Understanding the Master's Engineering Workforce Landscape: Employer Demands and Student Goals

Dr. Herman Ronald Clements III, University of Nebraska - Lincoln

Mitchell Gerhardt, Virginia Polytechnic Institute and State University

Mitchell Gerhardt is a Ph.D. candidate in Engineering Education at Virginia Tech. He earned his B.S. in Electrical Engineering from Virginia Tech and worked as a software engineer for General Motors in Detroit, Michigan, before returning to graduate school. Mitch's research focuses on engineering expertise and generative artificial intelligence (GAI); in particular, how GAI is transforming the way engineering expertise is developed, displayed, recognized, and trusted. His current research examines the use of GAI for qualitative research methods, STEM graduate students' GAI use and norms, and how STEM instructors negotiate personal, professional, and student GAI applications in higher education.

YiXiang Shawn Sun, Virginia Polytechnic Institute and State University

Shawn Sun is an Engineering Education PhD student and a Computer Science MS student at Virginia Tech. He is advised by Dr. David Knight. He is also the non-resident researcher at Research Institute for Democracy, Society, and Emerging Technology (DSET, Taiwan). His research spans comparative engineering education, workforce development in critical and emerging technologies, and global technology governance, as well as affective computing and human-robot/machine interaction. He investigates how talent education ecosystems in critical and emerging technology sectors are shaped across borders, how ethical principles are operationalized in emerging technologies, and how human-robot/machine interactions can foster trust and empathy in diverse cultural contexts.

Riya Budhathoki, University of Nebraska - Lincoln

Riya Budhathoki is a master's student in computer science and a research student in engineering education at the University of Nebraska–Lincoln. She holds a bachelor's degree in computer engineering.

Dr. Maura Borrego, University of Texas at Austin

Maura Borrego is the E.P. Schoch Professor in Engineering, Director of the Center for Engineering Education and Professor of Mechanical Engineering and STEM Education at the University of Texas at Austin. Dr. Borrego is a Fellow of the American Society for Engineering Education and currently serves as Senior Associate Editor for Journal of Women and Minorities in Science and Engineering. She was previously a rotating program officer at the National Science Foundation, a Vice President and member of the Board of the American Society for Engineering Education, an associate dean in the graduate school, Deputy Editor of the Journal of Engineering Education and Associate Editor for International Journal of STEM Education. Her research awards include U.S. Presidential Early Career Award for Scientists and Engineers (PECASE), a National Science Foundation CAREER award, and two outstanding publication awards from the American Educational Research Association for her journal articles.

Dr. Jessica R Deters, University of Nebraska - Lincoln

Dr. Jessica Deters is an Assistant Professor of Mechanical and Materials Engineering and Discipline Based Education Researcher at the University of Nebraska - Lincoln. She holds her Ph.D. in Engineering Education and M.S. in Systems Engineering from Virginia Tech.

Dr. Andrew Katz, Virginia Polytechnic Institute and State University

Andrew Katz is an assistant professor in the Department of Engineering Education at Virginia Tech. He leads the Improving Decisions in Engineering Education Agents and Systems (IDEEAS) Lab.

Dr. David B Knight, Virginia Polytechnic Institute and State University

David Knight is a Professor in the Department of Engineering Education at Virginia Tech and also serves as Chief of Strategy in the College of Engineering and Special Assistant to the Provost. His research tends to be at the macro-scale, focused on a systems-level perspective of how engineering education can become more effective, efficient, and inclusive, and considers the intersection between policy and organizational contexts. Knight currently serves as the co-Editor-in-Chief of the Journal of Engineering Education.

RFE: Understanding the Master's Engineering Workforce Landscape: Employer Demands and Student Goals

Introduction

This paper presents findings from the first phase of a mixed-method project examining the alignment between mechanical engineering (ME) job advertisements and enrollment decisions made by ME students. Although there are four times as many master's engineering degrees awarded as PhDs, there is less work specifically examining career decisions and workforce implications for engineering master's students. Existing work that investigates engineering master's degree holders tends to focus on potential individual economic benefits, primarily increased salaries, which is justified by the additional skills and knowledge master's programs provide and are needed for higher-paying, higher-demand jobs; additionally, these approaches often look at an aggregate of STEM degrees rather than specifically engineering [1-3]. However, other demographic factors, such as race and gender, show a similar predictive relationship to pay [4], so the connection between pay and degree may not be as clear-cut as assumed. Student motivation and decision-making to pursue a master's degree is also complex, with factors outside of salary considerations, like academic performance and access to resources, influencing students' decisions [2]. Focusing on salaries can overshadow other considerations in a student's decision-making, such as local higher education availability, desired career mobility rooted in non-financial reasons, familial or social expectations, employer requirements, or subject area interest. These factors, while related to financial justifications for pursuing a degree, provide important signals for programs about students' expectations and their choice of discipline, advisors, and academic focus. However, they are not a common research focus despite the increase in STEM master's programs over the last decade, including the expansion of accelerated master's programs and specialization topics to address industry demands [5-7]. Such trends coexist with high rates of international students enrolling in U.S.-based master's programs, raising concerns about their attractability and retention of American students who encounter alternative career advancement or skill development opportunities [7]. Ultimately, the emphasis on the financial justifications for pursuing STEM master's degrees may overgeneralize *why* and *how* students make the decision, reducing potential factors and processes central to maintaining supportive and relevant graduate programs.

Toward this effort, this paper reports on findings from an ongoing NSF-funded project examining why students transition from industry careers to pursue an ME master's degree. We investigate the alignment between the perceived benefits of an ME master's degree program from both a student and industry practitioner perspective using an exploratory concurrent mixed-methods approach [8]. This ongoing project includes: (1) in-depth semi-structured interviews with returning ME master's students (n = 20) to provide insight into their motivations for pursuing the degree; (2) analysis of 1.3 million ME job postings collected by Burning Glass Technologies, using natural language processing techniques to extract information about their qualifications, employee knowledge and skills, job tasks and responsibilities, and tools and technologies used. These data are compared to understand how students' perceptions of master's degree programs align with the desired characteristics described in job opportunities. Using an adapted version of Perna's model of student college choice to guide analysis [9], we present findings based on the research question: What is the (mis)alignment between the skills associated with jobs in ME that require a master's degree and current master's students' perceptions of the skills needed for employment? This work is funded through the NSF Research in the Formation of Engineers (RFE) program.

Project Findings to Date

Industry Demands and Needs: Natural Language Processing. Diverging from previous studies that focus purely on one of these aspects in isolation, ME was selected to scope the preliminary investigation and provide granular details about what can be considered a "broad" engineering discipline with many possible career paths and program offerings. To explore these possible career paths and options available to students, we leveraged natural language processing (NLP) techniques to analyze over 250,000 ME job postings collected by Burning Glass Technologies (BGT) from January 2010 through December 2022. These postings were carefully filtered from an original sample of 372,135,198 job postings using a multi-stage programmatic process that identified ME jobs according to their contents (e.g., job titles, job descriptions, desired qualifications, mentioned software/technologies). The filtering process was iteratively developed and validated by the research group to achieve a high F1-score accuracy across a human-evaluated subset of job postings. Once achieved, those jobs that passed the filtering were subsequently evaluated according to their qualifications (i.e., minimum degree accepted for the position) and BGT-determined skills, with the latter encapsulating ranging worker characteristics from job features and desired technological abilities to interpersonal capacities and tooling experience.

The job qualifications and skills from the postings were aggregated, allowing us to evaluate trends in their frequency across the 13-year study period and further scope analysis of the skills related to jobs applicable to ME master's students. For example, the research group filtered out skills observed across less than 5% of jobs each year, narrowing our attention to those skills broadly desired. We then compared skills, such as "Scripting Languages" and "Industrial Design," against one another, noting their relative frequencies across the job postings, the desired qualifications that accompany skills, and their trends to provide feedback to administrators and program directors about the abilities desired among graduating ME students. Put together, this NLP-based workflow to analyze BGT-collected job postings provided a reproducible and reliable process for extracting ME jobs, while concurrently preparing their contents for subsequent analysis.

Students' Motivations, Goals, and Skill Development: Interviews and Surveys. Alongside the use of NLP, we employ in-depth, semi-structured interview methods with ME master's students (n =

20) and an adapted EVT survey instrument (n = 100) to gain insight into the perceived skill needs, motivations, and challenges that influenced students' decisions to pursue a master's degree [10]. Originally adapted to study Ph.D. students', changes included shifting the language to focus on master's students and removal of items that are unique to the doctoral education process. Additionally, to prioritize data related to industry perceptions, we specifically recruited master's students who intend for their degree to be their terminal degree, and who were in the last or second-to-last semester of study. Interview questions included general pathway and decision-making process questions, desired and actual skill development, perceptions of the industry and job market, and future aspirations. Students were also asked to provide their underlying assumptions about the role of engineering, what they perceived as the most important values and ideals present in their work, and how that might interact with those present within the workforce. Preliminary findings from student interviews include diverse perspectives on motivations for pursuing an ME master's degree, similarities in desired and achieved skill development, and wide-ranging reflections on perceptions of the role of engineering and how personal goals and values influence desired jobs and work experiences.

Next Steps

For the industry demands and needs approach, the BGT-labeled data present difficulties during processing because it is unclear precisely how these labels were generated (e.g., each job has a "SkillClusters" value that comprises an unknown list of skills determined and extracted by BGT through an unknown process). Consequently, the labels proved unsuccessful signals for reliably observing employers' desired job characteristics over time. To remedy this, one aspect of our current work is finely combing the raw job postings, manually extracting the tools and technologies, job tasks and responsibilities, employee knowledge and skills, and qualifications indicated by employers (ONET Content Model) [11]. Reflexive content analysis [12] guides this process, with active member-checking to achieve alignment and reliability. The second aspect of the quantitative process involves building out the programmatic workflows to reproducibly scale the researcher-created labels to the entire dataset [13]. This entails using generative artificial intelligence (GAI)-based workflows, whether fine-tuned foundational models [14-15] or using larger language models to break down and process text [16-18]. We are actively experimenting with these alternatives, considering how GAI can best complement our research goals, without obfuscating our relationships to the data and the knowledge derived from it [18-20].

For the student-centered interview and survey approach, interview data have been collected and are currently being analyzed with a thematic approach [21] to develop rich descriptions of students' degree motivations, skill development, and perceptions/pathways into industry. Results from the adapted EVT survey will be used to support a detailed examination of the differences and similarities between master's students based on work experience, returner status, and desired work sector. Due to the recruitment approach, participants are clustered by institution, providing an opportunity for case study methods to be used to highlight differences and similarities based on program. Following the concurrent development of findings along both avenues of the project, the final steps will include pulling from both project foci to develop a model highlighting the complex influences that go into students' decision-making processes concerning master's program attendance and discrepancies or congruences between industry demands, student goals and perspectives, and program offerings and support.

Acknowledgements. This work is funded through the NSF program for Research in the Formation of Engineers (RFE). This material is based upon work supported by the National Science Foundation under grant numbers 2433100 and 2433101. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] H. Metcalf, "Stuck in the Pipeline: A Critical Review of STEM Workforce Literature," *InterActions: UCLA Journal of Education and Information Studies*, vol. 6, no. 2, May 2010, doi: 10.5070/d462000681.

[2] A. M. Zamfir, A. A. M. Davidescu, and C. Mocanu, "Understanding the influence of business innovation context on intentions of enrolment in master education of STEM students: a multi-level choice model," *Humanities and Social Sciences Communications*, vol. 11, no. 1, Dec. 2024, doi: 10.1057/s41599-024-03601-5.

[3] D. Gándara and R. K. Toutkoushian, "Updated Estimates of the Average Financial Return on Master's Degree Programs in the United States," 2017.

[4] H. Okahana and Y. Hao, "Are They Worth It?: Master's Degrees and Labor Market Outcomes in the STEM Workforce," *Innovative Higher Education*, vol. 44, no. 3, pp. 165–185, Jun. 2019, doi: 10.1007/s10755-019-9455-5.

[5] A. Srivastava, E. J. Glantz, K. Khurana, and S. Stager, "Enhancing Revenue and Student Outcomes at Small Universities through Professional STEM Master's Programs," in *Proceedings of 25th Annual Conference on Information Technology Education, SIGITE 2024*, Association for Computing Machinery, Inc, Dec. 2024, pp. 74–78. doi: 10.1145/3686852.3686854.

[6] R. Kelchen and F. Barrett, "Exploring the Growth of Master's Degree Programs in the United States," Apr. 2024. https://www.american.edu/spa/peer/upload/peer_masters-degrees_b-2.pdf.

[7] A. Leshner and L. Scherer, Eds., *Graduate STEM Education for the 21st Century*. Washington, D.C.: National Academies Press, 2018. doi: 10.17226/25038.

[8] L. W. Perna, "Studying College Access And Choice: A Proposed Conceptual Model," in *Higher Education:*, Dordrecht: Kluwer Academic Publishers, 2006, pp. 99–157. doi: 10.1007/1-4020-4512-3_3.

[9] J. W. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 4th ed. Sage, 2014.

[10] E. A. Mosyjowski, S. R. Daly, D. L. Peters, S. J. Skerlos, and A. B. Baker, “Engineering PhD Returners and Direct-Pathway Students: Comparing Expectancy, Value, and Cost,” *Journal of Engineering Education*, vol. 106, no. 4, pp. 639–676, Oct. 2017, doi: 10.1002/jee.20182.
[11] O*NET® Resource Center, “The O*NET® Content Model,” Website. Accessed: Jan. 20, 2026. [Online]. Available: https://www.onetcenter.org/content.html
[12] M. Nicmanis, “Reflexive Content Analysis: An Approach to Qualitative Data Analysis, Reduction, and Description,” *International Journal of Qualitative Methods*, vol. 23, Jan. 2024, doi: 10.1177/16094069241236603.
[13] R. Chew, J. Bollenbacher, M. Wenger, J. Speer, and A. Kim, “LLM-Assisted Content Analysis: Using Large Language Models to Support Deductive Coding,” Jun. 2023, [Online]. Available: http://arxiv.org/abs/2306.14924
[14] F. Wang *et al.*, “A Comprehensive Survey of Small Language Models in the Era of Large Language Models: Techniques, Enhancements, Applications, Collaboration with LLMs, and Trustworthiness,” *ACM Transactions on Intelligent Systems and Technology*, vol. 16, no. 6, pp. 1–87, Dec. 2025, doi: 10.1145/3768165.
[15] S. Ozdemir, *Building Agentic AI: Workflows, Fine-Tuning, Optimization, and Deployment*, 1st ed. Jon Krohn’s Pearson AI Signature Series, 2025.
[16] P. Belcak *et al.*, “Small Language Models are the Future of Agentic AI,” Sep. 2025, [Online]. Available: http://arxiv.org/abs/2506.02153
[17] C. M. Montes, R. Feldt, C. M. Martos, S. Ouhbi, S. Premanandan, and D. Graziotin, “Large Language Models in Thematic Analysis: Prompt Engineering, Evaluation, and Guidelines for Qualitative Software Engineering Research,” Oct. 2025, [Online]. Available: http://arxiv.org/abs/2510.18456
[18] M. Nicmanis and H. Spurrier, “Getting Started with Artificial Intelligence Assisted Qualitative Analysis: An Introductory Guide to Qualitative Research Approaches with Exploratory Examples from Reflexive Content Analysis,” *International Journal of Qualitative Methods*, vol. 24, Jun. 2025, doi: 10.1177/16094069251354863.
[19] K. Maton, “Reflexivity, relationism, & research: Pierre Bourdieu and the epistemic conditions of social scientific knowledge,” *Space and Culture*, vol. 6, no. 1. pp. 52–65, 2003. doi: 10.1177/1206331202238962.
[20] D. Reeping, C. Hampton, and D. Özkan, “Interrogating the Use of Large Language Models in Qualitative Research Using the Qualifying Qualitative Research Quality Framework,” *Studies in Engineering Education*, vol. 6, no. 2, pp. 1–23, 2025, doi: 10.21061/see.174.
[21] R. Y. Pang *et al.*, “Understanding the LLM-ification of CHI: Unpacking the Impact of LLMs at CHI through a Systematic Literature Review,” in *Conference on Human Factors in Computing Systems - Proceedings*, Association for Computing Machinery, Apr. 2025. doi: 10.1145/3706598.3713726.
[22] J. W. Creswell and C. N. Poth, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*, 4th ed. Sage, 2017.