

# The Role of Diversity in the Scientific and Engineering Workforce and Impacts on Innovation

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# Study Objectives

- Review the body of literature related to science, technology engineering, and mathematics (STEM) workforce diversity and innovation
- Improve understanding of the quantitative evidence of workforce diversity's impact on innovation
- Identify the direct and indirect linkages between workforce diversity and innovation as understood from a collection of empirical studies to date

# Definitions

## Adopted wide-ranging definitions of diversity and innovation

### Diversity

- Social: demographic characteristics (e.g., age, gender, and race/ethnicity)
- Informational: characteristics related to skills (functional background (in organizations or departments), education, tenure in teams and organizations, experience (across industries), collaboration networks, and disciplines)
- Value: differences in personalities, attitudes, and beliefs

### Innovation

- General concepts: products, processes, and services
- Task outcomes: productivity and quality measures common in organizations (e.g., return on investment, sales) and in STEM contexts (e.g., number of and citations to scientific publications)
- Team performance: conflict resolution and communication, among others, which may impact innovation

# Approach

- Literature search and relevance
  - Searched more than 600 search terms
  - Applied relevance criteria, including that studies performed statistical analyses
  - Identified 63 articles published from 1958 to 2015
- Collection of diversity variables and measures
  - Identified 15 distinct diversity variables studied in literature
  - Collected over 1,000 measures (effect sizes from statistical analyses)
  - Analyzed the direction (positive or negative) and if reported measures were statistically significant or not (95% confidence level, equivalent to  $p < 0.05$ )
- Analysis
  - Compiled measures based on frequency counts and statistical significance
  - Provided a qualitative description of findings

Diversity Attribute
General diversity (index of multiple diversity variables)
Social diversity (index of multiple variables)
Age
Gender
Race/Ethnicity
Informational diversity (index of multiple variables)
Education
Functional background
Tenure (organization)
Tenure (team)
Experience
Collaboration/Network
Discipline
Value diversity
Personality

# Major Findings of Diversity Impacts on Innovation

- Majority of the diversity variables showed no statistically significant impacts on innovation or findings were mixed
- Of 1,000+ measures, about 390 (38%) reported statistically significant measures, of which about 240 (62%) and 150 (38%) were significantly positive and negative, respectively
- Affirmed early scholars' evaluations
  - That the state of findings in the literature is inconsistent (Bell et al. 2011; Joshi and Roh 2009; Hulsheger, Anderson, and Salgado 2009; Stahl, Maznevski, Voigt, and Jonsen 2009)
  - From one meta-analysis that indicated the majority of past research found no significant effects (Joshi and Roh 2009)

# Illustrative Examples

- Watson, W.E. et al (1993) Cultural Diversity's Impact on Interaction Process and Performance: Comparing Homogeneous and Diverse Task Groups, *Academy of Management Journal*.
  - Studied racially homogeneous and diverse groups working in teams. Found that initially homogeneous groups scored higher on both process and performance effectiveness, and over time both groups showed improvement and differences converged. By the end of the study, there were no differences in processes or outcomes, and heterogeneous group scored higher on two performance measures – the range of perspectives and alternatives generated. This finding suggests that initially, diversity may be a hurdle as values and culture can be initial barriers, but after teams work together for a longer time, the benefits of diversity begin to emerge.
- Sastre. J.F. (2015) The Impact of R&D Teams' Gender Diversity on Innovation Outputs, *Int J Entrepreneurship and Small Business*
  - The aim of this research was to study how gender diversity within R&D teams, among other factors, impacts innovation, drawing on data from an innovation survey in Spain. Findings support the assertion that gender diversity within R&D teams generates certain dynamics that foster novel solutions leading to radical innovation. The results indicate that gender diversity is positively related to radical innovation. However it does not promote incremental innovation in the same way.

# Contextual Factors that Influence Diversity and Impacts

- Mixed findings partly explained by the positive or negative influence from contextual factors, such as
  - Organizational—describing variables an organization or institution
  - Team or task—describing dimensions related to the make-up of the team or characterizing the task
  - Experimental—describing attributes of the study and methodology
- Of the 63 studies, 24 (~40%) analyzed 80 different contextual variables, comprising, about one-third (319, 30%) of the measures
- Multiple contextual variables—task complexity, type of leadership, human resource practices, and industry, among others—changed the significance level and direction of the relationship when tested in statistical analysis
- Individual contextual variables have not been analyzed well or often across studies or organizational environments

# Considerations for Managing Workforce Diversity from STEM Studies

- Actual benefits may depend on the types and complexity of the problem, the anticipated solution, and whether problems require a team or individual effort
  - Important consideration in STEM fields given the high technical complexity of research
- Studies of high-tech companies indicated that the type of diversity can either be beneficial (for informational diversity) or harmful (for social diversity)
- Contextual factors that positively influenced impacts include
  - Presence of transformational leaders, engagement in open debate, and sparse collaboration network structures for social and informational diversity variables
  - Existence of long-term groups and teams with higher capability to combine experiential knowledge from diverse backgrounds

# Considerations for Managing Workforce Diversity from Non-STEM Studies

## *Influence of Values and Culture*

- Individual values and understanding are critical to positive functioning of diverse teams and developing improved outcomes
- Organizational cultures and human resource practices affect team members' beliefs, stereotypes, and prejudices
- In one study, education and feedback on how to effectively work in groups benefited group interactions over time and led to improvements in performance
- Recognition within an organization (e.g., from leadership) to communicate diversity's value and relevancy in the organization could facilitate improved outcomes

# Conclusion

- Studies fall short in clearly articulating the evidence for how diversity impacts processes critical to effective workgroups and outcomes, including psychological, motivational, and cognitive factors, such as bias
- Statistical studies have many limitations including small sample sizes or not controlling for other diversity attributes that can contribute to innovation
- Influence of contextual factors demonstrates the need to move beyond the broad dialogue about “diversity” and further understand impacts as related to sub-populations and combinations of individual, group, organizational, and cultural diversity characteristics
- There is a need for the research community to advance learning from prior studies and identify the pathways by which diversity can lead to impacts on innovation

# References

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# BACKUP SLIDES

# Approach: Literature Relevance

- Identified empirical studies published on workforce diversity and innovation prior to August 2015
  - Developed search terms combination of keywords related to STEM (e.g., “science,” “technology,” “engineer”), diversity (e.g., “race,” “ethnic,” “age,” “discipline,” “culture”), and innovation (e.g., “performance,” “impact,” “creativity”)
  - Queried more than 600 search term combinations in Scopus publication database
  - Identified the top 50 citing articles resulting from search term queries
- Applied criteria for relevance: the study (1) was quantitative with statistical analysis; (2) was not a “thought piece”; (3) was not theoretical; (4) was focused on diversity in teams and the workforce and not limited to STEM fields, occupations, and industries; and (5) included outcome variables related to innovation
- Identified 63 articles, including 6 meta-analyses, published from 1958 to 2015
- Literatures spanned many disciplines, mainly administration, business, and organizational management, but also psychology, behavioral science, and sociology; and top-tier journals, including *Academy of Management Journal*, *Journal of Organizational Behavior*, *Journal of Applied Psychology*, and *Research Policy*

# Approach: Collection of Diversity Variables and Measures

- Identified 15 distinct diversity variables studied in literature
- Collected over 1,000 measures (effect sizes from statistical analyses)
- Analyzed the direction (positive or negative) and if reported measures were statistically significant or not
- Statistically significant measures reported as significant at a 95% confidence level (equivalent to  $p < 0.05$ )

Diversity Attribute	Measures		Studies*	
	#	%	#	%
General diversity (index of multiple diversity variables)	33	3%	2	3%
Social diversity (index of multiple variables)	54	5%	8	13%
Age	97	9%	18	29%
Gender	203	20%	24	38%
Race/Ethnicity	206	20%	22	35%
Informational diversity (index of multiple variables)	41	4%	6	10%
Education	83	8%	15	24%
Functional background	119	11%	16	25%
Tenure (organization)	73	7%	11	17%
Tenure (team)	37	4%	8	13%
Experience	7	1%	1	2%
Collaboration/Network	34	3%	4	6%
Discipline	4	<1%	2	3%
Value diversity	23	2%	2	3%
Personality	24	2%	4	6%
Grand Total	1,038	100%	--	--

\* Does not represent unique studies since one study could analyze and report measures for one or more diversity attributes. Number of studies does not sum to 63, percentage of studies does not sum to 100%, and percentages of studies listed are based on 63 studies. |

# Approach: Analysis

- Compiled the measures based on frequency counts and statistical significance
- Compared measures for individual variables across multiple studies
- Identified influential contextual factors analyzed in studies
- Provided a qualitative description of findings
- Identified limitations of studies related to the findings
- Developed considerations for managing workforce diversity in STEM and non-STEM contexts

# Summary of STEM Relevant Findings and Caveats

- 25 articles (40 percent) related to STEM
- STEM studies analyzed some diversity variables not previously studied in non-STEM contexts (experiential, network, and disciplinary diversity)
- There were more measures and studies in non-STEM contexts
- No other notable differences across STEM and non-STEM findings
- In particular for STEM studies, some findings are based on a small number of reported measures (<10); thus, interpretation should be made with caution

# Limitations of Studies Reviewed

- Small sample sizes, particularly in meta-analyses that study many diversity and interaction variables, limited the reliability of the conclusions
- Relatively few studies control for other diversity attributes in teams, which may confound the results
- Self-reported assessments tended to have more positive impacts than those using more objective measures of performance and innovation, denoting that individuals may be exaggerating their performance
- Diverse groups may have lower performance expectations than homogenous groups, which could lead to misinterpretation of results if studies do not account for these differences
- Generalizability of non-STEM findings to STEM contexts was limited given the range of problems, industries, cultures, and locations among other dimensions that may influence innovation processes in STEM fields
- Studies showed that certain diversity variables exhibited a curvilinear rather than linear relationship, which could impact the validity of the findings

# Considerations for Managing Workforce Diversity from Non-STEM Studies

## *Dynamic Nature of Relationship*

- Diversity impacts on innovation are dynamic and can change depending on the duration that a team is working together
- Diverse teams at inception have a learning curve that must be overcome to improve communication and group efficiency, which can lead to improved performance
- As group members become more familiar with each other, the risk for conflicts based on social categorization differences diminishes as the value obtained from variation in experience is strengthened