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Analysis of Collaboration Characteristics Among Research Team Members: Postprint

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Abstract

[Purpose/Significance] Analyze the collaborative relationships among team members from an individual perspective, reveal the internal collaboration characteristics of scientific research teams, and provide a basis for the selection, construction, and achievement acceptance of scientific research teams. [Method/Process] Divide team members along two dimensions: research output quantity and number of collaborators. Along the first dimension, segment into zero-output members and high-output members; along the second dimension, segment into isolated members and active members. Then, using 39 National Natural Science Foundation of China (NSFC) Innovation Research Groups as samples, analyze the numbers of zero-output members and isolated members, as well as the relationships between academic leaders and high-output members and active members. [Results/Conclusion] Zero-output members and isolated members are ubiquitous in scientific research teams. Academic leaders are not necessarily high-output or active members of the research team. The collaborative relationships among team members are relatively loose.

Full Text

Preamble

Analysis of Collaboration Characteristics among Members in Research Teams

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Abstract

[Purpose/Significance] Analyzing collaboration relationships among team members from an individual perspective reveals internal collaboration charac-

teristics of research teams and provides a basis for team selection, development, and performance evaluation.

[Method/Process] Team members were segmented along two dimensions: research output quantity and number of collaborators. Along the first dimension, members were classified as either high-output members or zero-output members. Along the second dimension, they were classified as either isolated members or active members. Using a sample of 39 Innovative Research Groups funded by the National Natural Science Foundation of China, this study analyzed the numbers of zero-output and isolated members, as well as the relationship between academic leaders and high-output/active members.

[Result/Conclusion] Zero-output members and isolated members are prevalent in research teams. Academic leaders are not necessarily the high-output or active members of their teams. Collaboration relationships among team members are relatively loose.

Keywords: research team, member, collaboration, characteristic

1 Introduction

Research teams represent an effective organizational form for scientific collaboration [1], and synergistic cooperation among team members constitutes the soul of team formation, growth, and innovation [2]. Consequently, investigating the collaborative characteristics of research team members holds significant practical value for team selection, development, and performance evaluation.

Current academic research has examined collaboration characteristics among scientists using social network analysis metrics such as density [3], subgroups [4-5], and centrality [6], as well as bibliometric indicators including collaboration degree [7], collaboration rate [8], and authorship patterns [9]. However, these studies exhibit three major limitations. First, most analyze teams at the aggregate level without delving into internal collaboration relationships from the individual member perspective. Second, many examine broad collections of researchers from a discipline, field, institution, or region rather than focusing specifically on research teams, resulting in scarce literature on team member collaboration. Third, empirical studies typically rely on small samples of 1-2 teams, limiting the generalizability of their findings. This paper addresses these gaps by segmenting team members along two dimensions—output quantity and number of collaborators—and analyzing collaboration patterns within a sample of 39 National Natural Science Foundation Innovative Research Groups to reveal internal collaboration characteristics.

2 Research Team Structure and Member Segmentation

A research team is defined as a group of researchers with complementary expertise who voluntarily assume mutual responsibility for shared scientific purposes, objectives, and working methods [10]. Related concepts such as innovation

teams and innovative research groups are treated interchangeably in this study. Research teams require stability, which manifests partly through a stable membership base [11]. Based on member stability, this study conceptualizes research teams as comprising three components: academic leaders, core members, and peripheral members. The academic leader serves as the team's head and scientific leader. Core members represent the research backbone and main force beyond the leader, maintaining stable, long-term, formal affiliations with the team. Peripheral members primarily consist of doctoral students, master's students, and interns characterized by high mobility and poor stability, typically exiting upon graduation. These characteristics render peripheral members' relationships with the team as informal, temporary, occasional, and dynamic, which blurs team boundaries and complicates analysis. Therefore, this study excludes peripheral members and focuses exclusively on academic leaders and core members.

Members can be segmented along different dimensions using various criteria. During a given period, a team member may produce a certain number of research outputs and establish collaborative relationships with varying numbers of teammates—two critical dimensions for observing collaboration characteristics. This study segments members based on output quantity and number of collaborators. Output quantity refers to the total number of research outputs produced by a member, including both independent and collaborative works. For collaborative outputs, this study adopts the full counting method [12], whereby each co-author receives credit for one output regardless of the number of contributors. The number of collaborators refers to how many other team members a given member has collaborated with.

Drawing on the Pareto principle [13], this study uses the “80/20 rule” as the segmentation criterion for each dimension. Based on these dimensions and criteria, members are classified as follows: drawing on the concept of prolific authors in bibliometrics [14], high-output members are defined as the top two members in output quantity within their team, while zero-output members are those with zero outputs. Borrowing the concept of isolated nodes from graph theory, isolated members are defined as those with zero collaborators among members who have at least one research output. Active members are the top two members in terms of number of collaborators within their team.

3 Research Framework and Hypotheses

A Cartesian coordinate system was established with output quantity and number of collaborators as axes. Segmented member types were positioned according to their classifications, yielding the research framework shown in Figure 1 [Figure 1: see original paper]. This framework analyzes member distribution across both dimensions and identifies the academic leader's position. Regarding output quantity, two questions are examined: Do zero-output members exist? Is the academic leader necessarily a high-output member? Regarding collaboration, two parallel questions are addressed: Do isolated members exist? Is the academic leader necessarily an active member? While these questions may seem

intuitively answerable, intuition often proves unreliable, as “many everyday intuitions contradict data-driven conclusions” [15]. Google Chief Engineer Jun Wu provides numerous examples illustrating the power of big data. Therefore, this study uses empirical team data to validate these assumptions.

3.1 Discussion on Output Quantity

Scholars widely advocate that team members should collectively share responsibility for team goals [16-17]. As a tightly collaborative entity, research teams particularly emphasize high-level, direct participation from all members [18]. Since the collective goal is achieving the team’s core mission—scientific research—and output quantity serves as a key metric for research performance, producing research outputs represents the primary manifestation of member engagement and responsibility. Consequently, in an ideal research team, every member should contribute outputs, meaning zero-output members should not exist. Based on this analysis, Hypothesis H1 is proposed:

H1: No zero-output members exist in research teams.

As academic leaders, team heads must possess convincing scholarly strength and research capabilities. A natural conclusion would be that academic leaders should be the most productive members. Some scholars have found that prolific authors in higher education research are all team leaders [8], seemingly confirming this assumption. Others propose identifying academic leaders based on output quantity or related centrality metrics. However, this study argues that while academic leaders need not be the absolute top producers, they should be among the high-output members. Thus, Hypothesis H2 is proposed:

H2: The academic leader is one of the high-output members.

3.2 Discussion on Number of Collaborators

In research teams, “members must maintain relatively close collaborative relationships; isolated points should not occur. If isolated points appear, they can be directly identified as invalid members and should be excluded during team structure optimization” [20]. These “isolated points” include two scenarios: members with no research outputs (zero-output members) and members with outputs but no collaboration (isolated members). The former has been discussed; this section focuses on whether isolated members should be permitted. In practice, academic leaders often decompose research objectives and assign sub-goals to members, which may be completed independently or collaboratively. This can produce both single-authored and co-authored outputs, with the former potentially creating isolated members. Therefore, isolated members may legitimately exist in research teams. However, if all members are isolated, the team becomes fragmented and cannot be considered a true team. Thus, at least two members should have collaborative relationships. For analytical purposes, this study defines “collaboration scale” as the number of members who

have collaborated with at least one other member, calculated as: Collaboration Scale = Total Team Members - Isolated Members - Zero-Output Members.

Based on this analysis, Hypotheses H3 and H4 are proposed:

H3: Isolated members exist in research teams.

H4: Collaboration scale ≥ 2 .

Regarding collaboration numbers, active members represent the opposite of isolated members. As the most collaborative members, they play crucial roles in maintaining network connectivity and stability. Active members emerge spontaneously during team operations, meaning any member could potentially become one. This raises the question: Is the academic leader necessarily an active member? In social network analysis, this characteristic is termed degree centrality. Many scholars have explored academic leader identification based on degree centrality [11], implicitly assuming leaders have the highest centrality. However, as team organizers and coordinators, academic leaders should at least be among the active members. Therefore, Hypothesis H5 is proposed:

H5: The academic leader is one of the active members.

4 Empirical Analysis

The National Natural Science Foundation's Innovative Research Group Program aims to cultivate research groups that occupy a place on the international scientific frontier, representing China's high-level research teams. This study selected several such groups as research samples and analyzed collaboration relationships based on co-authorship patterns in their submitted outcomes.

4.1 Data Sources

Given that Innovative Research Group projects typically last three years (extended to six years since 2014), this study selected samples from the 64 groups funded in 2010. Two selection criteria were applied: (1) to avoid team size effects, all teams must have identical member counts (academic leaders plus core members); and (2) to fully capture internal collaboration, the number of outcomes must be substantial. Among the 64 groups, 42 had exactly 10 members, meeting the size consistency requirement. Data on these groups' outcomes (journal articles, conference papers, books, and awards, collectively termed "research outputs") from January 1, 2011, to December 31, 2013, were retrieved from the NSFC's Science Fund Shared Service Network (<http://npd.nsfc.gov.cn>). Three groups were excluded due to insufficient data, leaving 39 groups for analysis.

To improve data quality and facilitate subsequent analysis, the sample underwent the following processing:

1. **Peripheral member removal.** As previously stated, this study focuses only on academic leaders and core members. Any contributors beyond these categories were removed from outcome records. Academic leaders

and core members were identified using rosters obtained from the NSFC, which match information in the groups' funding applications. Individuals not on these rosters were classified as peripheral or non-members.

2. **Data verification.** All outcomes submitted by the 39 groups were verified individually in Web of Science, CNKI, and other databases to supplement missing information and correct errors, ensuring completeness and accuracy of titles, author names, and other details. Outcomes without academic leaders or core members as contributors were removed. After processing, the 39 groups produced a total of 4,656 outcomes.
3. **Member ID assignment.** For analytical convenience, each team member was assigned an ID number. Within each team, the academic leader received ID 0, while other members were numbered sequentially (1, 2, 3, ..., 7, 8, 9) according to their order on the NSFC rosters.

4.2 Results Analysis

The five hypotheses were tested using the sample data. Since H1, H3, and H4 address similar issues, as do H2 and H5, the analysis first examines zero-output and isolated members, then separately verifies whether academic leaders are high-output or active members.

4.2.1 Numbers of Zero-Output and Isolated Members NetDraw was used to visualize collaboration networks for the 39 teams and identify isolated nodes, which correspond to zero-output and isolated members. Zero-output members are inevitably isolated due to having no outcomes, while isolated members remain disconnected despite having independent outputs. Table 1 presents the statistical results. Let set A represent zero-output members, set B represent isolated members, set TA represent teams with zero-output members, set TB represent teams with isolated members, and T represent total teams ($T=39$). The data yield the following statistics: (1) $|A|=48$, $|A|/T=1.23$; (2) $|B|=108$, $|B|/T=2.77$; (3) $|TA|=18$, $|TA|/T=46.15\%$; (4) $|TB|=34$, $|TB|/T=87.18\%$; (5) $|TA \cap TB|=16$, $|TA \cap TB|/T=41.03\%$; (6) $|TA \cup TB|=36$, $|TA \cup TB|/T=92.31\%$.

From the member perspective: Among 390 team members, 48 were zero-output members (average 1.23 per team), and 108 were isolated members (average 2.77 per team). From the team perspective: 18 teams (46.15%) had zero-output members, 34 teams (87.18%) had isolated members, 16 teams (41.03%) had both, and only 3 teams (7.69%) had neither. These data demonstrate that having zero-output and/or isolated members is common in research teams.

Furthermore, the "Total" column in Table 1 shows that among the 39 teams, the combined count of isolated and zero-output members ranged from 0 to 10. Notably, 3 teams had 10 such members, meaning they consisted entirely of isolated and/or zero-output members, resulting in a collaboration scale of zero.

4.2.2 Relationship Between Academic Leaders and High-Output Members Based on the definition of high-output members, the top two producers in each team were identified (Table 2). The table uses “x,y” format, where “x” indicates the highest-output member and “y” the second-highest. For ties, “(m,n,⋯)” notation is used. For example, “4,(1,5)” means member #4 had the most outputs, while members #1 and #5 tied for second. The third column shows output quantities for “x” and “y” respectively.

The data reveal that academic leader ID “0” appears in the “x” position 27 times and in the “y” position 6 times, totaling 33 occurrences (84.62% of all academic leaders). While this proportion is high, it falls short of 100%, indicating that academic leaders are not necessarily the highest-output members.

4.2.3 Relationship Between Academic Leaders and Active Members Based on the definition of active members, the top two collaborators in each team were identified (Table 3). The table format mirrors Table 2, with two differences: (1) “Other” indicates members tied beyond the top two positions due to numerous ties; (2) Teams #1, #2, and #15 had collaboration scales of zero (all members isolated), making collaboration comparisons impossible, marked with “-” .

The data show that across 39 teams, academic leader ID “0” appears in the “x” position 24 times (14 ties for most collaborative) and in the “y” position 7 times (6 ties for second-most collaborative), totaling 31 occurrences (79.49% of academic leaders). Thus, not all academic leaders are active members.

5 Conclusions and Discussion

This study analyzed internal collaboration characteristics among members of 39 NSFC Innovative Research Groups. The results reject four of the five hypotheses, accepting only H3. The findings lead to the following conclusions and discussion points.

5.1 Prevalence of Zero-Output and Isolated Members

The prevalence of teams with zero-output and/or isolated members, combined with their absolute numbers, demonstrates that having several such members has become common in research teams. This phenomenon raises three discussion topics:

1. **Why do zero-output members exist?** From a productivity standpoint, if a member contributes no outputs, is their presence necessary? Can initial expectations for these members be fulfilled? These questions warrant deeper investigation. One possible explanation involves “honorary authorship” [21], where academic leaders recruit “big names” [22] or “benefactors” [23] to enhance team prestige. While these recruits may

help secure funding, they rarely perform actual research tasks, making zero-output status unsurprising.

2. **Are teams with zero collaboration scale truly teams?** While a few zero-output or isolated members may be normal, teams composed entirely of such members raise serious questions about collaboration authenticity and effectiveness. Three such teams appeared in our sample. Does this reduce research collaboration to a loose collection of individual achievements [24]? Has the research team devolved into a temporary assembly for project acquisition [25]? How should such teams be evaluated during review or continued funding decisions? These issues require further study. Additionally, isolated members far outnumber zero-output members, making them the primary cause of small or zero collaboration scales. Why do isolated members emerge? One explanation suggests academic leaders artificially divide research tasks into independent sub-tasks assigned to individual members. While this reduces leadership burden, it neglects the coordinator role and encourages siloed behavior, increasing the risk of zero collaboration scale.
3. **Can isolated academic leaders remain effective?** Six teams in our sample had isolated academic leaders (Table 1). As team conveners and organizers, leaders must maintain close collaborative relationships [26]. When leaders lack collaborative ties, have they fulfilled their leadership mission? This merits serious reflection.

5.2 Academic Leaders Need Not Be Productivity or Collaboration Leaders

In our sample, 15.38% of academic leaders were not high-output members, and 20.51% were not active members. This indicates that while leaders bear irreplaceable responsibility for research tasks and internal collaboration, they need not dominate scientific productivity [27] or serve as the sole collaboration hub. This phenomenon raises two questions:

1. **What impact does this have on teams?** Some argue this decentralized state facilitates knowledge exchange and benefits overall development [20], while others contend moderate concentration maintains research efficiency [28]. This study suggests that such dispersion provides space for other members' actions and growth, stimulating initiative and creativity to harness collective intelligence.
2. **Does this hinder academic leader identification?** Beyond traditional organizational structures, scholars increasingly attempt to identify research teams through co-authorship and citation data. These methods typically identify leaders using centrality metrics, then locate other members through snowball sampling. However, this study shows academic leaders need not rank highest in output or collaboration, complicating identification. Using our sample, identifying leaders from high-output

members achieves 49.25% precision and 84.62% recall; identification from active members achieves only 19.50% precision and 79.49% recall. These poor results indicate significant challenges for such approaches.

5.3 Loose Collaboration Relationships Among Members

Table 1 data yield an average collaboration scale of 5.85 members, indicating that despite 10-person teams, fewer than six members actually collaborate. Based on Table 3, the average number of collaborators per member across all teams is 1.49. The distribution shows: 1 team with 7 collaborators, 4 teams between 3-4, 7 teams between 2-3, 13 teams between 1-2, 11 teams between 0-1, and 3 teams with zero collaborators. The 27 teams (69.23%) with fewer than 2 collaborators per member demonstrate insufficient interaction and inadequate collaboration.

This study has limitations in sample selection, data preprocessing, and analysis. The sample only covers NSFC Innovative Research Groups, limiting representation across team types, sizes, and disciplines. Peripheral members were excluded, restricting the analysis to academic leaders and core members without revealing full team characteristics. Additionally, collaboration manifests in various forms; this study only used co-authorship relationships as evidence of collaboration.

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