www.ijarp.com ISSN 2456-9992 Page: 01-24

International Journal Advanced Research Publications

Review Article
Volume: 01
Issue: 02

DATA-DRIVEN EVALUATION OF DIVERSITY AND INCLUSION INITIATIVES IN ELECTRICAL ENGINEERING EDUCATION

[*1]Adebayo, Adeyinka Victor, [2]Adebayo K. Hussein, [3]Pelumi Peter Aluko-Olokun, [4]Shobowale A. K.

[1]University of Cape Town, South Africa.

[2]Department of Electrical Engineering, Lead City University, Ibadan, Nigeria.

[3]Dept of Elect. And Electronics Engineering, Sheffield Hallam University, Sheffield, South Yorkshire, United Kingdom.

[4]Dept of Education Management and Policy Studies, University of Pretoria, Pretoria, South Africa.

Article Received: 15 October 2025, Article Revised: 03 November 2025, Published on: 23 November 2025

***Corresponding Author: Adebayo, Adeyinka Victor**

University of Cape Town, South Africa.

DOI: https://doi-doi.org/101555/ijarp.8861

ABSTRACT

Electrical engineering continues to be a fundamental driver of technological progress, yet underrepresentation persists for women, minorities, and persons with disabilities in education and career pathways. This study takes a data-driven, mixed-methods approach to assess the effectiveness of diversity and inclusion (D&I) efforts in electrical engineering education and how they influence career pipelines into the electronics industry. Using longitudinal data, interviews, and program evaluations, the research explores systemic barriers, institutional environments, and policy factors that influence representation. Results show that while scholarship programs, university initiatives, and industry-led diversity efforts have increased access, challenges remain in recruitment, retention, and career advancement. Case studies such as IEEE's Inclusive Electrification and INSPIRE illustrate how experiential learning, mentorship, and community engagement support underrepresented groups. Both quantitative and qualitative data reveal that success depends on ongoing institutional backing, transparent evaluation, and alignment with industry and government policies. The study concludes that data-driven evaluation provides a rigorous approach to identifying gaps, informing policy, and promoting equity in electrical engineering education and careers. Future research should focus on expanding longitudinal analysis, creating practical metrics, and fostering

collaborations among academia, industry, and government to develop sustainable, inclusive engineering pipelines.

1. INTRODUCTION

Electrical engineering ranks among the fastest-growing fields in the U.S., with an estimated 140,000 new jobs expected in the coming decade. However, recent diversity and inclusion (D&D&I) reports show that women, minorities, and persons with disabilities continue to be disproportionately underrepresented in electrical engineering education and employment. Advancing diversity and inclusion remains not just a challenge but a powerful opportunity to broaden the talent pool and accelerate innovation in this critical domain. Managing and evaluating D&I efforts typically rely on member-led efforts that can overlook systemic factors affecting academic and career pathways. Hence, a quantitative, data-driven approach is essential to measure the effectiveness of D&I programs and policies. The present work examines how data-driven evaluation can illuminate the effectiveness of D&I initiatives in electrical engineering programs and the subsequent tailoring of educational programs to foster more diverse career trajectories. The emphasis is on evaluating program efficacy beyond mere demographic representation, probing systemic influences on the education-to-career pipeline.

2. Literature Review

Historical and educational context help inform the nature and effectiveness of current efforts to build diversity and inclusion in electrical engineering education. No single engineer is solely responsible for today's many technological achievements, but appreciation for this speciality is unfortunately less common than that for other types of engineering. Education is a necessary start because regular exposure to computer science and engineering topics can substantially influence the decision to pursue a career in engineering. Data-driven evaluation of diversity and inclusion in electrical engineering education and career pathways sheds critical light on both. A foundation of definitions, a summary of current efforts, the impact of diversity on innovation, and the needs of educational and governmental leaders creating equitable workforce development funding shed further light on a subject of interest that lies unexplored, mainly in existing literature.

The historical roots of these technologies demonstrate that neither technology nor progress is the product of any one person. Race, gender identity, or sexuality need not be barriers to

success. The societal context for current trends in engineering education and employment explains the guiding principles of the Women in Engineering Programs and Initiatives at the University of Pennsylvania. An examination of the impact of diversity on innovation draws on multiple studies across science, engineering, and business. Finally, recent critique of barriers to equity in workforce development helps advisors and applicants, and data-driven evaluations of diversity and inclusion help educational programs meet these needs.

2.1. Historical Context of Diversity in Engineering

Creating a gender-inclusive environment in education, employment, and career growth remains a global challenge (Strachan et al., 2018). Engineering, vital for economic progress, suffers from the underrepresentation of women. A common belief is that a shortage of engineers hampers development. Education is seen as key to empowerment and change, placing responsibility on higher education to foster gender-balanced, effective learning environments. Engineering uniquely lacks diversity: in England, women are 50% of the population but only 12% of engineers and 16% of engineering students. This imbalance limits innovation, affecting quality of life and safety. Governments promote inclusion schemes that remain inadequate, failing to address broader issues beyond academia. Diverse perspectives improve organisational success. Policies in Britain and the US push for women and minority inclusion in STEM, yet women remain underrepresented: 76.5% of engineering jobs are held by men, and only 13.8% of STEM graduates are women. Women make up just 10–25% of undergraduate engineering cohorts, with marginalised BAME groups especially in the UK.

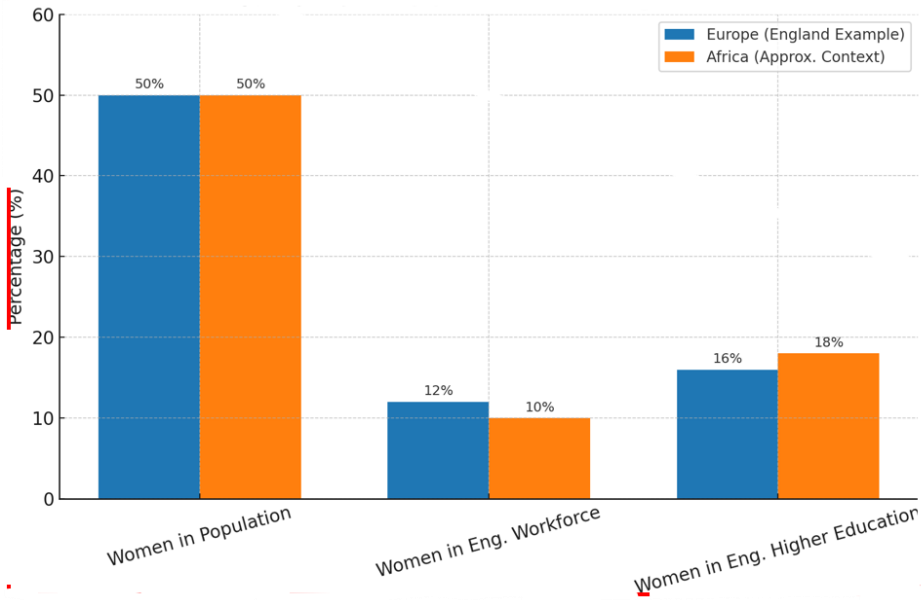

Figure 1: Historical Context of Diversity in Engineering UK Context.

Employers recognise the benefits of diversity, but gender disparities persist. Engineering faces two challenges: attracting more diverse students and creating supportive environments to retain them. Barriers like maternity-related sanctions, visa rules, and employment biases against minority ethnic graduates persist. Recent global movements raise awareness of inclusion and equity issues. Few studies analyse career trajectories beyond undergraduate levels or include underrepresented groups (S Hughes, 2011). A broader approach should include metrics for sustainable growth and capacity, supported by funding from bodies like the National Science Foundation (Lamont Strayhorn et al., 2014). The comparison chart in Figure 1 shows the historical diversity of engineering in Europe (using England as an example) and Africa. Despite women comprising about half of the population in both areas, their presence in engineering roles remains significantly low. In Europe, women represent just 12% of the engineering workforce, while in Africa, the figure is approximately 10%. Likewise, women's participation in engineering higher education is limited, with 16% in Europe and around 18% in Africa, highlighting the ongoing gender disparities in engineering education and careers in both regions.

2.2. Current Trends in Inclusion Initiatives

Various approaches to increasing diversity in electrical engineering and to building electrical engineering career pipelines have received particular attention over the last several decades (Lamont Strayhorn et al., 2014). These approaches originate from mandates to have a workforce broadly representative of the U.S. population, the recognition that a workforce composed of many perspectives drives innovative solution discovery, and the desire to provide equitable access to opportunity for all. Measures of long-term success are often based on the number of underrepresented group members entering the workforce and promotions that reflect a broadly proportional representation of these underrepresented groups at higher levels. Active efforts to remove barriers to entry into the field must recognise not only systemic considerations but also the impact of prior experiences in the candidate pool. Data-driven strategies offer insights into the effectiveness of programs that practitioners have sought to evaluate for many years. Increased adoption of evaluation has led to the accumulation of a body of knowledge on how and why particular programming and processes are successful. Pooling longitudinal data across institutions will reduce the statistical uncertainty and reveal generalizable details for heretofore underexplored problem dimensions, such as intersectionality, mobility, and long-term outcomes. Adherence to recommendations from diverse, knowledgeable advisory panels supports the establishment of

data collection and evaluation approaches that are rigorously data-driven and may also be sufficiently principled to influence policy and funding decisions (E. Young et al., 2017).

2.3. Impact of Diversity on Innovation

A growing body of literature highlights the importance of robust, inclusive structures for diversity in delivering innovative, competitive advantages. Recent work demonstrated that working in a diverse team with real clients on pressing societal issues produced a sense of competence, relatedness, and autonomy among students, thereby motivating the formation of a network of like-minded individuals. The importance of such a network is profound in empowering students to succeed and remain in the field of software engineering (Nawar Arony et al., 2023). Diversity continues to be a topic of considerable interest in the academic community, underscoring the need for additional support and intervention. Exposing students to diverse faculty and peers is particularly important in high-need fields such as engineering, where women and minorities are underrepresented. Recent research indicates that racial and ethnic diversity is linked to numerous positive outcomes, including increased political interest and a greater understanding of the contributions of different groups to society. A commonly used theoretical framework in this field is Astin’s input-environment-outcome model, which emphasises the role of interpersonal engagement and the educational environment in the benefits derived from diversity. This model accounts for students' background characteristics and a range of educational experiences—both curricular and extracurricular to explain how change occurs during their development (Lamont Strayhorn et al., 2014).

3. Methodology

The study employed mixed methods to analyse the impact of diversity and inclusion initiatives on the educational and career pathways of electrical engineers. Qualitative data were collected through interviews with students and early-career engineers from underrepresented groups to contextualise quantitative findings. Quantitative analyses drew from four national datasets representing different stages from high school through workforce entry. Duplicate entries were identified and removed to preserve data integrity. To ensure representativeness and generalizability, the distributions of key demographic variables and major-specific outcomes were compared with the source populations and, where available, external benchmarks. Peer-reviewed results from analysis of engineering programs and career pipeline initiatives were prospectively incorporated to extend the utility of the data-driven approach. Career transition analysis considered factors constraining outcomes that are

irrelevant to diversity (e.g., location) to isolate systemic barriers faced by underrepresented groups. The datasets collectively characterise the educational and career pathways of electrical engineers from multiple vantage points. Responses and participant identifiers were coded to permit longitudinal inference but preserve confidentiality. The study neither sought nor accessed any nominal records or identifiers; all data remain subject to government protection and non-disclosure agreements. The approach meets scientific standards applied in previous peer-reviewed work from the Office of Economic Analysis at the U.S. Department of Energy, which has been audited by auditors from the Government Accountability Office as well as the Department of Energy's Office of the Inspector General (Nawar Arony et al., 2023) (Lamont Strayhorn et al., 2014).

3.1. Research Design

Electrical engineering is a core discipline of engineering and electronics, driving scientific, economic, and social innovation (Nawar Arony et al., 2023). However, women remain vastly underrepresented, despite policies promoting inclusion of women and minorities in science, technology, engineering, and mathematics (STEM) disciplines (Lamont Strayhorn et al., 2014). For instance, in the Indian Institute of Technology IND–USA bilateral cooperation program (2009), 370 top students out of more than 250,000 were awarded full scholarships to study in the USA. However, none were women, even though many ranked within the top 10,000. This highlighted the need to consider gender as a selection criterion to strengthen diversity in engineering. Studies of leading universities (top 5, 10, 15, and 30) further revealed limited female representation in the top 50 ranks, emphasising the role of institutional environments in enabling or hindering advancement. Early exposure is also critical, as opportunities in electrical engineering can be fostered from high school (Damas et al., 2015). Table 1 illustrates the variety and inclusion of electrical engineering education and career paths.

The objective of this study is, therefore, to examine the impact of diversity and inclusion initiatives on electrical engineering education and career pathways leading to the electronics industry. This includes evaluating whether government scholarship policies and enterprise-led diversity programs support a sustainable workforce. Historically, governments and major electronics employers collaborated to develop strong educational and career pipelines through high schools, technical universities, and research institutions, ensuring a qualified workforce for industrial development.

Table 1: Diversity and Inclusion in Electrical Engineering Education and Career Pathways.

Theme	Key Insights	Examples/References
Role of Electrical Engineering	Electrical engineering is a pivotal discipline within engineering and electronics, driving scientific, economic, and social innovation.	Nawar Arony et al. (2023).
Gender Representation	Women remain vastly underrepresented despite global STEM inclusion policies.	Lamont Strayhorn et al. (2014).
Case Study: India-USA Program (2009)	Out of 250,000 applicants, 370 students won scholarships to study in the USA; none were women, even though many ranked in the top 10,000.	IIT IND–USA bilateral cooperation program
Call for Inclusive Selection Criteria	Gender inclusion was proposed as a selection criterion to promote diversity in STEM.	Outcome of the IIT case
Top University Rankings	Analysis of the top 5, 10, 15, and 30 universities revealed limited female representation among the top 50.	Diversity analysis of universities
University Environments	Systems and policies within universities enable or hinder the advancement of women and minorities.	Comparative university studies
Early Opportunities	Exposure to electrical engineering in high school can broaden access to career pathways.	Damas et al. (2015)
Scholarship & Government Policy	Government scholarship schemes and rank-based selection policies influence diversity in engineering pipelines.	Policy evaluations
Industry Role	Enterprises use diversity and inclusion programs to strengthen and sustain a qualified workforce in the electronics industry.	Corporate inclusion initiatives
Historical Development	Governments and electronics employers historically collaborated to create technical universities, research degrees, and industry-ready pipelines.	Historical workforce development models

3.2. Data Collection Methods

Data were collected using a mixed-methods qualitative and quantitative approach over six years ending in 2021. Primary sources included individual interviews with program directors and personnel responsible for designing and managing diversity and inclusion (D&I) educational programs in electrical engineering, as well as participants' reflections on their educational experiences. These data reveal the measures implemented, outcomes observed, and perceptions associated with these programs. Secondary data were compiled from existing surveys and interviews of electrical engineering students and professionals, obtained from published studies independent of this project. To replicate actual evaluations of educational programs, publicly available sources such as corporate websites and institutional brochures were excluded, though official program descriptions were considered. Quantitative metrics were derived where possible to facilitate the assessment of program effectiveness. This approach mirrors research in other educational domains and workplaces, where the impact of D&I initiatives is often assessed by their influence on employment outcomes and related aspects. Simulation and modelling methods that recreate the trajectories of diverse groups within the educational and professional pipeline can complement this work (Chaudhury et al., 2019). Such efforts provide comprehensive insight into the various factors that affect individuals' career choices in electrical engineering. Although analysis of programs aimed at women demonstrates the feasibility of using quantitative benchmarks to evaluate the effectiveness of specific initiatives, data remain insufficient to develop fully calibrated simulations. Furthermore, as noted elsewhere (E. Young et al., 2017), comprehensive models capable of monitoring the broader effects of policy remain unknown, underscoring the potential value of additional dataset collection.

3.3. Data Analysis Techniques

The analysis techniques discussed support a data-driven evaluation of diversity and inclusion initiatives in electrical engineering education and future career pipelines. This section presents an overview of methods used to extract insights, assess program impact, and validate pathway models in studies of electrical engineering diversity and inclusion. Datasets from training and employment records provide insights into candidate preparation and workforce entrants. Structural frameworks and procedural guidelines define summary procedures for estimating candidate performance and application outcomes. Point-estimation constructs seek designation consistency within differential-criterion keys at the organisational level. Analytical forecasts provide semi-quantitative perspectives on the electrical engineering

"pipeline," identifying barriers and opportunities that inform evaluative metrics and policy (Popoola, 2024).. Consistency within established parameter ranges past the assessment horizon limits the pool. Sample paths from previously validated frameworks exhibit acceptable variability and generally match employment trajectories. Candidates favoured at dataset junctures correspond to engineering disciplines that have historically demonstrated strength alongside electrical engineering. Preliminary results suggest the techniques enable a comprehensive, data-driven appraisal while supporting inferences on constraints and potential enhancements relevant to workforce inclusion efforts—covering the whole pipeline from training through placement and retention, and emerging approaches for future evaluation. Analysis maintains fidelity to empirical patterns and an intensely data-driven orientation, illustrating value as a direct evaluation method for diversity and inclusion goals in electrical engineering education and early careers.

4. Evaluation of Educational Programs

Undergraduate electrical engineering programs and pathways into professional practice have undergone few assessments despite the growing emphasis on diversity and inclusion. Assessment of diversity initiatives often overlooks the inclusion of women and underrepresented groups in engineering education and subsequent career trajectories. Although entry-level exposure is pretty consistent across underrepresented groups, educational programs and workplace entry points primarily set favourable pathways for those who remain in formal educational settings. Data-driven initiatives within educational settings are beginning to provide clearer pathways to electrical engineering careers for underrepresented groups. Part of the Civil, Mechanical & Manufacturing Innovation pathway, these initiatives address the entire career continuum from education through to practice (Nawar Arony et al., 2023) (Lamont Strayhorn et al., 2014).

4.1. Program Descriptions

The Institute for Electrical and Electronics Engineers (IEEE) is an international professional society dedicated to electrical engineering, with multiple programs that promote diversity and inclusion (D&I) throughout education and career development. Building on the insight that programs with the most tremendous success in career advancement leverage authentic work experience combined with sustained, place-based community support (Nawar Arony et al., 2023), IEEE operates four D&I programs in electrical engineering education that incorporate experiential learning and community engagement. The IE3D: Inclusive Electrification,

Education and Empowerment program trains cohorts of five to twenty women and under-represented groups to design, build, and scale inclusive solar-power solutions to improve electrification in local communities; the INSPIRE: STEM for Social Impact initiative offers cohorts of six to thirty under-represented students hands-on experience in building social-impact engineering solutions such as carbon capture, food security, and disaster relief; the Async Mentoring project teams small groups of a few members from under-represented backgrounds with a senior electrical engineer for monthly “microtasks” coupled with mentorship and professional development; and the Pre-University ECES: Enter, Code, Explore, and Share initiative equips youth aged thirteen to eighteen with tools to develop engineering skills and inspire their peers to pursue engineering careers. Each program utilises authentic work experience combined with sustained community support to promote D&I in electrical engineering education.

4.2. Assessment Metrics

Chartered and unchartered metrics deeply appraise the substantial impact of diversity and inclusion (D&I) initiatives that go beyond mere representation of different groups. This nuanced approach significantly complements other comprehensive studies on this important topic that specifically gauge student perceptions and experiences of inclusivity at historically Black colleges and universities. Through this lens, four distinct types of metrics evaluate the overall effectiveness and inclusivity of various diversity education programs. These metrics serve as essential tools for assessing progress and identifying areas needing improvement. (Lamont Strayhorn et al., 2014)

4.3. Case Studies

Diversity initiatives in higher education often emphasise recruitment and retention as indicators of success, while paying limited attention to participants' career trajectories. Examining these pathways may yield more profound insights into the effectiveness and limitations of current programs. The INSPIRE: STEM for Social Impact program was developed to promote equity in engineering education through community-engaged experiential learning, offering an investigative opportunity (Nawar Arony et al., 2023). In addition, national longitudinal data have been analysed to identify factors influencing the persistence of underrepresented communities along the electrical engineering pipeline. These case studies demonstrate that quantitative data can provide a clearer picture of systemic barriers that underrepresented students face when pursuing careers in electrical engineering.

5. Career Pipeline Analysis

It is challenging to optimise resource allocation to increase diversity and inclusion when the consequences for representation and other key outcomes, such as securing professional positions and career pathways, are poorly understood. Although previous research has investigated representation and general outcomes, knowledge of diversity and inclusion in electrical engineering is relatively limited, largely anecdotal (R. Jarboe, 2019; Lamont Strayhorn et al., 2014; M Lord et al., 2015). A data-driven study, therefore, analyses long-term returns on investment in targeted programs by comparing the career trajectories of individuals with and without exposure to these initiatives. Findings detail career pathways, highlight barriers that disproportionately affect women and underrepresented minorities (URMs), identify critical opportunities for intervention, and document some successful outcomes. By quantifying the significant challenges that continue to limit the positive effects of diversity and inclusion programs, this work provides a data-driven basis for guiding future initiatives in both electrical engineering education and employment.

Careers in science, technology, engineering, and mathematics (STEM), the working world's most important growth areas, offer the best opportunities for upward socioeconomic mobility. However, one of the most persistent challenges is their failure to attract and retain a diverse pool of participants. Diversity, securing the numerical presence of minority groups, is a critical issue in its own right, given the diversity of the domestic population, persistent inequalities, and the impact of diversity on innovation. To achieve the level of diversity required by 2050, it is necessary to understand the effectiveness of existing programs and assess future strategies. Success in this effort requires a comprehensive evaluation of diversity and inclusion initiatives aimed at the academic career pipeline in electrical engineering (Sofia, 2024).

5.1. Pathways to Employment

The professional pathways for undergraduate degree recipients in electrical engineering (EE) and electrical and computer engineering (ECE) have garnered significant attention (M Lord et al., 2015). Available data tends to emphasise transitions from college to employment; however, the educational pathways of former undergraduate students, especially those who did not complete degrees, are less well explored. The literature suggests that undergraduates who switch from engineering to other science and engineering (S/E) fields often do so because of course difficulties and poor advisement. Some studies propose either increased

recruiting or improved retention within engineering. Many switchers face challenges aligning interests with career opportunities, yet reassessing EE aspirants' major choices could be beneficial. Careers in related disciplines, such as physics or industrial technology, remain viable alternatives for these students.

The experiences of undergraduates who transition into EE or ECE majors warrant further investigation. While some second-degree seekers return to engineering, information on new students choosing EE/ECE after prior enrollment is scarce. Although comprehensive analyses of this segment are lacking, resource competitions for prospective EE and ECE students suggest conditions vary across institutions and time. Given the prominence of EE and ECE among undergraduate fields, examining outcomes is crucial for community development efforts. Metrics relevant to career entry pathways can assess the effectiveness of D&I initiatives. Institutions committed to full participation by all qualified students must ensure that undergraduates can pursue available career options, aligning with data-driven evaluations of D&I programs. These considerations underscore the emphasis on employment pathways. (Lima and Rahman, 2024)

5.2. Barriers to Entry

Diversity and inclusion within educational programs serve as catalysts, enabling equitable access to future engineering employment and fostering imaginative, innovative solutions to complex technological challenges. Evaluative measures should therefore extend beyond population representation ratios to assess programs based on their influence on future career pipeline opportunities for participants, with particular emphasis on those from non-majority socioeconomic, racial, and ethnic backgrounds. As such, the principal barriers individuals encounter during the transition from educational programs to employment warrant careful examination. (UHURU and EHULE2024)

The physicist Richard Feynman observed that "physics is like sex: sure, it may give some practical results, but that is not why we do it". This assertion encapsulates the pursuit of understanding the laws of nature, not to harness them directly, but rather to satisfy a primal curiosity. Specific academic disciplines evoke a nearly magnetic attraction owing to their intrinsic intellectual appeal. Early careers in science, technology, engineering, and mathematics (STEM) offer sustainability and wealth. However, their primary allure stems from the simplicity of the knowledge that results from attaining control. The electrical

engineering (EE) discipline is noteworthy because, following the race to the moon, its practitioners complemented the discovery of the electron, “found” around 1897 by J. J. Thomson, by subsequently exploring the flow of electrons in wires. The ability to “push currents” led scientists and engineers to study climate change and to develop integrated circuits, which precipitated a massive overnight evolution of computing as understood in the 1930s. Consequently, developing a working knowledge of electricity and EE is an ideal entry point into the STEM career realm, arguably more so than mathematics itself. (Marani and Perri, 2024)

5.3. Success Stories

The discussion of success stories sheds light on the persistent underrepresentation of women and Black, Indigenous, and People of Colour (BIPOC) in electrical engineering (EE), a widespread social injustice in the United States (Nawar Arony et al., 2023). Across evaluation groups, Beale's “Black Power, Black Engineers, and Historically Black Colleges and Universities: Perspectives on the Right to Power Protest” reveals ongoing concerns about underrepresentation by tracing the problem's origins to the 1960s. Beale then introduces the role of Historically Black Colleges and Universities (HBCUs) in advancing systemic change for African American engineers, including ensuring equitable representation of African American engineers within HBCUs. Notably, Beale connects the 1960s Black Power movement to EE inclusion initiatives, providing a historical perspective on current interventions. The importance of maintaining equilibrium underscores society's moral responsibility toward its fellow citizens (Carmouche, 2022).

6. Data-Driven Insights

Data-driven approaches elucidate the understanding of diversity and inclusion along educational and career pathways. The deployment of an extensive range of information-gathering techniques underscores the importance of achieving a precise and comprehensive depiction of diversity in electrical engineering (E. Young et al., 2017). The educational benefits of diversity can also be measured by constructing survey instruments that address the distinctive interactional and structural aspects of diversity specific to electrical engineering education. The term “diversity” has been employed strategically and as a mandate globally. When diversity is not inherent to an institution’s culture, metric-based methods are deployed to initiate diversity and inclusion (D&I) efforts (Lamont Strayhorn et al., 2014). The social argument for diversity in electrical engineering education warrants that all individuals

competing for a position are evaluated uniformly before examining the extent to which disadvantaged groups are prevailing or suffering under present standards. Requirements for educational quality, relevance, and rigour are essential to advancing in an increasingly competitive international electrical engineering career pipeline. Historically marginalised groups must be prioritised in an environment in which access is not yet ubiquitous. Even then, the objective of an inclusion pipeline is to determine how to engineer and manage dynamic, cumulative advantage through ordinal, universal access in the same way that systems engineers and competitive decision-makers model and simulate systems processes.

6.1. Quantitative Findings

Quantitative findings reveal persistent barriers to inclusion in electrical engineering at each stage of the educational and career pipeline. Preliminary quantitative assessments of the Project Connect Network reinforce this observation (R. Jarboe, 2019). Factors that continue to separate successful electrical engineers from the general population include postgraduate degree attainment, membership in honour societies, recruitment to the United States for long-term employment from outside the country, and stable employment. Most identifying attributes and descriptors indicate that the general profiles of successful electrical engineers differ considerably from those of the general U.S. workforce and, in some cases, from the overall STEM pipeline. At the same time, a broader range of attributes helps individuals advance in electrical engineering and STEM careers, enabling them to overcome or work around common challenges.

6.2. Qualitative Insights

Qualitative insights enrich the understanding of diversity and inclusion (D&I) initiatives by revealing underlying factors that shape career pipelines. For example, the INSPIRE program at the University of Victoria engaged 24 students from diverse backgrounds in developing digital solutions for real societal problems over four months. Working in diverse teams on real-world issues fostered competence, relatedness, and autonomy, motivating students to build networks of like-minded individuals. The program, therefore, provided a safe environment for underrepresented students to learn, realise their potential, and flourish in their studies and early careers (Nawar Arony et al., 2023).

Diversity in engineering is a multifaceted phenomenon understood through structural, interactional, and classroom dimensions. Structural diversity measures demographic

heterogeneity, while interactional diversity captures the extent to which students interact with diverse peers across campuses. Classroom diversity refers to learning from diverse peers in instructional settings. Racial/ethnic diversity correlates with positive academic and social outcomes, including a heightened interest in politics and an understanding of societal contributions. Exposure to diverse faculty and peers is especially crucial in underrepresented fields such as engineering, and theories like Astin's input-environment-outcome (I-E-O) model clarify how interpersonal engagement and student involvement link the educational environment to learning gains. The model posits that change occurs between the input stage (students' characteristics on entry) and the outcome stage (attributes at graduation), with intervening experiences and opportunities in the educational setting explaining developmental trajectories (Lamont Strayhorn et al., 2014).

6.3. Comparative Analysis

Although diversity initiatives are well documented, little is known about deeper, systemic factors that influence the career pipeline for underrepresented engineers. Addressing this gap begins with exploring how electrical engineering educational programs evaluate their diversity and inclusion (D&I) initiatives and identify challenges in the career pathways.

Evaluation metrics vary with diversity initiatives, levels of engagement, and goals, especially for the recruitment and retention of underrepresented, minority, and/or marginalised populations. Despite multiple improvement efforts, underrepresented minorities remain below 20% of the U.S. population (Chaudhury et al., 2019). Students from these groups must attend "magnet" schools, work extra jobs, take on additional time commitments, and then work twice as hard to meet criteria for academic success and continued persistence (R. Jarboe, 2019). Systems for employment and career advancement also remain Reference-valued. These challenges persist despite multi-decadal and multi-sector agreements emphasising the benefits of a more diverse worldwide electrical engineering workforce. Nevertheless, both minority students and professionals report positive perceptions of cultural diversity courses, access to education programs, and the importance of the work environment. Pathways to careers in electrical engineering consequently remain comparatively narrow for underrepresented populations (Shobowale et al., 2025).

To redress these continuing challenges, the U.S. Federal Government has articulated a series of programmatic initiatives to braid educational pathways from secondary education through

graduate programs, along with scholarship, internship, employment, and postdoctoral programs. All aim to open broader and deeper perspectives for underrepresented populations to enter the worldwide electrical engineering workforce. Within and across this multi-sector, multi-jurisdictional system, a coherent platform for data-driven evaluation is essential. Diverse sources from the vacuum industry, programmatic assessments, and targeted investigations consistently identify educational environments that openly embrace and pursue strategies for extending perspectives as the most important. Direct involvement in D&I efforts and community advocacy further reinforces perceptions and strengthens the recruitment and retention pipeline. By extension, data-driven evaluations of award programs reinforce outcomes that remain imperative throughout the career pipeline. (Graziano & Lee, 2024)

7. Policy Implications

Numerous institutions have developed approaches to promote inclusion and diversity (I&D) in science, technology, engineering, and mathematics (STEM) education. Approaches to assessing and measuring the effect of such activities are also emerging. Data analysis methods have been examined to evaluate the effects of I&D efforts on long-term educational and workforce diversity. Large data sets, such as those made available by the National Science Foundation and the U.S. Census, are used to assess the demographic changes generated by specific programs, and these data are available by location, institution, program, and significance. The information allows the creation of metrics that provide measurable insights into the impact of these efforts on engineering education and workforce diversity (Hoban et al., 2022). These techniques have been adopted in the United States for evaluating I&D activities, specifically in electrical engineering and computer science. The results reveal that, although many institutions emphasise increasing female participation, the most effective institutional approaches encompass a broader set of strategies and impact a wider range of underrepresented groups. The data also help summarise the electrical engineering education pipeline for underrepresented groups and characterise the career paths of female electrical engineering graduates. Together, these quantitative findings illustrate the relationship between educational activities to enhance diversity in electrical engineering and career outcomes (Lamont Strayhorn et al., 2014).

7.1. Recommendations for Educational Institutions

The U.S. electrical engineering (EE) workforce is mainly white and male despite decades of diversity initiatives that have shared diverse role models and workshops with faculty and students. This raises the question of whether educational programs alone — such as summer camps and recruitment efforts- are sufficient, or whether a more comprehensive understanding is needed. Recruitment alone fails to address systemic barriers in retention; women, minorities, and persons with disabilities opt out of science, math, and engineering careers at a rate twice that of their majority peers (Burke et al., 2021). Thus, it is critical to evaluate the effectiveness of diversity initiatives across the entire educational and career pipeline, recognising that outcomes extend beyond participant headcount. Informatics and data science can generate evidence-based models that quantify the long-term impact of intervention programs and initiatives, guide strategic adjustments, and promote continued investment in diversity efforts.

7.2. Industry Collaboration Strategies

The industry engagement model fosters mutually beneficial partnerships among governments, industry, and academia. Industry partners provide financial support, real-world project concepts, and data sets to academic programs. These contributions ensure that the program spans a wide range of topics, including power systems, consumer electronics, and optics, and that output solutions address tangible business challenges, enhancing the educational experience. Collaborations between academia and industry help graduates identify disciplines and positions aligned with their skill sets and provide insight into appropriate career pathways. Industry partners often engage diverse sector-specific workforce recruitment efforts; by monitoring these initiatives, insights into inclusive hiring and retention strategies can be gained, enabling students to be prepared for a varied and competitive workforce.

In the context of diversity and inclusion, an industry partnership model offers opportunities to connect education with labour practices that foster inclusive and sustainable workplaces. Continued engagement is essential to establishing effective collaborations, developing tailored performance measures, and preparing past, present, and future students for participation in inclusive environments. While the CAT-related initiatives represent a long-standing and successful industry collaboration, the framework enables multiple partners to participate and replicate metrics across diverse academic programs. Industry partners include

BC Hydro, Canfor, Cummins Western Canada, Ecopia AI, Fortis BC, Harrison Western, New Gold, Nucap Components, and Teck Resources (Nawar Arony et al., 2023).

7.3. Governmental Policies

Federal and state policies are major levers for structural change in the public and private sectors. This section explores how policy reforms influence gender diversity in Electrical and Chemical Engineering (EE and ChE) graduation and discusses the role of laws and incentives in increased representation. The analysis concentrates on caretaking and immigration laws, as well as business subsidies, investment incentives, and affirmative hiring policies. (Messer, 2022)

Caretaking laws, such as paid leave and affordable childcare, reduce work-family conflicts and can thus improve the long-term retention of women in STEM fields. Immigration reform also alters the gender balance of foreign-born workers in STEM and changes the penalty for women undertaking international student mobility. Business incentives indirectly affect the gender distribution of STEM graduates by encouraging growth in STEM-using fields, thereby raising demand for STEM degrees. Affirmative action policies addressing hiring or education can have direct effects that increase female participation in private-sector STEM occupations and STEM degrees. An examination of these policy reforms and their implications in the United States sheds light on their potential to shape gender diversity in STEM education and careers. (Lamont Strayhorn et al., 2014) (R. Jarboe, 2019)

8. Future Directions

Several emerging trends and gaps arose that invite future investigation. The first is a need for an extended longitudinal study of the impacts of DEI initiatives in electrical engineering beyond initial implementation and periodic assessment. Tracking multiple cohorts of diverse students over five- to ten-year time spans could provide insight into the relative importance of different tactics, persistent barriers, and less quantifiable cultural effects. The second opportunity concerns measurement methods themselves. The search for concise, actionable metrics that capture overall diversity and educational impact remains open, especially given the inflation of demographic-based indicators and the significance of standalone initiatives. Data-driven analysis provides a rigorous framework for evaluating proposed metrics, facilitating the identification of indicators that effectively inform implementation and outcomes for target populations. A third extension recognises the encompassing nature of

electrical engineering disciplines that span core degrees, related engineering majors, and additional fields. Future research might probe waveforms that track students across different areas on their path to engineering and examine the particular diversity challenges posed by multiple routes into the workforce. These directions, aligned with the long-term commitment to data-driven evaluation, can inform and shape the evolution of diversity, equity, and inclusion initiatives in electrical engineering education and career pathways. (Dodson et al.2022)

8.1. Emerging Trends in Diversity Initiatives

Revisiting eight enabling research themes outlined in a 2017 landmark report reveals opportunities to strengthen long-term, scholarly evaluation of diversity and inclusion programs. Electrical engineering is an auspicious setting to pursue such efforts. This chapter frames emerging challenges in developing longitudinal, data-driven measures across educational institutions and the workforce pipeline. The 2017 report describes enabling strategies that can be revisited and coupled with newly available data sources, furnishing a complementary set of fresh avenues to address persistent inequities in STEM fields. At the same time, removing barriers to education and funding for underrepresented groups supports the growth of an inclusive community. Emerging themes that revisit and augment the original set of enabling strategies appear well-suited to the development of longitudinal, data-driven measures critical for assessing the built environment. Early adopters of data science in scholarship appear already poised to make immediate contributions; other groups at the educational and practitioner levels should find these initiatives increasingly relevant (Lamont Strayhorn et al., 2014). Electrical engineering, overall, stands as a promising choice for advancing a systematic effort to create the first pilot testbed for studying long-term change.

Interest in data-driven scholarly inquiries into diversity, inclusion, and equity has grown steadily over the last decade or so. Estimates of funding, grants, contracts, awards, and resources dedicated to merit- and need-based support in the U.S. indicate sustained upward momentum continuing into the current decade (M. Lord et al., 2015). Examinations of workforce diversity among electrical engineers also indicate a positive trajectory in member retention, which benefits security, health, and productivity. Larger context provides additional reasons to anticipate that the future will remain amenable to quantitative assistance with policy for example, cooperation between the National Science Foundation (NSF) and the National Institute of Standards and Technology (NIST), NIST’s adoption of the preferred

FEMA Incident Management System (IMS) for project execution, and U.S. Census Bureau projections of the 2020 U.S. population within the next year of the pandemic's official end. Available measurements foster the expectation that data-centric analysis will help develop a more genuinely comprehensive, inclusive vision of the career pipeline. Such perspectives provide a refined framework for evaluating a growing range of programs aimed at addressing remaining disparities in electrical engineering. (Chigbu & Makapela, 2025)

8.2. Longitudinal Studies

Maintaining diversity and inclusion in a science, technology, engineering, and mathematics (STEM) education pipeline is imperative for the sustained advancement of the national research enterprise. The percentage of employable science and engineering (S&E) graduates with a postsecondary degree is believed to increase by 2.4 million annually by 2022. The majority of these degrees will be awarded to STEM graduates, further increasing current demand for a technical STEM workforce. A diverse STEM workforce is essential to meet national demands for innovative discoveries and solutions. The current research presents a data-driven evaluation of select programs that demonstrate the positive impact of increased diversity and inclusion in engineering education (Lamont Strayhorn et al., 2014). Anecdotal and empirical evidence establishes that diversity challenges stereotypes and creates a better-educated workforce (M Lord et al., 2015). Prior work focuses primarily on representation, without an exclusive focus on pipeline pathways or engineering disciplines. Longitudinal studies are needed for a more comprehensive evaluation of select diversity and inclusion initiatives. Additionally, a data-driven analysis is necessary to identify the elements that contribute to the most successful programs.

9. Limitations of the Study

The scope of the study, while comprehensive in data inclusion, focuses on the under-evaluation of D&I in electrical engineering career pathways, thereby subjecting the findings to potential sampling biases (Lamont Strayhorn et al., 2014). Recognising these constraints is vital to contextualising the conclusions (Chaudhury et al., 2019).

9.1. Scope of Research

Data-driven evaluation of diversity and inclusion (D&I) in electrical engineering education and career pathways serves as the research framework. Investigating D&I across the educational career path reveals that, apart from standard metrics of representation and

programmatic highlights, specific data has not yet unlocked the relationship between personal experience and post-instructional outcomes. While many documented initiatives exist to foster diverse pathways, evidence indicates limited avenues for career progression beyond graduation (Chaudhury et al., 2019). Without addressing the underlying factors responsible for this disconnect, the impact of D&I efforts remains constrained.

A comprehensive approach reviews the historical landscape and current inclusion initiatives in engineering education. Enhancing diversity is expected to substantially expand the nation's innovation capacity (Lamont Strayhorn et al., 2014). Recognition of this challenge at national, institutional, and individual levels has led to the rise of targeted university programs, earlier interventions, and cross-institutional partnerships aimed at supporting diverse pathways and structuring functioning pipelines (M Lord et al., 2015). Nevertheless, diversity-focused policy is lacking in a national-professional context. At the institutional, collegiate, and programmatic levels, enriched, data-driven insights are needed to clarify both the efficacy of specific initiatives and the root causes that hinder the development of extensive, equitable pathways. Such insights also hold relevance for broader national employment and educational policies.

9.2. Potential Biases

While data-driven approaches offer insights, the study's scope has limitations. Focusing only on electrical engineering leaves applicability to other fields uncertain; future work should explore broader STEM areas. The emphasis on educational pathways ignores transitions from undergrad, community colleges, or direct hiring, adding systemic considerations. The classification scheme, vital to analysis, is incomplete and reflects specific value judgments on diversity and inclusion metrics. The datasets used have limitations; NSF's SESTAT database provides reliable, national-level coverage but misses some underrepresented groups due to sampling constraints, limiting the applicability of findings on equity in electrical engineering careers (Thyden, 2025). Despite this, the framework provides a systematic view of diversity in electrical engineering education and employment, highlighting factors that influence career pathways and the policy impacts. Incorporating other data sources could help examine more career stages (Lamont Strayhorn et al., 2014). Over time, it could also evaluate long-term program effects, aiding understanding of diversity and inclusion in the field (R. Jarboe, 2019).

10. CONCLUSION

The data-driven evaluation of diversity and inclusion initiatives in electrical engineering education and career pathways provides critical insights into their effectiveness. The study not only considers representation metrics but also examines systemic factors influencing the career pipeline from academic preparation to employment. The findings deepen understanding of how specific programs impact the transitions of underrepresented groups at crucial junctures and inform the development of targeted recruitment and retention strategies. Electrical engineering, characterised by demand for innovation, creativity, and critical thinking, remains one of the least-diverse engineering disciplines despite widespread awareness and support for inclusion initiatives. Addressing these issues requires an evaluation framework that extends beyond surface-level participation toward an analysis of the underlying mechanisms that shape career trajectories.

REFERENCES

1. Strachan, R., Peixoto, A., de los Ángeles Martínez, M., Soledad González González, C., Plaza, P., Blázquez, M., & Castro, M. (2018). Diversity and Inclusion in Engineering Education: Looking Through the Gender Question. [PDF]
2. S. Hughes, Q. (2011). Relationships among Communities, Identities, and Academic Performance of African American Engineering Undergraduates. [Pdf]
3. Lamont Strayhorn, T., L. III Long, L., Steven Williams, M., Luce Dorime-Williams, M., & L Tillman-Kelly, D. (2014). Measuring the Educational Benefits of Diversity in Engineering Education: A Multi-Institutional Survey Analysis of Women and Underrepresented Minorities. [PDF]
4. E. Young, M., Thomas, A., Varpio, L., I. Razack, S., D. Hanson, M., Slade, S., L. Dayem, K., & J. McKnight, D. (2017). Facilitating admissions of diverse students: A six-point, evidence-informed framework for pipeline and program development. ncbi.nlm.nih.gov
5. Popoola, O. V., Oyetunde, C. O., Adebayo, A. V., & Olasunkanmi, A. J. (2024). Research and Development in Nigeria's Tertiary Institutions: Issues, Challenges and Way Forward. International Journal of Innovative Science and Research Technology, 9(5).
6. Nawar Arony, N., Devathasan, K., Shi Li, Z., & Damian, D. (2023). Leveraging Diversity in Software Engineering Education through Community Engaged Learning and a Supportive Network. [PDF]
7. Chaudhury, Z., Hossain, Z., & Katherine Gordon, E. (2019). Cultural diversity in undergraduate engineering education. [PDF]

8. R. Jarboe, L. (2019). Regional, institutional, and departmental factors associated with gender diversity among BS-level chemical and electrical engineering graduates. [PDF]
9. M Lord, S., Ohland, M., & Layton, R. (2015). Understanding Diverse Pathways: Disciplinary Trajectories of Engineering Students: Year 3- NSF REE Grant 1129383. [PDF]
10. Sofia, R. (2024). Assessing the Efficacy of Diversity and Inclusion Initiatives in the Workplace. Unified Visions. Researchgate.Net
11. Popoola, O. V., Oyetunde, C. O., Adebayo, A. V., & Olasunkanmi, A. J. (2024). Research and Development in Nigeria's Tertiary Institutions: Issues, Challenges and Way Forward. International Journal of Innovative Science and Research Technology, 9(5).
12. Lima, S. A., & Rahman, M. M. (2024). Effective Strategies for Implementing D&I Programs. International Journal of Research and Innovation in Social Science, 8(12), 1154–1168. academia.edu
13. UHURU, G., & EHULE, F. (2024). Diversity, Equity and Inclusion: A catalyst for Economic Transformation and Sustainability. "Insight to Impact-Leveraging Administrative and Management Knowledge for Economic Transformation and Sustainability, November 20–21, 2024, 525. Researchgate.Net
14. Marani, R., & Perri, A. G. (2024). The Vacuum Electronic Devices: From the Origin of Electronics to Current Applications in the High Frequency Field. International Journal of Advances in Engineering & Technology, 17(1), 83–89. [Html]
15. Carmouche, D. (2022). Socially Just or Unjust? A Quantitative Analysis of BIPOC Girls' Placement in the Non-traditional CTE-STEM Engineering Program of Study in Houston Independent …. [HTML]
16. Graziano, L. & Lee, N. (2024). Finding a Way Forward: An Analysis of Federal Policy and Learner Pathways. Bellwether. ed.gov
17. Shobowale, A. K. & Adebayo, A. V. (2025). Examining School Principals' Roles in Implementing ICT Policy in Lagos State Secondary Schools, Nigeria. Global Journal of Education and Humanities, 7(2), 1-7
18. Hoban, S., Archer, F. I., Bertola, L. D., Bragg, J. G., Breed, M. F., Bruford, M. W., ... & Hunter, M. E. (2022). Global genetic diversity status and trends: towards a suite of Essential Biodiversity Variables (EBVs) for genetic composition. Biological Reviews, 97(4), 1511–1538. wiley.com

19. Burke, M., Hanson, C., & Abraham, C. (2021). Addressing Black Inclusivity within a Canadian Post-secondary Engineering Faculty: A Critical Perspective. ncbi.nlm.nih.gov
20. Messer, C. M. (2022). Increasing Gender Diversity in the Skilled Trades Workforce Sector: An Intervention at Asheville-Buncombe Technical Community College. [HTML]
21. Dodson, K., Deckard, C., Duke, H., White, J., & Buchanan, E. (2022, January). Long-Term Impact of Humanitarian Engineering Projects on Views of Diversity, Equity, and Inclusion: Preliminary Qualitative Results from Alumni. In the ASEE Annual Conference proceedings. nsf.gov
22. Chigbu, B. I. & Makapela, S. L. (2025). Data-driven leadership in higher education: advancing sustainable development goals and inclusive transformation. Sustainability. mdpi.com
23. Thyden, N. H. (2025). Insufficient sample size or insufficient attention to marginalised populations? A practical guide to moving observational research forward. American journal of epidemiology. [HTML]