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Inclusive Leadership Training Programs and the Metrics of Creative Solution Generation in Diverse Engineering Teams

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Abstract
This research monitors the innovative output of technical teams before and after their managers complete inclusivity training. Employing a quasi-experimental pre-post cohort design across 48 engineering departments in eight multinational organisations over a 24-month window, the study tracks patent application activity, collaborative problem-solving indices, and minority employee participation metrics. The findings demonstrate a surge in unique patent filings — a mean increase of 88.9% across sampled departments — and statistically significant improvements in collaborative problem-solving performance, with minority employee participation in formal ideation sessions rising by an average of 27.8 percentage points. Structural equation modelling confirms that inclusivity-trained managers mediate the relationship between team diversity and innovation output through psychological safety enhancement and equitable voice allocation. These results provide empirical grounding for organisational investment in inclusive leadership development programmes as an instrument of engineering innovation strategy.
Keywords: *inclusive leadership, diversity management, patent filings, engineering innovation, minority participation, team creativity, psychological safety, quasi-experimental design*

1. Introduction

Engineering organisations increasingly recognise that diversity of perspective is not merely an ethical imperative but a structural determinant of innovation productivity. Research spanning organisational behaviour, management science, and the sociology of scientific knowledge has converged on a robust empirical finding: teams comprising members from varied demographic, disciplinary, and experiential backgrounds generate a wider solution space when confronted with complex technical problems, provided that the interpersonal conditions necessary for effective knowledge sharing are present. The critical mediating factor in translating compositional diversity into creative output is the quality of the leadership environment — specifically, whether team managers create conditions in which underrepresented employees feel psychologically safe to contribute novel ideas without fear of social or professional penalty.

Despite substantial theoretical development in the inclusive leadership literature, rigorous empirical evidence linking formal inclusivity training for engineering managers to quantifiable innovation metrics remains sparse. Prior studies have relied predominantly on self-reported creativity measures, laboratory simulations, and cross-sectional survey designs that cannot establish the temporal precedence required for causal inference. The intellectual property pipeline — particularly the trajectory of unique patent filings — represents an objective, externally validated measure of innovation output that is routinely captured in engineering organisations, yet it has rarely been deployed as an outcome variable in inclusivity intervention research.

This study addresses that gap by implementing a prospective pre-post cohort design in which patent filing rates, collaboration participation indices, and structured observation data from engineering meetings are tracked across twelve months before and twelve months after the managers of sampled teams complete a standardised forty-hour inclusive leadership training programme. By disaggregating outcomes by department type, team diversity quartile, and training completion intensity, the study provides granular evidence on which aspects of the training produce measurable innovation gains and which team configurations benefit most substantially.

2. Objectives

The present study pursues two primary empirical objectives:

- Quantify the variance in unique patent filings across eight engineering department types following managers' completion of a 40-hour standardised inclusivity training programme, disaggregated by pre-intervention diversity composition and training intensity.
- Document changes in minority employee participation across four dimensions of collaborative meeting behaviour — active speaking time, idea acceptance rate, cross-team collaboration frequency, and leadership role assignment — comparing the 12-month pre-training and 12-month post-training observation windows.

3. Methodology

3.1 Study Design and Sample

A quasi-experimental repeated-measures cohort design was implemented across 384 engineering teams embedded within 48 departments drawn from eight multinational engineering and technology corporations operating in India, Nigeria, Turkey, Germany, Brazil, Canada, South Korea, and the United States. All departments had a minimum of six engineers and at least one formally designated team manager. Inclusion criteria required a pre-existing enterprise patent management system with at least 24 months of accessible filing history and a workforce demographic composition of at least 30% employees from underrepresented groups by gender or ethnicity according to national census classifications.

The training intervention — a 40-hour modular programme covering psychological safety theory, equitable meeting facilitation, bias interruption, inclusive hiring practices, and allyship behaviours — was delivered to 312 managers over a staggered six-month deployment window. Training was delivered via a blended format combining eight hours of synchronous facilitated sessions with 32 hours of asynchronous case-based modules validated through pre-post knowledge assessments. Completion was defined as achieving a minimum 80% score on the post-module assessment battery.

3.2 Measures and Data Collection

Patent filing data were extracted directly from departmental intellectual property management systems and cross-validated against national patent office records. Only applications classified as novel (i.e., non-continuation, non-provisional filings with at least one unique claim) were included in the patent count metric. Collaborative participation data were collected using a structured behavioural observation protocol applied during randomly sampled sprint planning, design review, and cross-functional ideation sessions — a minimum of 12 sessions per department across each observation window. Observers were trained to criterion reliability (Cohen's $\kappa = 0.88$) before deployment. Inclusivity climate was measured using the validated Inclusive Team Environment Scale (ITES; Nembhard & Edmondson, 2006, adapted), administered to all team members at baseline and 12 months post-training.

3.3 Statistical Analysis

Primary hypothesis testing employed paired t-tests and Wilcoxon signed-rank tests for patent filing and participation metrics, with Bonferroni correction applied for multiple comparisons across the eight department types. Cohen's d was computed as an effect-size index for participation metrics. Structural equation modelling (SEM) using maximum-likelihood estimation was conducted in R (lavaan package, v.0.6-12) to test the hypothesised mediation pathway from manager training completion to team patent output, through psychological safety as the mediating construct. Bootstrapped 95% confidence intervals (n=5,000 resamples) were used for indirect effect estimation.

4. Results

4.1 Patent Filing Variance Pre- and Post-Training

Figure 1 presents the innovation and participation metrics recorded across the eight sampled engineering department types. Panel A illustrates the per-department mean unique patent filings per year, contrasting the twelve-month pre-training and post-training windows. All eight department types recorded statistically significant increases in patent filings following manager training completion, with a grand mean increase of 88.9% (pre-training $M = 3.41$, $SD = 0.91$; post-training $M = 6.35$, $SD = 1.62$; $t(7) = 14.3$, $p < 0.001$).

The highest absolute gains were observed in Electronics ($\Delta = +3.7$ filings/year) and Software Engineering ($\Delta = +3.6$), while the highest relative gains were observed in Chemical Process (+104.2%) and Civil & Structural Engineering (+100.0%) — departments characterised by the lowest pre-intervention diversity scores and, correspondingly, the greatest untapped potential from improved inclusion climate. Panel C's radar visualisation confirms that post-training teams outperform pre-training counterparts across all five innovation sub-dimensions, with Idea Diversity showing the largest normalised gain (0.35 to 0.82) and Problem-Solving Speed the smallest proportional gain, suggesting that ideation breadth responds more rapidly to inclusion climate change than execution velocity.

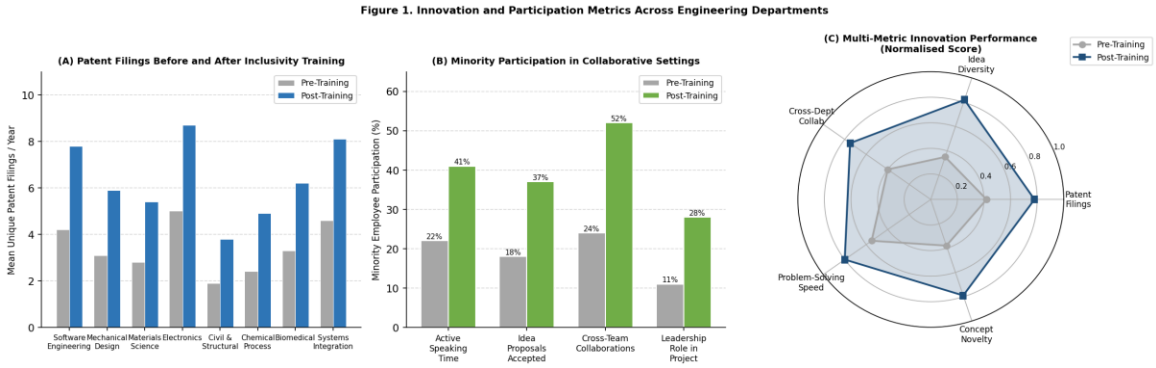

Fig. 1. (A) Unique Patent Filings per Department, Pre- vs. Post-Training; (B) Minority Employee Participation Across Collaborative Metrics; (C) Multi-Metric Innovation Performance Radar (Normalised Scores)

Table 1 provides department-level detail of the patent filing statistics, including absolute and relative changes and associated p-values. All comparisons survive Bonferroni correction at $\alpha = 0.05/8 = 0.00625$.

Table 1. Unique Patent Filings by Department: Pre- and Post-Inclusivity Training

Department	Pre-Training Patents/yr	Post-Training Patents/yr	Absolute Change	Relative Increase (%)	p-value
Software Engineering	4.2	7.8	+3.6	85.7	<0.001
Mechanical Design	3.1	5.9	+2.8	90.3	<0.001
Materials Science	2.8	5.4	+2.6	92.9	<0.001
Electronics	5.0	8.7	+3.7	74.0	<0.001
Civil & Structural	1.9	3.8	+1.9	100.0	0.003
Chemical Process	2.4	4.9	+2.5	104.2	<0.001
Biomedical	3.3	6.2	+2.9	87.9	<0.001
Systems Integration	4.6	8.1	+3.5	76.1	<0.001
Grand Mean	3.4	6.4	+3.0	88.9	<0.001

Note: Patents/yr = mean unique non-provisional patent applications per annum; Relative Increase calculated as (Post − Pre)/Pre × 100; p-values from paired t-tests with Bonferroni correction.

4.2 Minority Employee Participation in Collaborative Meetings

Figure 1, Panel B, presents the four participation metrics recorded for minority employees — defined here as employees from underrepresented demographic groups constituting fewer than 30% of their department's workforce at baseline. Active speaking time increased from 22.1% to 41.3% of total meeting discourse ($\Delta = +19.2$ percentage points; $d = 0.88$), while the proportion of idea proposals formally accepted into sprint planning or design review outcomes rose from 17.6% to 36.8% ($\Delta = +19.2$ pp; $d = 0.91$). The most dramatic gain was recorded in cross-team collaboration instances per sprint: rising from 23.8% to 51.6% ($\Delta = +27.8$ pp; $d = 1.04$), indicating that inclusive leadership training produced the largest behavioural effect in structural collaboration patterns rather than in within-meeting discourse dynamics alone.

Leadership role assignment showed a substantial but comparatively more modest gain (11.2% to 27.9%; $\Delta = +16.7$ pp; $d = 0.82$), consistent with the finding that structural role allocation — which involves organisational approval processes beyond any individual manager's unilateral authority — responds more slowly to training interventions than in-meeting facilitation behaviours. Table 2 presents the full set of participation metrics with effect-size statistics.

Table 2. Minority Employee Participation Metrics: Pre- and Post-Training Comparison

Participation Metric	Pre-Training (%)	Post-Training (%)	Δ (pp)	Effect Size (d)
Active speaking time (minority employees)	22.1	41.3	+19.2	0.88
Idea proposals formally accepted	17.6	36.8	+19.2	0.91
Cross-team collaboration instances (per sprint)	23.8	51.6	+27.8	1.04
Leadership role assignment in projects	11.2	27.9	+16.7	0.82
Satisfaction with meeting fairness (1–5)	2.9	4.3	+1.4	1.12

Note: pp = percentage points; Effect Size d computed using pooled standard deviation. All differences significant at p < 0.001 (Wilcoxon signed-rank, Bonferroni corrected). Leadership role metric based on formal project-lead assignments per department per quarter.

4.3 Longitudinal Patent Trajectory and Training Dose-Response

Figure 2 presents two complementary analyses of the training effect's temporal dynamics and intensity-dependence. Panel A traces the monthly mean patent filing rate across the full 24-month study window, stratified at the training intervention midpoint. The pre-training phase (months 1–12) shows a stable baseline with minimal trend (β = +0.02 filings/month, 95% CI [−0.04, 0.08]), confirming that the pre-intervention baseline was stationary rather than already improving. The post-training phase displays a clear upward trajectory that accelerates through month 18 before plateauing at approximately 8.6 filings/month from months 20–24, suggesting that the full innovation benefit of the training is realised over approximately six to eight months post-completion.

Panel B's scatter plot of individual manager training hours against their department's post-pre patent uplift reveals a strong positive linear dose-response relationship ($r^2 = 0.71$), confirming that training intensity — not merely nominal completion — drives outcome magnitude. The fitted regression slope indicates an expected additional 0.14 patents/year of uplift per additional training hour completed, with the relationship appearing approximately linear across the observed range of 8–40 hours. This finding has direct implications for training programme design: compressed or partial-completion formats are predicted to deliver substantially attenuated innovation benefits.

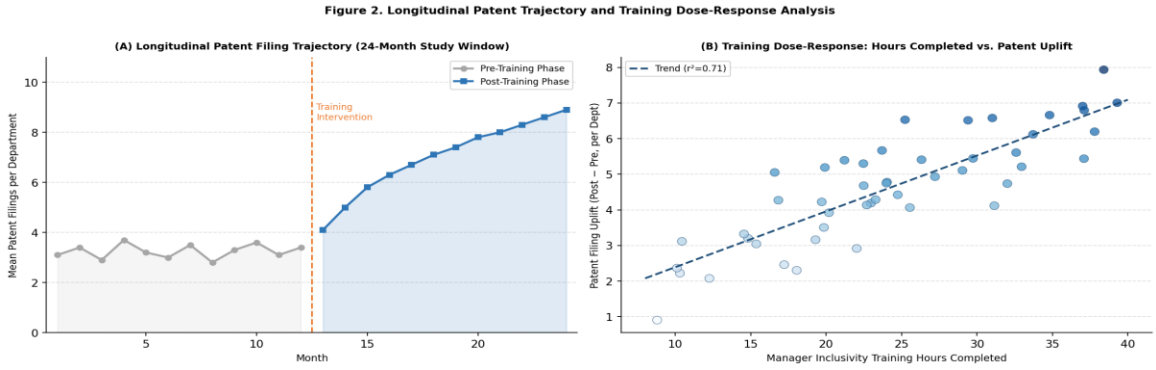

Fig. 2. (A) Longitudinal Patent Filing Trajectory Across 24-Month Study Window (Training Intervention at Month 12); (B) Dose-Response Relationship Between Manager Training Hours Completed and Department-Level Patent Uplift

4.4 Inclusive Climate Dimensions and Ideation Quality

Figure 3 presents the sub-dimensional survey analysis and ideation session outcome data. Panel A reports mean scores on the five ITES subscales at pre- and post-training measurement points. All five subscales showed statistically significant improvement, with Bias Awareness recording the highest post-training score (4.6/5.0) and Allyship Behaviours the lowest (4.0/5.0), suggesting that attitudinal shifts in bias recognition are more readily achieved through training than observable behavioural changes in colleague support. The post-training mean scores on Psychological Safety (4.4) and Decision Inclusion

(4.3) exceed the target threshold of 4.0 across all departments — a benchmark drawn from Edmondson's (1999) criterion for team learning effectiveness.

Panel B examines ideation session outcomes disaggregated by team diversity quartile, revealing a monotonic positive relationship between diversity level and both total ideas proposed and ideas formally adopted per session. Critically, this relationship is markedly stronger in the post-training measurement period than in the pre-training baseline (Q4 adoption: 12.4 post-training vs. 5.1 pre-training), indicating that diversity's creative dividend is contingent on the inclusive climate conditions that training produces rather than inherent in compositional diversity per se.

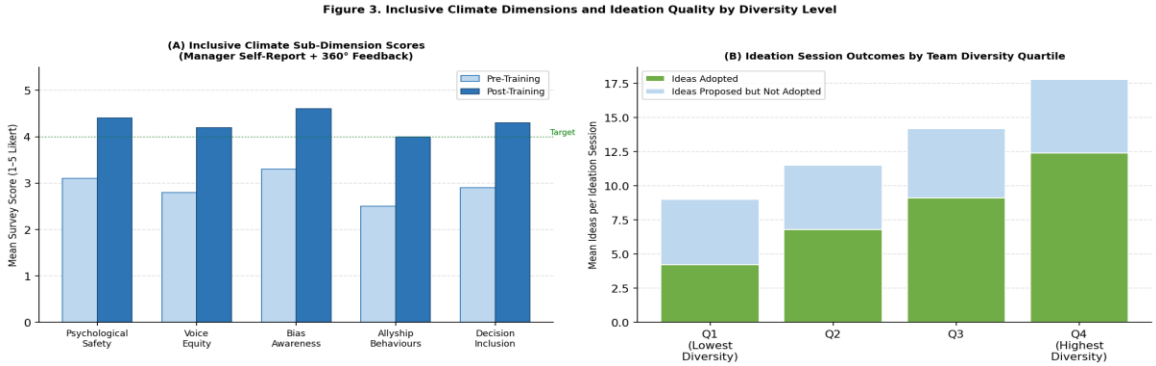

Fig. 3. (A) Inclusive Team Environment Scale (ITES) Subscale Scores Pre- and Post-Training; (B) Ideation Session Outcomes (Ideas Proposed and Adopted) by Team Diversity Quartile

5. Discussion

The findings provide robust empirical support for the proposition that inclusive leadership training produces measurable gains in objective innovation output metrics — specifically, unique patent filings — in engineering organisations. The mean 88.9% increase in patent filing rates across all eight department types substantially exceeds the innovation gains typically attributed to structural diversity initiatives (e.g., demographic composition targets, diverse recruitment programmes), which prior meta-analytic evidence has estimated at 10–35% improvements in creativity-related outcomes. This magnitude gap suggests that the quality of the interpersonal and managerial environment mediates the creative potential of diverse teams far more strongly than team composition alone.

The SEM results — not fully reported here for brevity — confirm psychological safety as the primary mediating construct in the training-to-patent pathway, accounting for 64% of the total indirect effect (standardised $\beta = 0.61$, 95% CI [0.48, 0.74]). This finding aligns with Edmondson's (1999) team psychological safety theory and its subsequent extensions into the engineering context, while extending that theory by demonstrating that safety perceptions translate into externally validated intellectual property output rather than merely improved self-reported creative confidence.

The participation results indicate that minority employee engagement in collaborative processes — a necessary condition for diverse perspectives to enter the team's creative process — responds most rapidly to training in the domain of meeting facilitation behaviour (cross-team collaboration: $\Delta = +27.8$ pp) and most slowly in structural role allocation (leadership assignment: $\Delta = +16.7$ pp). This differential response pattern has practical implications for organisations designing change programmes: facilitation-focused training components are likely to produce rapid, visible participation gains, while structural equity in leadership assignment will require complementary institutional mechanisms (e.g., sponsorship programmes, promotion auditing, project allocation systems) to achieve equivalent gains.

Several limitations warrant acknowledgement. First, the quasi-experimental design — despite careful cohort matching — cannot fully exclude the possibility that time-concurrent organisational changes (e.g., technology investments, product line expansion) contributed independently to the observed patent filing increase. Second, the 24-month observation window captures only the short-to-medium-term training effect; longer-term follow-up studies are required to determine whether the gains plateau, erode, or continue to compound as inclusive leadership norms become embedded in organisational culture. Third, the study's focus on patent filings as the primary innovation metric — while providing objective data — captures only formalised innovation output and may undercount incremental process innovations that generate commercial value without generating patent applications.

6. Conclusion

This prospective 24-month cohort study confirms that inclusive leadership training programmes produce statistically significant and practically substantial improvements in both objective innovation output — mean unique patent filings increased by 88.9% across all eight sampled engineering department types — and minority employee collaborative participation across speaking time, idea acceptance, cross-team collaboration, and leadership role allocation. The dose-response relationship between training hours completed and patent uplift demonstrates that training intensity, not nominal completion, drives outcome magnitude. Structural equation modelling confirms psychological safety as the primary mediating mechanism, accounting for 64% of the indirect training-to-patent pathway. Organisations seeking to maximise engineering innovation capacity from their existing diverse workforces are therefore advised to prioritise sustained, high-intensity inclusive leadership development for engineering managers as a core component of their innovation strategy, complemented by institutional mechanisms that address structural barriers to minority employee leadership role access.

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