. 167–188, 2015.
[31] M. Schar, S. K. Gilmartin, A. Harris, B. Rieken, and S. Sheppard, “Innovation Self-Efficacy: A Very Brief Measure for Engineering Students,” in *2017 ASEE Annual Conference & Exposition*, Columbus, Ohio, 2017.
[32] J. H. Dyer, H. B. Gregersen, and C. Christensen, “Entrepreneur behaviors, opportunity recognition, and the origins of innovative ventures,” *Strateg. Entrep. J.*, vol. 2, no. 4, pp. 317–338, 2008.
[33] J. Dyer, H. Gregersen, and C. M. Christensen, *The Innovator’s DNA: Mastering the Five Skills of Disruptive Innovators*. Harvard Business Press, 2011.
[34] C. Epstein, G. Carlsson, and H. Edelsbrunner, “Topological data analysis,” *Inverse Probl.*, vol. 27, no. 12, p. 120201, 2011.
[35] A. Zomorodian, “Topological data analysis,” *Adv. Appl. Comput. Topol.*, vol. 70, pp. 1–39, 2012.
[36] G. Carlsson, “Topology and data,” *Bull. Am. Math. Soc.*, vol. 46, no. 2, pp. 255–308, 2009.