

Research on Engineering Practice: Catalyzing a Scholarly Community

Samantha R. Brunhaver
The Polytechnic School
Arizona State University
Mesa, Arizona, USA
samantha.brunhaver@asu.edu

Brent K. Jesiek
School of Engineering Education
Purdue University
West Lafayette, Indiana, USA
bjesiek@purdue.edu

Alexandra Coso Strong
Franklin W. Olin College of Engineering
Needham, Massachusetts, USA
alexandra.strong@olin.edu

Russell Korte
Graduate School of Education
and Human Development
The George Washington University
Washington, District of Columbia, USA
rkorte@email.gwu.edu

Reed Stevens
School of Education and
Social Policy
Northwestern University
Evanston, Illinois, USA
reed-stevens@northwestern.edu

Abstract— This highly interactive special session has two goals: developing a deeper understanding of current research on engineering practice, and connecting and growing a diverse and vibrant scholarly community interested in this topic. There has arguably never been a more exciting time to examine engineering practice. In addition to a strong employment outlook for most engineering specialties, engineering careers are being reshaped and reimagined by rapid technological change, intensified globalization trends, new cross-disciplinary interactions, demographic shifts, and changing organizational structures. Colleges, universities, and organizations such as ABET, Inc., the National Academy of Engineering (NAE), and the National Science Foundation (NSF) are leading the charge to improve the alignment of engineering education with the demands of professional practice in response to these trends, potentially revolutionizing how current and future engineers are prepared as innovators, leaders, and change agents. Yet, not much is known about the diverse and multi-faceted realities of modern engineering practice and how this knowledge can be used to improve the education and training of engineers across career stages. Through presentations, networking opportunities, and group discussions, the special session will focus on using research on engineering practice to transform engineering education and the workforce.

Keywords—*engineering profession, preparation, research methods, theoretical frameworks, research to practice*

I. INTRODUCTION

Research on engineering practice has proliferated in recent years. The number of conference papers, journal articles, and research grants concerned with studies of engineering practice continues to grow. There have also been considerable numbers of NSF CAREER awards and Ph.D. dissertations devoted to the topic in the last ten years. Still, additional scholarly work is needed for engineering education to keep pace with the evolving nature of professional practice and develop a more comprehensive picture of engineers, their practices, and their work environments. The 2006 National Engineering Education Research Colloquies (EERC) research agenda identified

“Engineering Epistemologies”, concerned with “describing and defining the nature of engineering work”, as one of five main research strands in the field [1]. Summarizing the current state of research on professional engineering work, Stevens, Johri, and O’Connor point to a need for further “concrete and trustworthy images of professional engineering” [2]. Trevelyan similarly prefaced his own book of engineering practice by pointing to “a tiny number of earlier research studies”, then stating, “[e]ngineering has been invisible to nearly all of its participants” [3].

High quality investigations of engineering practice could profoundly influence ongoing efforts to improve the alignment of engineering education and the workplace, in turn leading to better preparation, increased satisfaction, and greater retention of engineering graduates. More nuanced understandings of the day-to-day experiences of engineering work can also make it easier to creatively reimagine professional practice to better serve working engineers, their employers, and society. In fact, coordinated efforts in this direction would directly address what Walther and Radcliffe have described as a “competency dilemma” in engineering education, “where programs designed to meet the stated needs of industry, still seem to fail to produce graduates with the necessary competencies for successful performance in practice” (pp. 48) [4]. This special session will help narrow these gaps between industry needs and graduate capabilities by appraising the current state of research on engineering practice while working to seed and grow an emerging scholarly community that is well positioned to carry out evidence-based transformations of engineering education programs in both academic and industry settings.

II. PREVIOUS WORK ON ENGINEERING PRACTICE

Previous work on engineering practice includes a rich collection of studies across both disciplines and time. One of the earliest empirical examinations of engineering practice was a comparative study of different technical groups in industry by Barnes in 1960 [5]. Studies of engineering practice started to proliferate in the 1980s and 1990s, with many adopting the

ethnographic and observational traditions of Science and Technology Studies (STS). Anderson et al. identified, in their own review of the literature, three main insights to which this body of work contributed, namely that engineering work: is uncertain and, therefore, “messy”, is a social and collaborative endeavor, and revolves around problem solving [6].

More recent work on engineering practice has been more diverse, partly due to increased attention over the last two decades to engineering education and workforce issues, coupled with interest from a wider variety of academic fields. Notable topics under the larger umbrella of current research on engineering practice include: (1) engineering design practices, (2) engineering collaboration across geographic and disciplinary boundaries, (3) the development of engineering expertise and situated workplace learning, (4) new engineer socialization, mentorship, and learning, (5) the difference between engineering problem solving at work and at school, (6) early career engineers’ perceptions of engineering work, (7) the experiences and retention of women in engineering workplaces, and (7) international perspectives on engineering practice.

Current studies on engineering practice contribute significantly to understandings of engineering practice. At the same time, they are limited in scope, scale, and methodology, with many based primarily in interviews and observations. Furthermore, the use of theoretical or conceptual frameworks in studies of engineering practice has been sparse, and those who have adopted frameworks for their research have not generally agreed on which are most suitable and generative. The field is also only just beginning to look at the workplace experiences of underrepresented groups in engineering such as racial/ethnic minorities and LGBTQ individuals, as well as engineers from non-Western cultures. There is a question of whether and how engineering practice is changing over time, possibly rendering earlier findings obsolete. Lastly, it is unclear what influence scholarly work on engineering practice has had on other researchers, educators, and/or employers.

For research on engineering practice to continue to evolve, the field must expand its use of different research methods and theories, engage different subject populations, and leverage one another’s expertise, and perhaps even datasets, to arrive at new insights about engineering practice that are rich, robust, and transferrable to educational and organizational practice. This special session will help begin to lay this foundation.

III. SESSION GOALS

Prior to this special session, the organizers conducted a workshop with researchers and others interested in engineering practice to examine the nature of engineering practice and the state of the research regarding our knowledge of engineer practice. The outcomes of this workshop will be presented in this special session.

The specific goals for this special session include: (1) to connect a diverse and scholarly community focused on engineering practice, which can seed new research collaborations, projects, and funding proposals, (2) to help identify promising topics, sites, partners, methods, and theories related to research on engineering practice, and (3) to explore

how theory and research findings on engineering practice can be used to further reimagine and transform engineering education and the workplace format.

This session represents a unique opportunity to engage researchers, educators, policymakers, and employers in conversation about how they can work together to ensure the success of engineers in the workplace. One of the most immediate impacts of the session will be an increased understanding of practicing engineers’ experiences. Better understanding of engineering practice represents a significant impact to the engineering education community, which strives to improve the preparation and training of engineers. This work will also stimulate other engineering education researchers to conduct their own studies related to engineering practice; along these lines, the session has a specific aim to help grow the number of junior scholars (i.e., graduate students, post-docs) involved in this research field.

IV. SESSION PLAN

This highly interactive eighty-minute special session will be organized and run based on the following plan:

- Organizers introduce themselves and give a presentation on the current state of research on engineering practice, including an overview of ground-breaking practice studies from engineering education and other fields. (15 minutes)
- A “speed dating” activity to allow participants to network, learn about each other’s work, and find common interests. (15 minutes)
- Participants will then organize into small break-out groups to discuss topics and themes related to research on engineering practice. Possible topics/themes include: mapping the ecosystem of current research on engineering practice, identifying key problems or gaps in knowledge, developing new research questions, sharing best known methods for research on engineering practice, and discussing how findings from research on engineering practice can be used to advance engineering education. (20 minutes)
- Each small group will then report out to the group as a whole, followed by large group discussion and synthesis. (20 minutes)
- The session will conclude with a summary of insights that emerged from the small and large group discussions, as well as recommendations for next steps as a field. (10 minutes)

V. SESSION ORGANIZERS

The five organizers have background, experience, and expertise in a range of methodological, topical, and theoretical considerations related to research on engineering practice.

- Samantha Brunhaver studies engineers’ school-to-work transitions and early work experiences, the “gaps” in engineering education for preparing students for professional practice [7-10]. She has expertise in Social

Cognitive Career Theory and longitudinal and mixed-methods research.

- Brent Jesiek studies global engineering practice and early career engineering practice, with emphasis on probing day-to-day work experiences and identifying key competencies [11-14]. He has expertise in longitudinal and mixed-methods research and theorizing engineering as sociotechnical work.
- Alexandra Coso Strong studies engineering teams engaging in complex system design, including the use of communicative artifacts, the role of persuasion in decision-making, and the integration of stakeholder considerations [15-18]. She has expertise in conducting multiple case studies and collaboration as it informs design work.
- Russell Korte studies the experiences of engineering students and graduates as they transition from school to work [8-10, 19-21]. He has expertise in longitudinal and mixed-methods research, the philosophies and theories of engineering education and practice, and engineering student identity, and career development.
- Reed Stevens studies engineers in situ to understand how engineers learn in universities and workplaces [2, 22-25]. He has expertise in ethnographic and video-based research and cognition and learning in STEM workplaces.

VI. SESSION OUTCOMES

The proposed session is a relatively modest intervention designed to grow community and collaboration, and yet, has high potential for a large return on investment. The organizing team will carry out the following post-session actions in order to directly link the activities of the session with a longer-term vision for capacity and network building in the field: (1) write up, send to all session attendees, and post publicly a brief white paper summarizing key insights and recommendations from the session, and (2) create and distribute a mailing list or other directory to help session attendees (and others) identify complementary sources of expertise and connect with others around topics of mutual interest.

The session will also contribute to the following long-term outcomes: (1) a global agenda to inform key stakeholders in decisions about future research on engineering practice, (2) the development of a community of researchers, employers, and educators dedicated to exploring how research findings on engineering practice can be used to bring engineering education and professional engineering work into closer alignment, and (3) new research collaborations, projects, and funding proposals to reimagine engineering practice. An external evaluator will collect data during and after the session to evaluate both short-term and long-term outcomes.

ACKNOWLEDGEMENTS

The organizers thank the National Science Foundation for their support of this special session, as well as Gary Downey,

Marie Parette, David Radcliffe, and Sheri Sheppard for their feedback and advice.

REFERENCES

- [1] Steering Committee of the National Engineering Education Research Colloquies, "The research agenda for the new discipline of engineering education (Special Report)," *J. Eng. Educ.*, vol. 95, no. 4, pp. 259-261, 2006.
- [2] R. Stevens, A. Johri, and K. O'Connor, "Professional engineering work," in *Cambridge Handbook of Engineering Education Research*, A. Johri and B. Olds, Eds. Cambridge, UK: Cambridge University Press, 2014, pp. 120.
- [3] J. Trevelyan, *The Making of an Expert Engineering*. Boca Raton, FL: CRC Press, 2014, pp. xxiv.
- [4] J. Walther, and D. F. Radcliffe, "The competence dilemma in engineering education: Moving beyond simple graduate attribute mapping," *Aust. J. Eng. Educ.*, vol. 13, no. 1, pp. 41-51, 2007.
- [5] L. B. Barnes, *Organizational Systems and Engineering Groups: A Comparative Study of Two Technical Groups in Industry*. Cambridge, MA: Harvard University, Division of Research, Graduate School of Business Administration, 1960.
- [6] K. J. B. Anderson, S. S. Courter, T. McGlamery, T. M. Nathans-Kelly, and C. G. Nicometo, "Understanding engineering work and identity: A cross-case analysis of engineers within six firms," *Eng. Stud.*, vol. 2, no. 3, pp. 153-174, 2010.
- [7] S. R. Brunhaver, *Early Career Outcomes of Engineering Alumni: Exploring the Connection to the Undergraduate Experience*, Ph.D. dissertation. Stanford, CA: Stanford University, 2015.
- [8] S. R. Brunhaver, R. F. Korte, S. R. Barley, and S. D. Sheppard, "Bridging the gaps between engineering education and practice," in *U.S. Engineering in a Global Economy*, R. B. Freeman and H. Salzman, Eds. Chicago, IL: University of Chicago Press, 2018.
- [9] S. Brunhaver, R. Korte, M. Lande, and S. Sheppard, "Supports and barriers that recent engineering graduates experience in the workplace," *Proc. Am. Soc. Eng. Educ. Ann. Conf.*, Louisville, KY, 2010.
- [10] R. Korte, S. Brunhaver, and S. Sheppard, "(Mis)Interpretations of organizational socialization: The expectations and experiences of newcomers and managers," *Hum. Resour. Dev. Quart.*, vol. 26, no. 2, pp. 185-208, 2015.
- [11] B. K. Jesiek, A. Mazzurco, N. M. Trellinger, and K. Ramane, "Becoming boundary spanners in engineering: Identifying roles, activities, and competencies," *Proc. Ann. Frontiers Educ. Conf.*, El Paso, TX, 2015.
- [12] B. K. Jesiek, N. M. Trellinger, and A. Mazzurco, "Becoming boundary spanning engineers: Research methods and preliminary findings," *Proc. Ann. Frontiers Educ. Conf.*, New Orleans, LA, 2016.
- [13] B. K. Jesiek, N. M. Trellinger, and S. Nittala, "Closing the practice gap: Studying boundary spanning in engineering practice to inform educational practice," *Proc. Ann. Frontiers Educ. Conf.*, Indianapolis, IN, 2017.
- [14] B. K. Jesiek, N. M. Trellinger, S. Nittala, and S. J. Campbell, "Interns in the wild: Using structured reflection to investigate early career engineering practice," *Proc. Am. Soc. Eng. Educ. Ann. Conf.*, Columbus, OH, 2017.
- [15] A. E. Coso, *Preparing Students to Incorporate Stakeholder Requirements in Aerospace Vehicle Design*, Ph.D. dissertation. Atlanta, GA: Georgia Institute of Technology, 2014.
- [16] A. E. Coso, and A. R. Pritchett, "Role of design teams in the integration of stakeholder considerations," *J. Aircraft*, vol. 52, no. 4, pp. 1136-1145, 2015.
- [17] A. R. Pritchett, and A. Coso Strong, "Integrating cognitive engineering into industry design teams," *J. Cogn. Eng. Dec. Making*, vol. 10, no. 2, pp. 134-137, 2016.
- [18] T. Stockman, C. Kincaid, T. Heale, S. Meyer, and A. Coso Strong, "Preparing students for a collaborative engineering design work environment: A Study of practicing engineers," *Proc. Am. Soc. Eng. Educ. Ann. Conf.*, Columbus, OH, 2017.

- [19] R. Korte, and S. Lin, "Getting on board: Organizational socialization and the contribution of social capital," *Human Relations*, vol. 66, no. 3, pp. 407-428, 2013.
- [20] R. F. Korte, "How newcomers learn the social norms of an organization: A case study of the socialization of newly hired engineers," *Hum. Resour. Dev. Quart.*, vol. 20, no. 3, pp. 285-306, 2009.
- [21] R. Korte, S. Sheppard, and W. Jordan, W, "A qualitative study of the early work experiences of recent graduates in engineering," *Proc. Am. Soc. Eng. Educ. Ann. Conf.*, Pittsburgh, PA, 2008.
- [22] P. Davis, A. Vinson, and R. Stevens, "Informal mentorship of new engineers in the workplace," *Proc. Am. Soc. Eng. Educ. Ann. Conf.*, Columbus, OH, 2017.
- [23] R. R. Stevens, *Disciplined Perception: Comparing the Development of Embodied Mathematical Practices in School and at Work*, Ph.D. dissertation. Berkeley, CA: University of California, Berkeley, 1999.
- [24] R. Stevens, K. O'Connor, L. Garrison, A. Jocuns, and D. M. Amos, "Becoming an engineer: Toward a three-dimensional view of engineering learning," *J. Eng. Educ.*, vol. 97, no. 3, pp. 355-368, 2008.
- [25] A. Vinson, and R. Stevens, "Staying in or getting out: The relationship between undergraduate work exposure and job satisfaction after graduation," *Proc. Am. Soc. Eng. Educ. Ann. Conf.*, New Orleans, LA, 2016.