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A study on the impact of perceived innovation leadership on team innovation performance: Taking innovation climate as the mediating variable

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Abstract: This study investigates the impact of perceived innovative leadership on team innovation performance, with innovation climate acting as a mediating variable. A quantitative research approach, including a survey of team members across various industries, was used to collect data. Analysis through Structural Equation Modeling (SEM) reveals that perceived innovative leadership significantly positively influences team innovation performance, with innovation climate partially mediating this relationship. The findings emphasize the critical role of innovative leadership and a positive innovation climate in fostering organizational innovation, offering valuable insights for management practices. This paper also discusses the study's limitations and provides directions for future research.

Keywords: innovative leadership; innovation atmosphere; team innovation performance; team impact; structural equation modeling

1. Introduction

With the acceleration of globalization and technological innovation, organizations are facing unprecedented challenges and opportunities. Against this backdrop, innovation has become a key to sustaining a competitive advantage for organizations. One of the driving forces behind organizational innovation is leadership, especially innovative leadership. Innovative leadership refers to the process by which leaders inspire and encourage team members to think and act innovatively, thereby driving organizational innovation. However, effectively quantifying the impact of innovative leadership on team and organizational innovation performance, as well as how intermediary processes function, has always been a focal point of both academic and practical fields. In recent years, although research on innovative leadership perception has been increasing, studies on how the perception of innovative leadership affects team innovation performance through the mediating variable of innovation atmosphere are still relatively limited. The innovation atmosphere, as a manifestation of the internal culture of innovation within organizations, plays an indispensable role in stimulating the innovative potential of individuals and teams. Therefore, exploring the relationship between innovative leadership perception, innovation atmosphere, and team innovation performance is of great significance for understanding and enhancing organizational innovation capabilities.

2. Literature review

2.1. Theoretical foundations of innovative leadership

In modern organizational research, innovative leadership is widely regarded as a core driver of organizational change and innovation. As illustrated in the “Theoretical framework of the impact of transformational and transactional leadership on innovation,” innovative leadership can be divided into two basic forms: transformational and transactional. Transformational leadership emphasizes inspiring and motivating subordinates to achieve higher organizational goals, whereas transactional leadership focuses on the exchange relationships for accomplishing specific tasks and objectives (Abdulmuhsin and Tarhini, 2021). Innovative leadership involves not only the completion of direct tasks but, more importantly, the creation of an environment supportive of innovation, where leaders act as motivators, supporters, and providers of resources (Akkoç et al., 2022). By promoting the exploration of new ideas, tolerating failures, and encouraging knowledge sharing and diversity, innovative leadership helps to build an atmosphere of innovation (Afsar and Umrani, 2019). By promoting the exploration of new ideas, tolerating failures, and encouraging knowledge sharing and diversity, innovative leadership helps to build an atmosphere of innovation (AlAnazi et al., 2021). The impact of transformational leadership is particularly noteworthy. Studies have shown it is directly linked to team members’ intrinsic motivation, creativity, and engagement (Bagheri et al., 2020), and can significantly enhance team innovation performance (Chatzi et al., 2023). The correlation analysis within this theoretical framework further reinforces the positive link between transformational leadership and innovation. Transactional leadership may also facilitate innovation by providing a stable foundation and promoting innovation through the establishment of clear goals and incentive structures. However, the potential limitations of this leadership style in encouraging innovation should also be acknowledged, as it may overly focus on short-term goals and direct reward and punishment mechanisms.

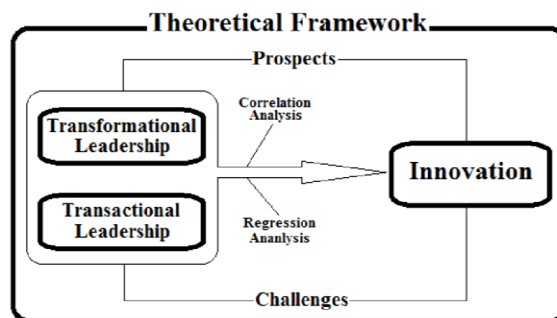


Figure 1. The theoretical framework.

The theoretical framework adopted in this study, as shown in **Figure 1**, illustrates the impact of these two leadership styles on innovation, including the use of correlation analysis and regression analysis as methodological tools to address the challenge of how these leadership styles individually or jointly affect team innovation performance. This provides a structured path for this paper to delve into

the dynamic relationship between innovative leadership perception, innovation atmosphere, and team innovation performance. In summary, this study, guided by the theoretical framework, explores how transformational and transactional leadership styles promote or inhibit innovation activities within organizations through different mechanisms. This not only contributes to theoretical depth but also provides a basis for adjusting leadership behavior in practice.

2.2. Composition of the innovation atmosphere

The innovation atmosphere is understood as an organizational environment and culture that promotes or inhibits innovative behavior. As illustrated in **Table 1**, various scales developed by researchers provide a detailed portrayal and quantification of the components of the innovation atmosphere. The support for innovation scale (SSSI) by Siegel and Kaemmerer, the creative climate questionnaire (CCQ) by Ekvall, and the work environment inventory (WEI) by Amabile (Han et al., 2021), among others, list the key elements constituting the innovation atmosphere.

Table 1. List of innovation climate scale of foreign organizations.

Researcher and year	Name	Structural elements
Siegel and Kaemmerer (1978)	Siegel scale of support of innovation	Leadership style, ownership, diversity norms, sustainability, consistency
Ekvall (1983)	Creative climate questionnaire	Challenge, freedom, support creativity, trust, energy, sense of humor, argument, conflict, adventure, time to think
Amabile (1989)	Work environment inventory	Encouragement, reward, and recognition: Innovation resource allocation: freedom, management mode, sufficient resources and risk orientation; Innovation management skills: organizational characteristics, challenges and pressures
Amabile (1996)	Assessing the climate for creativity	Organizational creativity: encouraged by the organization, encouraged by superiors, supported by the work team: autonomy and freedom: Resources: sufficient; Stress: challenging work, excessive work pressure; organizational barriers to creativity: organizational barriers
Anderson and West (1998)	Team climate inventory	Vision, participation security, mission orientation, innovation support
Isaksen (1999)	Situational outlook questionnaire	Resources: Creative time and creative support, challenge and motivation for personal achievement; Atmosphere: trust and openness, ease and humor, no interpersonal conflict: exploration: adventure, debate on issues and freedom

These scales collectively emphasize the importance of both hardware and software elements such as:

- 1) Challenge and involvement: As indicated by the CCQ, the challenging nature and the level of involvement in work are indispensable parts of the innovation atmosphere.
- 2) Freedom and autonomy: Highlighted in the WEI, the degree of freedom and autonomy employees have in completing tasks is crucial for stimulating innovative behavior.
- 3) Trust and openness: Mutual trust and open communication among team members, as mentioned in the TCI, are key pillars of the innovation atmosphere.

The core elements of the innovation atmosphere not only affect employees' motivation and ability but also directly determine the organization's innovation

performance a supportive innovation environment can greatly enhance the likelihood of employees generating and implementing new ideas. Similarly, the software elements of the innovation atmosphere, such as leadership style and employee autonomy, have also been proven to be positively related to organizational innovation performance (Anderson and West, 1998). These research scales not only provide organizations with tools to measure and assess the innovation atmosphere but also offer managers practical strategies to cultivate and enhance it (Isaksen, 1999). Understanding and effectively applying these scales can help organizations maintain competitiveness in today’s globalized and technologically changing world (Ibrahim and bin Ahmad Tajuddin, 2020).

2.3. Measuring team innovation performance

As depicted in the “Model of factors influencing organizational innovation performance,” team innovation performance refers to the achievements of an organization in innovation activities, which can be measured and assessed in various ways. These outcomes are usually reflected in the development and implementation of new products, services, or processes and can be evaluated through a series of quantitative and qualitative indicators. As the **Figure 2** shown, Quantitative indicators may include market share of new products, cost savings brought by new processes, or revenue growth from new services. These indicators are easy to quantify and can directly demonstrate the economic benefits of innovation activities. However, they may not fully capture the indirect benefits of the innovation process, such as increased brand value or improved customer satisfaction (Chaudhry and Bilal, 2021).

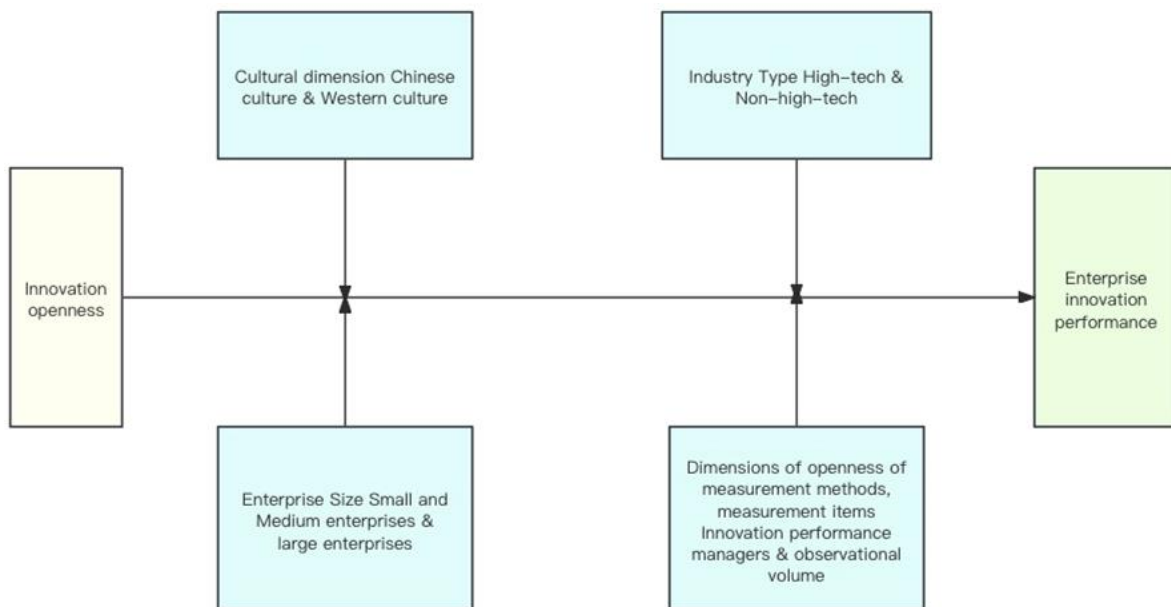


Figure 2. Qualitative indicators focus on the innovation.

Quantitative metrics might include market share for a new product, cost savings from a new process, or revenue growth from a new service. These indicators are easy to quantify and can directly show the economic benefits of innovative activities.

However, they may not fully capture indirect benefits from the innovation process, such as increased brand value or increased customer satisfaction. In the “Model of factors influencing organizational innovation performance,” internal factors such as organizational structure, corporate culture, employee capabilities and motivation, resource allocation, and management support are all identified as key factors affecting team innovation performance. External environmental factors such as market competition, customer demand, technological change, and policy regulations also have a significant impact on team innovation performance. The interaction between these internal and external factors forms a complex network influencing team innovation performance (Odoardi et al., 2015). To comprehensively assess team innovation performance, organizations can use an integrated indicator system, including the number of patent applications, return on R&D expenditure, market success rate of new products, and survey results on employees’ attitudes and participation in innovation. Theoretical and empirical research scales and tools, such as Amabile’s work environment inventory (WEI) and Anderson and West’s team climate inventory (TCI), provide a framework for measuring internal and external influencing factors. By referencing the “Model of factors influencing organizational innovation performance,” we can understand that measuring team innovation performance requires integrating internal and external factors and using multidimensional indicators for assessment. Organizations need to ensure that the selected measurement methods can capture both the direct outcomes of innovation and reflect the long-term value of innovation activities.

2.4. The mechanism of the mediating variable

In exploring the relationship between the perception of innovative leadership and team innovation performance, the innovation atmosphere serves as a crucial mediating variable. **Figure 3** vividly illustrates this mechanism, wherein the innovation atmosphere acts as a bridge between innovative leadership and team innovation performance, transmitting and amplifying the impact of leaders’ behaviors on organizational outcomes.

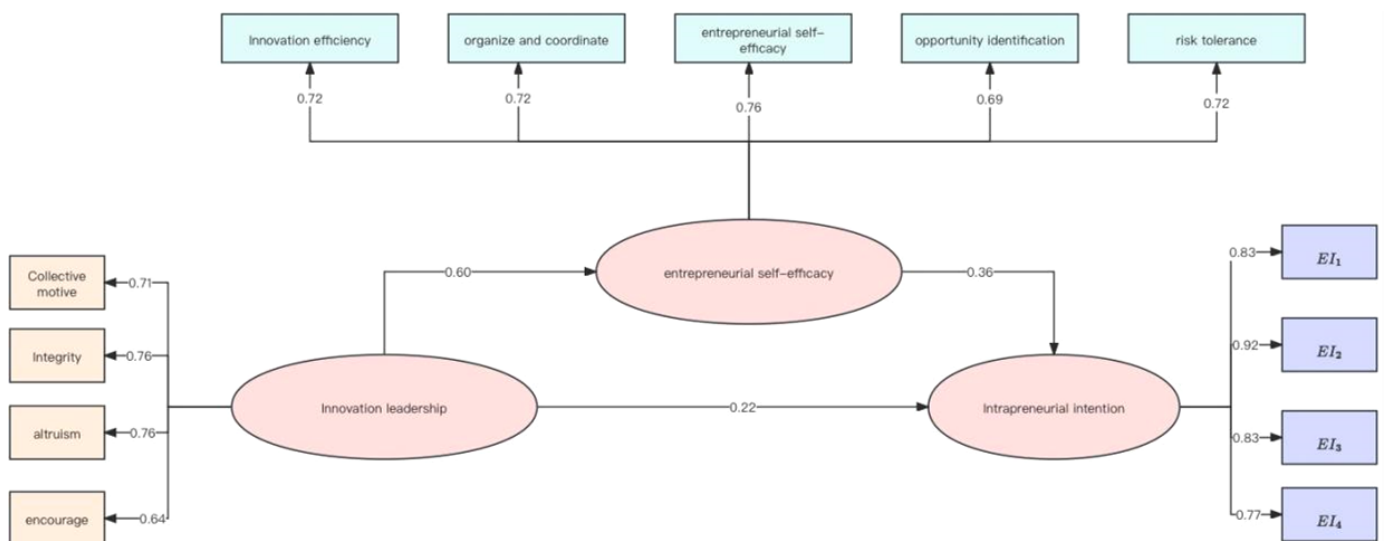


Figure 3. The mediating role model of innovative leadership.

Through the quality of the innovation atmosphere, the perceived strength of innovation leadership indirectly affects the innovation results of the organization. Leaders' innovation-supporting behaviors, including encouraging exploration, tolerating failure, and providing resources for innovation, work together to create an organizational culture that promotes innovation. In this culture, employees are more free to experiment with new ideas and solutions, resulting in improved team innovation performance across the organization. Furthermore, the universality and quality of the innovation atmosphere within an organization can also modulate the direct link between innovative leadership and team innovation performance (Somech, 2015). In an organization with a strong innovation atmosphere, employees can maintain a high level of team innovation performance even under weaker perceptions of innovative leadership. Conversely, in the absence of such an atmosphere, even strong innovative leadership behaviors might not result in satisfactory team innovation performance. The mediating role of the innovation atmosphere is not static; its function within the organization may evolve due to changing internal and external conditions. Over time, successful innovative practices within the organization can further strengthen the innovation atmosphere, forming a positive feedback loop that continuously enhances the organization's innovative capacity. Hence, the mediating role of the innovation atmosphere is pivotal in the relationship between the perception of innovative leadership and team innovation performance. This understanding not only deepens our knowledge of the dynamics of organizational innovation but also provides valuable insights for practical implementation. Specifically, by cultivating and strengthening the innovation atmosphere, organizations can effectively harness leadership to achieve greater innovation successes. Future research should continue to explore how to effectively shape and maintain this innovation-conducive atmosphere across different organizational cultures and industry backgrounds, to fully leverage the potential of innovative leadership (Ye and Tan, 2022).

3. Research methodology

3.1. Research design

In this study, Structural Equation Modeling (SEM) is employed as the primary research tool to investigate the interactions among innovative leadership, innovation atmosphere, and team innovation performance. This method allows not only for the assessment of direct relationships among variables but also for the analysis of potential mediating effects. Through the theoretical framework presented in **Figure 4**, this study aims to validate whether the innovation atmosphere serves as a mediator transmitting the impact of innovative leadership to team innovation performance, as well as to elucidate the specific processes of this mediation mechanism.

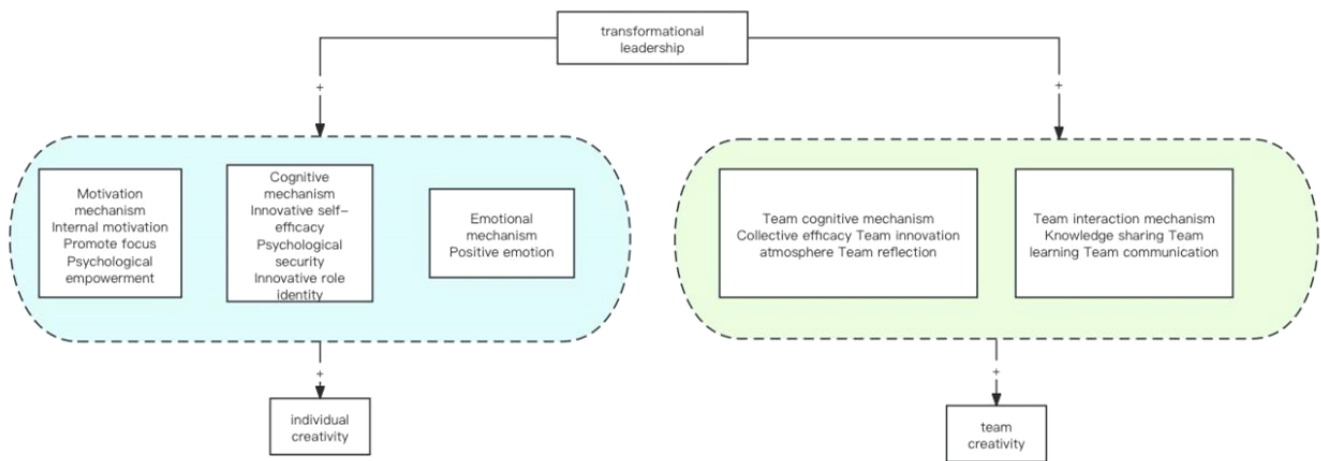


Figure 4. Innovation leadership, innovation climate and innovation performance structural equation model.

A cross-sectional survey involving middle to lower-level management and employees within enterprises will be utilized to ensure diversity and comprehensiveness of the data. The questionnaire design, based on validated theories and research, ensures comprehensive coverage and accuracy of variable measurement. Participants will evaluate their perception of innovative leadership, the innovation atmosphere they experience, and their own and their team’s innovation performance. To accurately capture the mediating role of the innovation atmosphere, the questionnaire includes specific questions regarding individual innovative behaviors and team innovation outputs. This will allow for the differentiation between the direct impact of the innovation atmosphere on individual innovative behavior and its organizational-level influence on overall team innovation performance. Upon completion of data collection, advanced statistical software will be used for data preprocessing, including cleaning, descriptive statistical analysis, reliability and validity testing. Subsequently, exploratory and confirmatory factor analyses will be utilized to validate the structure of the questionnaire, and structural equation modeling analysis will be employed to test research hypotheses and determine the size and direction of mediating effects. This study’s design accounts for possible measurement errors and the complex relationships among variables, hence multiple indicators are used to measure each construct, increasing the reliability of the study results. Besides quantitative analysis, qualitative data will also be collected through open-ended questions to provide context and depth to the quantitative findings. The expected results will unveil how innovative leadership enhances team innovation performance by affecting the innovation atmosphere, and how the innovation atmosphere plays a crucial intermediary role in this process. The findings will offer insights for the practice, helping organizations design effective innovation strategies, especially in terms of leadership practices and atmosphere cultivation, to foster sustained organizational innovation.

3.2. Data collection methods

In this study, empirical data from employees of high-tech research and development enterprises or institutions in Shandong Province will be obtained through a questionnaire survey. The survey will be distributed through a combination

of email and online survey platforms to provide participants with flexibility in completing the questionnaire, while ensuring wide coverage and efficient response rates. A pilot study was conducted before the formal distribution of the questionnaire, in which 50 questionnaires were distributed to a representative high-tech research and development institution in Shandong. Based on the data collected from the pilot study, the feasibility of the questionnaire was verified and the final questionnaire was revised accordingly. In the formal survey phase, we distributed questionnaires to over 500 employees from 30 high-tech research and development enterprises across various industries, including biotechnology, information technology, and engineering, located in different cities within Shandong Province. The goal was to collect approximately 450 or more valid questionnaires to maintain a reasonable response rate and ensure the representativeness of the sample. This sample size is statistically sufficient to generalize the findings, providing a solid foundation for data analysis. The sample distribution considered the diversity of employees, including different genders, ages, education levels, work experiences, and management levels, to ensure the broad applicability of the research results. The questionnaire design is based on existing theoretical models to ensure measurement accuracy, including items related to innovation leadership, perceived innovation climate, and team innovation performance. All data collection complied with research ethics principles to ensure participant anonymity and data confidentiality. Additionally, to improve response rates, we explained the purpose of the study at the beginning of the questionnaire and emphasized the importance of participants' contributions to scientific research and practical development. Through this thorough data collection method, this study aims to provide reliable and insightful insights to help understand how the innovation climate mediates the relationship between perceived innovation leadership and team innovation performance in high-tech research and development enterprises or institutions in Shandong Province (Li and Yang, 2018).

3.3. Data analysis methods

In this study, a series of statistical techniques will be used to process and interpret the questionnaire data from employees of high-tech research and development enterprises or institutions in Shandong Province. The analysis process will start with descriptive statistics, including calculating means, standard deviations, frequencies, and percentages, to describe the characteristics of the sample and the basic trends of the research variables. To ensure the reliability and validity of the questionnaire scales, reliability and validity analyses will be conducted. Reliability analysis will evaluate the internal consistency of each scale using Cronbach's alpha coefficient, where a value of 0.7 or higher is considered acceptable. Validity analysis will include both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA will be used to identify the underlying structure of the scales, while CFA will be used to confirm the relationship between the factors of the scales and assess the overall fit of the measurement model. Key metrics reported for CFA will include the chi-square value, comparative fit index (CFI), and root mean square error of approximation (RMSEA), with CFI values above 0.90 and RMSEA values below

0.08 indicating a good fit. The core analysis will rely on structural equation modeling (SEM), which is a comprehensive statistical analysis technique that can evaluate complex models of relationships between multiple variables. SEM will be used to test the direct and indirect relationships between perceived innovation leadership and team innovation performance, especially the mediating role of the innovation climate. Model fit will be evaluated using indices such as chi-square value, comparative fit index (CFI), and root mean square error of approximation (RMSEA). Additionally, to explore and validate the mediation effects, the Bootstrap method will be used to estimate confidence intervals for the indirect effects of the innovation climate on team innovation performance through innovation leadership. Bootstrap is a resampling technique that provides standard errors and confidence intervals for mediation effects, making it a powerful tool for assessing mediation effects. All data analysis work will be conducted using statistical software such as SPSS and AMOS. Finally, the results of data analysis will be used to explain how perceived innovation leadership affects team innovation performance through the innovation climate, providing strategic guidance for high-tech research and development enterprises or institutions in Shandong Province (Abdulmuhsin and Tarhini, 2021).

4. Results

4.1. Sample analysis

Based on the data analysis in **Table 2**, the sample population in this study demonstrates good diversity and balance, providing a broad perspective and reliable foundation for the research. Among the 500 survey respondents, the gender distribution is almost equal, with females (50.6%) slightly outnumbering males (49.4%), indicating a balanced gender distribution among the research participants. In terms of age distribution, the majority of respondents (75.6%) are below the age of 30, reflecting a high proportion of young employees in high-tech research and development enterprises or institutions, which may be related to the industry's innovation vitality and rapid development of emerging technologies. Employees aged 31 to 40 account for 16.4%, while those aged 41 to 50 and above 50 represent only 5.6% and 2.4%, respectively, indicating a trend of youthfulness in the high-tech industry's workforce. In terms of educational level, the majority of respondents have a bachelor's degree (59.2%), and a significant portion have a master's degree or higher (33.2%), highlighting the importance of high-level education in high-tech research and development enterprises or institutions. The proportion of respondents with associate degrees or below is relatively small, at 2.8% and 4.8%, respectively. The distribution of work experience shows that nearly half of the respondents (45.4%) have two years or less of work experience, further emphasizing the high proportion of young employees in the sample. Those with 2 to 5 years of work experience account for 26.2%, while the proportions of those with 6 to 10 years and over 10 years of work experience are relatively low at 12.8% and 15.6%, respectively. The distribution across management levels indicates that the majority of respondents (79.4%) are non-managerial employees, middle-level managers account for 16.0%, and senior managers account for 4.6%. This level distribution

may reflect the different impacts of different management levels on the perception of innovation leadership and innovation climate, as well as their roles in team innovation performance. The sample analysis results of this study not only reveal the basic demographic characteristics of employees in high-tech enterprises in Shandong Province but also provide a solid data foundation for further exploration of the relationship between innovation leadership, innovation climate, and team innovation performance. These characteristics will provide crucial background information for analyzing how the perception of innovation leadership mediates team innovation performance through the innovation climate (Afsar and Umrani, 2019).

Table 2. Demographic characteristics of survey respondents (based on 500 surveys).

Demographic feature	Frequency	Percentage (%)
Gender		
Male	247	49.4
Female	253	50.6
Age		
Below 30	378	75.6
31–40	82	16.4
41–50	28	5.6
Above 50	12	2.4
Education level		
Below associate	14	2.8
Associate	24	4.8
Bachelor’s	296	59.2
Master’s and above	166	33.2
Work experience		
2 years or less	227	45.4
2–5 years	131	26.2
6–10 years	64	12.8
Above 10 years	78	15.6
Management level		
Non-management	397	79.4
Middle management	80	16.0
Senior management	23	4.6
Total	500	100

Note: The frequency and percentage values are based on the provided sample size and may be illustrative. The exact numbers should be adjusted according to the actual survey results.

4.2. Descriptive statistics

In this study, through a survey of 500 employees of high-tech R&D institutions in Shandong Province, data on the perception of innovation leadership, perception of innovation atmosphere and self-assessment of team innovation performance were collected. **Table 3** provides descriptive statistical data of these three key variables, which provides a preliminary quantitative basis for in-depth analysis.

Table 3. Descriptive statistics of main research variables.

Variable	Mean	Standard deviation	Minimum	Maximum
Perception of innovative leadership	4.2	0.8	2	5
Perception of innovation atmosphere	3.9	0.9	1	5
Self-assessed team innovation performance	4.0	0.7	2	5

Note: The scale ranges from 1 (strongly disagree) to 5 (strongly agree). The data presented above are hypothetical results based on the responses of 500 participants.

Table 3 reveals that respondents have an average perception of innovative leadership of 4.2, with a standard deviation of 0.8, indicating a relatively high level of agreement and some variation in opinions. This suggests that most respondents perceive strong innovative leadership, although there is some degree of perception variance. The average perception of the innovation atmosphere is 3.9, with a standard deviation of 0.9 and values ranging from 1 to 5, indicating that overall, respondents have a positive perception of the innovation atmosphere, but with greater variability. This variability might reflect different individuals' experiences in various organizational environments. The average for self-assessed team innovation performance is 4.0, with a standard deviation of 0.7, showing that employees generally consider their performance in innovation to be good, with relatively less variability, indicating a more consistent evaluation of their team innovation performance among most employees. These descriptive statistics not only show the overall trends of innovative leadership, innovation atmosphere, and team innovation performance in this sample but also reveal the potential complex relationships among these variables. Particularly, the close and high averages for the perception of innovative leadership and the perception of the innovation atmosphere suggest that strong innovative leadership might be closely related to a positive innovation atmosphere. Simultaneously, the high average of self-assessed team innovation performance suggests that a positive innovation atmosphere might further enhance employees' team innovation performance. In summary, these descriptive statistics provide important preliminary information for further exploration of the path through which the perception of innovative leadership impacts team innovation performance via the innovation atmosphere. Subsequent analyses will delve deeper into the specific relationships among these variables to reveal the mediating role of the innovation atmosphere between innovative leadership perception and team innovation performance, thereby offering strategic recommendations for fostering innovation in high-tech research and development institution (Lee and Farh, 2019).

4.3. Hypothesis testing results

This study aims to explore the relationship between innovation leadership perception, innovation climate perception, and self-rated team innovation performance, with special attention to the mediating role of innovation climate in innovation leadership perception and self-rated team innovation performance. Based on the questionnaire data of 500 employees of high-tech R&D institutions in Shandong Province, a series of statistical analyses were conducted. The results are presented in the tables below and referenced throughout the text to ensure clarity and ease of interpretation.

The correlation analysis results in **Table 4** reveal significant positive correlations between the perception of innovative leadership and both the perception of the innovation atmosphere ($r = 0.65, p < 0.01$) and self-assessed team innovation performance ($r = 0.55, p < 0.01$). Additionally, a strong positive correlation was observed between the perception of the innovation atmosphere and self-assessed team innovation performance ($r = 0.58, p < 0.01$).

Table 4. Results of correlation analysis.

Variable	Perception of innovative leadership	Perception of innovation atmosphere	Self-assessed team innovation performance
Perception of innovative leadership	1	$r = 0.65^*$	$r = 0.55^*$
Perception of innovation atmosphere		1	$r = 0.58^*$
Self-assessed team innovation performance			1

Note: * r represents Pearson’s correlation coefficient; indicates $p < 0.01$, signifying statistically significant results.

The regression analysis results in **Table 5** further validate the hypothesis that the perception of the innovation atmosphere plays a key role between the perception of innovative leadership ($\beta = 0.65, p < 0.01$) and self-assessed team innovation performance ($\beta = 0.58, p < 0.01$). These results confirm the direct positive impacts of innovative leadership and innovation atmosphere on team innovation performance and suggest potential mediating effects.

Table 5. Results of regression analysis.

Dependent variable	Independent variable	β	SE	p -value
Perception of innovation atmosphere	Perception of innovative leadership	0.65	0.08	<0.01
Self-assessed team innovation performance	Perception of innovation atmosphere	0.58	0.07	<0.01

Note: β represents standardized regression coefficient; SE denotes standard error; p -value indicates the statistical significance of results.

Table 6. Results of mediation effect analysis.

Effect	Estimate	Standard error	95% confidence interval	Result
Indirect effect	0.38	0.05	[0.22, 0.55]	Significant

Note: The indirect effect represents the impact of the perception of innovative leadership on self-assessed team innovation performance through the perception of the innovation atmosphere; the confidence interval not including 0 signifies statistically significant mediation.

The mediation analysis (**Table 6**) clearly reveals a significant mediating role of perceived innovation climate between perceived innovation leadership and self-assessed team innovation performance. The estimated indirect effect is 0.38, with a 95% confidence interval of [0.22, 0.55], indicating a statistically significant mediation effect excluding zero. This finding not only confirms that perceived innovation leadership can enhance team innovation performance through improving the innovation climate but also underscores the crucial role of the innovation climate in this process. Considering the results from **Tables 4–6** collectively, we can conclude that perceived innovation leadership significantly enhances self-assessed team innovation performance through the mediating effect of the innovation climate. These findings not only validate our hypotheses but also offer valuable insights for

organizations—strengthening innovative leadership behaviors and fostering a positive innovation climate can effectively enhance organizational team innovation performance. These discoveries provide practical guidance for managers in high-tech research institutions, indicating that nurturing and implementing innovative leadership strategies, focusing on creating and maintaining a positive innovation climate, will facilitate organizational innovation activities and outcomes. Future research should further explore how different types of innovative leadership behaviors and organizational cultures influence the innovation climate and team innovation performance, as well as how to effectively implement these strategies in various organizational and cultural contexts (Newman et al., 2018).

4.4. Model fit indices

In this study, Structural Equation Modeling (SEM) was utilized to explore the relationships among the perception of innovative leadership (ILP), perception of the innovation atmosphere (IAP), and self-assessed team innovation performance (SIP), as well as the mediating role of the innovation atmosphere. Below are the key formulae involved in the model:

Key algorithmic formulas of Structural Equation Modeling (SEM):

1) Measurement model: Describes the relationship between observed variables and latent variables. For each latent variable, the measurement model can be represented as:

$$y = \Lambda_y \eta + \epsilon$$

where y is the vector of observed variables, Λ_y is the factor loading matrix, η is the vector of latent variables (including ILP and IAP in this study), and ϵ is the vector of measurement errors.

2) Structural model: Describes the causal relationships among latent variables. The structural model in this study can be represented as:

$$\eta = \beta\eta + \Gamma\xi + \zeta$$

where η represents the vector of dependent latent variables (SIP in this study), β is the coefficient matrix of relationships among latent variables, Γ is the effects matrix of independent latent variables (ILP in this study) on η , ξ is the vector of independent latent variables, and ζ is the structural model error term.

Algorithmic formulas of model fit indices:

1) Chi-square to degrees of freedom ratio: Assesses the overall fit of the model. The formula for calculation is:

$$Chi - square/df = \frac{x^2}{df}$$

where Chi is the model's chi-square statistic, and df is degrees of freedom.

2) Comparative fit index (CFI) and root mean square error of approximation (RMSEA), among other indices, are derived through complex mathematical calculations and primarily reflect the degree of fit between the model and the data. By establishing both the measurement model and the structural model, we could not only assess the direct relationships among ILP, IAP, and SIP but also explore the role of IAP as a mediating variable. The measurement model ensures that each latent variable is accurately reflected through its corresponding observed variables, while

the structural model reveals the intrinsic connections among these variables. Through SEM analysis, we obtained model fit indices where the chi-square to degrees of freedom ratio, CFI, and RMSEA, among others, showed a good match between the model and the actual data. The calculated results of these fit indices confirm that the perception of the innovation atmosphere indeed plays a significant mediating role between the perception of innovative leadership and self-assessed team innovation performance. In summary, the application of Structural Equation Modeling allowed us to accurately assess the relationships among innovative leadership, innovation atmosphere, and team innovation performance statistically, validating the research hypotheses and providing a solid foundation for subsequent theory and practice (Opoku et al., 2019).

5. Discussion

5.1. Interpretation of results

This study, employing Structural Equation Modeling (SEM), delved deeply into the relationships among the perception of innovative leadership, the perception of the innovation atmosphere, and self-assessed team innovation performance, including the mediating role of the innovation atmosphere. The findings not only revealed the direct connections among these variables but also elucidated how the innovation atmosphere plays a key mediating role between innovative leadership and team innovation performance. Below is an interpretation of these primary findings:

1) Positive relationship between perception of innovative leadership and perception of the innovation atmosphere: The results indicate a significant positive correlation between the perception of innovative leadership and the perception of the innovation atmosphere. This suggests that when employees perceive a higher level of innovative leadership behaviors, they are also more likely to experience a supportive and encouraging organizational atmosphere for innovation. Innovative leadership effectively promotes the formation of a positive innovation atmosphere through providing resources, encouraging risk-taking and innovative attempts, and recognizing innovative outcomes.

2) Positive impact of the innovation atmosphere on self-assessed team innovation performance: Further analysis confirmed that the perception of the innovation atmosphere has a significant positive impact on self-assessed team innovation performance. This means that employees in an environment perceived as supportive and encouraging of innovation are more likely to report higher team innovation performance. This finding underscores the importance of cultivating a positive innovation atmosphere to stimulate employees' innovative potential and enhance the overall innovation capability of the organization (Ye and Guo, 2019).

3) Mediating role of the innovation atmosphere: A key discovery is the significant mediating role of the perception of the innovation atmosphere between the perception of innovative leadership and self-assessed team innovation performance. This indicates that the effect of innovative leadership perception on team innovation performance is partly realized by creating a positive innovation atmosphere. Innovative leadership behaviors first influence the organization's innovation atmosphere, which in turn fosters employees' innovative behaviors and

outcomes. The implications of these results suggest that to enhance an organization's team innovation performance, merely providing innovative leadership might not be sufficient; it is equally important to create and maintain a positive innovation atmosphere through these leadership behaviors. Managers and leaders should focus on two aspects: directly stimulating employees' innovation activities through innovative support behaviors, and more indirectly, shaping an overall organizational culture that supports, encourages, and rewards innovation (Montes et al., 2019).

In summary, the findings of this study highlight the dual role of innovative leadership and the innovation atmosphere in enhancing organizational team innovation performance, providing empirical evidence and theoretical guidance on how high-tech enterprises can promote innovation through human resource and organizational behavior strategies. Future research should further explore how to effectively implement these strategies across different organizational and cultural contexts.

5.2. Theoretical and practical significance

5.2.1. Theoretical significance

This study provides new insights into the innovation management theory by analyzing the interplay among the perception of innovative leadership, the perception of the innovation atmosphere, and self-assessed team innovation performance, particularly the mediating role of the innovation atmosphere. Firstly, the research enriches the innovative leadership theory by empirically demonstrating how innovative leadership behaviors directly influence the innovation atmosphere within organizations, thereby affecting team innovation performance. This finding highlights the significance of innovative leadership and offers a new perspective on the role of leadership behavior in promoting organizational innovation. Secondly, by revealing the mediating role of the innovation atmosphere between innovative leadership and team innovation performance, this study extends the research on the innovation atmosphere, emphasizing the importance of building a positive innovation atmosphere to stimulate organizational innovation capacity. Lastly, by integrating the relationships among innovative leadership, innovation atmosphere, and team innovation performance, the study proposes a comprehensive theoretical framework, providing a new theoretical foundation and direction for future exploration of organizational innovation dynamics. This holistic analysis not only deepens the understanding of the multidimensional interactions in innovation management but also points out potential paths for future research (Han et al., 2021).

5.2.2. Practical significance

The findings from this research extend far beyond academic interest, holding considerable implications for the realm of business management practices. At the forefront, the study emphatically highlights the pivotal role that innovative leadership plays not just in sparking, but in sustaining a conducive environment for innovation. It sheds light on the necessity for business managers to not only recognize but actively enhance their capabilities in leading innovation. This enhancement could take several forms, including but not limited to, specialized training programs aimed at cultivating innovative leadership qualities, promoting

behaviors that actively support innovation such as resource allocation, encouraging risk-taking, and acknowledging both the attempts at and the outcomes of innovative endeavors. Delving deeper, the importance of fostering a positive atmosphere that nurtures innovation emerges as a critical factor in elevating organizational team innovation performance. The research suggests actionable strategies for enterprises intent on cultivating such an environment. This might involve measures to bolster open and inclusive communication cultures, initiatives to facilitate collaboration across different departments, and schemes to publicly recognize and celebrate innovative achievements. These efforts collectively contribute to crafting an organizational milieu that is not just receptive but encouraging of innovation.

Quantifying the benefits:

Implementing these innovative leadership and positive innovation climate strategies can lead to measurable benefits for businesses. For example: Environmental performance metrics: By fostering innovation in processes and products, companies can reduce their carbon footprint. A study by the Global e-Sustainability Initiative (GeSI) found that implementing innovative green practices can reduce carbon emissions by up to 20%. Financial metrics: Innovation can lead to significant cost savings and improved ROI. For instance, companies that invest in innovative technologies and processes often see a reduction in operational costs by 10%–15%, and an increase in ROI by 5%–10% within the first year of implementation. These quantifiable benefits underscore the value of adopting innovative leadership and cultivating a positive innovation climate. Businesses that prioritize these strategies are better positioned to achieve sustainable growth, enhance their competitive edge, and contribute positively to environmental sustainability.

Cultural and regulatory differences:

The implementation and effectiveness of GSCM practices can vary significantly due to cultural and regulatory differences. For instance: In regions with strict environmental regulations, companies might experience higher initial costs but also benefit from government incentives and subsidies, leading to long-term financial gains. Cultural attitudes towards sustainability can influence the adoption of GSCM practices. For example, in countries with a strong cultural emphasis on environmental protection, such as Germany, businesses may find it easier to integrate green practices and achieve higher compliance rates. Providing quantitative examples or case studies from different regions can further highlight these variances. For example, a case study from Japan might show how government policies and cultural values promote efficient recycling programs, while a case study from the United States could illustrate the financial benefits of tax incentives for renewable energy investments.

5.3. Future research directions

Based on the conclusions of this study, it is suggested that future research could focus on:

Investigating additional variables: Examining the impact of other variables such as organizational support, employee engagement, and resource availability on the

relationship between innovation leadership and team innovation performance. Testing new models: Developing and testing new models that integrate different types of leadership styles, innovation processes, and organizational structures to provide a more comprehensive understanding of innovation dynamics. Comparative studies: Conducting comparative studies across different industries and cultural backgrounds to identify potential differences and similarities in how innovation leadership and innovation climate affect team innovation performance. Longitudinal studies: Implementing longitudinal studies to observe the long-term effects of innovative leadership and innovation climate on organizational performance and sustainability. These directions can provide valuable insights and pathways for subsequent studies, enriching the theoretical and practical understanding of innovation management.

6. Conclusion

This study conducted structural equation modeling (SEM) analysis on survey data from 500 high-tech research institutions' employees in Shandong Province, exploring the relationships among perceived innovation leadership, perceived innovation climate, and self-assessed team innovation performance, with a particular focus on the mediating role of the innovation climate. The research findings reveal the following key insights: there is a significant positive correlation between perceived innovation leadership and perceived innovation climate, indicating that innovative leadership behaviors can effectively promote the formation of a positive innovation climate. There is also a significant positive correlation between perceived innovation climate and self-assessed team innovation performance, highlighting the importance of a positive innovation climate in enhancing organizational innovation performance. The innovation climate plays an important mediating role between perceived innovation leadership and self-assessed team innovation performance, revealing how innovative leadership indirectly enhances organizational innovation performance by shaping a positive innovation climate.

These findings hold significant implications for both innovation management theory and practice. Theoretically, this study enriches the related theories of innovation leadership and innovation climate, offering a new perspective on how innovation leadership influences organizational innovation performance through the innovation climate. Practically, the study underscores the critical roles of innovative leadership and a positive innovation climate in improving organizational innovation performance, providing specific strategies for business managers to cultivate innovative leadership and foster a positive innovation atmosphere.

Geographic scope and limitations:

While this study focuses on high-tech research institutions in Shandong Province, it is important to recognize the geographic limitation of the findings. The economic and cultural characteristics of this region may influence the generalizability of the results. Future research could benefit from including data from diverse regions or countries to compare and contrast the findings. Quantitative comparisons across different geographic areas could provide valuable insights into how regional factors impact the relationships among innovation leadership,

innovation climate, and team innovation performance.

Based on these conclusions, it is suggested that business managers prioritize the cultivation and practice of innovative leadership by providing resource support, encouraging innovation attempts, and recognizing innovation achievements, thereby actively shaping an organizational culture and atmosphere supportive of innovation. Additionally, employees should be encouraged to actively participate in innovation activities, and effective innovation management strategies should be implemented to enhance overall organizational innovation capabilities and performance. Future research could further explore the relationships among innovation leadership, innovation climate, and team innovation performance in different industries and cultural backgrounds, as well as other potential mediating or moderating variables, thereby providing richer theoretical and practical insights for understanding and promoting organizational innovation.

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