



Regional differences in teaching and research exchange based on social network analysis: a case study of geography teachers in city A and county B of Jiangsu province

Yiwen Tong¹, Ling Yuan², Qian Luo³, Shui Li⁴, Zhiqiang Yuan⁵, Chengfu Ye⁶, Jin Ji⁷, Xiaoxu Lu^{* 8}

Abstract

The regional differences in education have an impact on educational equity, making them an important issue for investigation. The importance of the regional differences is relatively apparent in extant research on teaching and how it is communicated. This study focuses on the characteristics of research communication among teachers within counties, examining their regional differences. Data on research communication are collected from 71 geography teachers in 9 units in City A and 97 geography teachers in 27 units in County B in the southern and northern regions of Jiangsu Province, China. Social network analysis (SNA) methods are used to compare network density, cohesive subgroups, centrality, and core-periphery structures. This study finds similarities and differences in the characteristics of research communication between the two regions. For example, the density of communication among geography teachers in County B is greater than it is in City A, and the network structure in City A is center-dispersed while in County B it is interwoven. The study also discusses the potential impact of research communication differences on education equity, conducting analysis and providing explanations for the observed differences. Furthermore, the study aims to develop a reference that could be used to eliminate educational inequality caused by regional differences and to prepare for the establishment of SNA standards for regional research communication.

Keywords

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¹ East China Normal University, School of Geographic Sciences, Shanghai, China, tongywecnu@foxmail.com

² East China Normal University, Faculty of Education, College of Teacher Education, Shanghai, China, 1093826281@qq.com

³ East China Normal University, Faculty of Education, College of Teacher Education, Shanghai, China, 1746363365@qq.com

⁴ Lianyungang Education Bureau, Teaching and Research Office, Lianyungang, China, LS0016@126.com

⁵ Changshu Education Bureau, Teaching and Research Office, Jiangsu, China, 345338327@qq.com

⁶ Donghai Education Bureau, Teaching and Research Office, Jiangsu, China, dhyfc@126.com

⁷ Suzhou Institute of Educational Sciences, Jiangsu, China, 957027544@qq.com

⁸ * **Corresponding author:** East China Normal University, School of Geographic Sciences, Shanghai, China, xxlu@geo.ecnu.edu.cn

Introduction

Educational equity is a crucial human rights issue, particularly in China, where there are significant disparities in regional development. The country's regional differences have led to pronounced educational inequality. Ongoing initiatives seek to address these imbalances both within and across regions. Promoting teaching and research exchanges at a regional level can facilitate knowledge transfer, resource sharing, and the enhancement of teacher professionalism. Moreover, bolstering these exchanges in less-developed areas can help mitigate educational disparities and promote equity.

Social network analysis (SNA), which describes the structure of group relations by modelling the interaction relationships between actors (Hu, 2011), is widely used in sociological research. In recent years, the method has been employed widely in the fields of intelligence, Internet technology, and enterprise economic management, and it is now being used in the field of education as well (Song, 2021). For example, Oshima et al. (2012) proposed an SNA application that uses learners' discourse as input data to study how learners develop knowledge through discourse, while Lin (2018) combined SNA with psychosocial testing to reveal the social relationships of college students. Combining SNA methods with psychosocial testing methods, they reveal the subjective and objective mechanisms of social relationships and learning network formation among college students. Tawileh (2016) demonstrated the substantial potential of SNA methods for developing an understanding of group dynamics in online virtual classrooms by utilizing information about instructor-student interactions in learning exchanges on social network platforms. Papanikolaou et al. (2020) demonstrated the positive effect of gamification of learning styles on the development of community learning networks, showing that network development has a positive effect on learning. Yan and Zhang (2017) analyzed the effects of professional segregation, adjustment stickiness, and professional demonstration in intercollegiate professional interactions in higher education institutions based on the theory of structural holes in a social network. While examining second-level colleges in Chinese universities, Zhong (2014) employed centrality theory to put forward a "strategy triangle" model that can be used to test the major decisions of colleges. Yang et al. (2011) studied the interactions of teachers at the interpersonal, inter-school, and regional levels in an urban-rural teachers' online learning community. Yang et al. (2017) analyzed the work, consultation, and affective networks of teachers in five elementary schools in Beijing, targeting all teachers in the city. Zhang et al. (2019) investigated climate concepts in geographic sciences, employing SNA to construct inter-conceptual relationship networks to develop a guide for the teaching of geography. Using communication data collected from students in a remedial class, Yuan et al. (2019) utilized SNA to identify core students in the class and take measures to improve the class by focusing on them. In summary, SNA is increasingly employed in the use of social network analysis to study of educational phenomena is gradually becoming a research hotspot, while the study of inter-school teaching and research by secondary school subject teachers has not yet matured. In this study, secondary school geography teachers in City A and County B of Jiangsu Province, China, were selected as research subjects, and by comparing the status of teaching and research exchanges in the two regions and analyzing their causes, we hope to develop reference material that can be used in efforts to eliminate educational inequities due to regional differences. Additionally, this study seeks to create a pre-preparation for the establishment of a standard for the analysis of regional teaching and research exchanges in social networks.

Method

Research ideas

This study focuses on geography teachers as the research subjects, aiming to explore common patterns in teaching and research exchanges across different disciplines. The selection of geography teachers as samples is representative: their subject status—positioned between core and non-core subjects—reflects the typical teaching workload and resource support available to secondary school teachers. This ensures that the research findings can be generalized to other subjects with similar class

schedules and instructional demands. Furthermore, the interdisciplinary nature of geography generates diverse needs for teaching and research collaboration, making it an ideal sample for observing patterns in teacher professional exchanges.

To obtain data for analysis, this study recruited geography teachers and research coordinators from a large area with high coverage within the counties of City A (county-level) in southern Jiangsu and County B in northern Jiangsu, China. The frequency of research exchanges between each group and other groups within their respective counties was investigated through online surveys. SNA methods were then employed to compare educational research exchange indicators, in order to identify commonalities and differences. This information was then used to make judgments, analyze observations, and propose countermeasures.

Content of the survey

The questionnaire was mainly used to collect information on the frequency of teaching and research exchanges between the groups, and the groups were asked to make a self-judgments on the frequency of teaching and research exchanges between themselves and the other groups. In some of the questions of the questionnaire, "1" meant "hardly ever," "2" meant "occasionally," "3" meant "usually," and "4" meant "more often." In others, "2" meant "occasionally," "3" meant "usually," "4" meant "more often," and "5" meant "often." The questionnaire was also designed to collect some demographic information on teachers, including gender, age, educational background, and professional title.

Sample recruitment

The sample recruitment and survey process design in this study complies with research ethics. The survey plan in City A has passed the ethical review of the Human Subjects Protection Committee at East China Normal University, while the survey plan in County B was approved by the Education Research Office of County B. Recruitment was completed in January 2020, and data collection was completed in October 2018 (Table 1). The education research offices in both regions provided support and assistance, resulting in a high recruitment rate was high. In City A, there were a total of 76 geography teachers and research coordinators, with 71 participants being ultimately recruited, resulting in a recruitment rate of 93.4%. All 97 geography teachers and research coordinators in County B were recruited, resulting in a 100% recruitment rate.

Table 1. Sample Attributes of City A and County B

Primary index	Secondary index	City A	County B
Sample size	/	71	97
Total Number of Units	/	9	27
Gender	Male	26 (36.6%)	53 (54.6%)
	Female	45 (63.4%)	44 (45.4%)
Age	20–25 years	6 (8.5%)	/
	26–30 years	14 (19.7%)	5 (5.2%)
	31–36 years	10 (14.1%)	22 (22.7%)
	37–45 years	21 (29.6%)	31 (32.0%)
	46–50 years	8 (11.3%)	24 (24.7%)
	51–55 years	9 (12.7%)	15 (15.5%)
	56–60 years	3 (4.2%)	/
	Average age	38.9	42.2
Education Background	Undergraduate	49 (69.0%)	92 (94.8%)
	Postgraduate	22 (31.0%)	5 (5.2%)
Professional Title	Full-time senior teacher	2 (2.8%)	/
	Senior teacher	24 (33.8%)	39 (40.2%)
	First-grade teacher	17 (23.9%)	31 (32.0%)
	Second-grade teacher	14 (19.7%)	24 (24.7%)
	Other	14 (19.7%)	3 (3.1%)

Methods of analysis

Using the collected data, this study generated separate original research and communication matrices for geography teachers in two different areas, performing binarization on the original research and communication matrices (Table 2). The value three was selected to represent "ordinary" communication frequency as the threshold, with values less than or equal to three being set to zero in the matrix. The zero values were used to indicate low communication frequency between two teachers, which was considered insufficient for establishing a stable, long-term research and communication relationship. Values greater than three were set to one, indicating a high communication frequency between two teachers that was considered sufficient for establishing a stable research and communication relationship. The binarized research and communication matrix served as the basis for subsequent series of data analysis operations. This study employed methods such as network density analysis, cohesive subgroup analysis, centrality analysis, and core-periphery structure analysis in SNA to progressively analyze the overall characteristics, group characteristics, and individual characteristics of the research and communication network within the region. Additionally, the methods were utilized to compare the characteristics of City A and County B. Data analysis was conducted using Excel 2021 and Ucinet 6.0.

Table 2. Results of the Construction of the Teaching and Research Exchange Matrix in City A

Original Teaching and Research Exchange Matrix										Binary Teaching and Research Exchange Matrix									
	X01	A01	A02	A03	B01	B02	...	H10	H11		X01	A01	A02	A03	B01	B02	...	H10	H11
X01		3	5	5	4	3	...	2	3	X01		0	1	1	1	0	...	0	0
A01	4		5	4	1	1	...	1	1	A01	1		1	1	0	0	...	0	0
A02	3	3		3	1	1	...	1	1	A02	0	0		0	0	0	...	0	0
A03	5	5	5		4	1	...	2	3	A03	1	1	1		1	0	...	0	0
B01	4	1	1	1		4	...	1	1	B01	1	0	0	0		1	...	0	0
B02	4	1	3	3	3		...	1	1	B02	1	0	0	0	0		...	0	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
H10	2	1	1	1	1	1	...		4	H10	0	0	0	0	0	0	...		1
H11	3	1	1	1	1	1	...	5		H11	0	0	0	0	0	0	...	1	

Evaluation indicators

Selection of indicators for analysis

Education development requires resources, and regional educational research is mainly accomplished through the optimization and integration of educational resources within the region. The process of integrating regional educational research resources comprises the allocation of individual resources to collective resources (Wang, 2019). Therefore, the level of regional educational research exchange is reflected in two dimensions: the "individual" and the "collective."

The "individual" level mainly refers to subject teachers and research coordinators within a region. Subject teachers are the core and main body of regional educational research, with a dual identity as researchers and practitioners. Research coordinators harmonize various relationships, help establish inter-school research mechanisms, and facilitate inter-school interactive exchanges (Zhang & Wu, 2012). They play an important role in teaching guidance, research promotion, teacher growth, and team-building. The number and quality of subject teachers, along with the coordinating ability and networking capability of research coordinators, will have a crucial impact on the level of regional educational research and exchange.

"The collective" level mainly refers to a group of teachers in a region who have a cooperative relationship, as well as the overall state of educational research and exchange in a region. The "educational research community" is a research group comprised of organizations or individuals with a common vision and who communicate, exchange, and share various educational research resources with each other during the research process, and jointly achieving specific research tasks. (Zhang & Wu, 2012). Building an educational research community helps to transition regional educational research transition from being singular and closed to being diverse and open. Moreover, an educational research community allows various forces to complement each other, cooperate for mutual benefit, and enhance the overall cohesion of regional educational research exchange, providing opportunities for innovation

and development in regional educational research. The scale, number, and level of cooperation within the educational research community also affect the level of regional educational research exchange.

This study will use indicators such as the density of educational research exchange networks, the density of cohesive subgroups, centrality, and core-ness to characterize the level of regional educational research exchange in a region. The definitions and functions of the related indicators are shown in Table 3.

Table 3. Definition and Function of Indicators

Dimension	Indicator	Definition	Function
The collective	Network density	The closeness of the association of individual nodes in the network	Determining the overall teaching and research exchange profile of a region
	Cohesive subgroup density	A cohesive subgroup refers to a secondary group formed by nodes with particularly close relationships in a network. The cohesion subgroup density can be divided into internal density and external density, reflecting the degree of closeness of the connections between nodes within the subgroup and the connections between different subgroups in the network.	To determine the existence of an educational research community in a region, as well as the communication tendencies among different groups within the network.
Individual	Centrality	Degree centrality	The direct connections of a node with other nodes in a network
		Betweenness centrality	The ratio of the number of times a particular node is traversed by other nodes along the shortest path to the total number of shortest paths in the network.
		Closeness centrality	The ease of traversal from one node to another within the network.
	Core–periphery structure – core-ness	The core-ness divides the overall network into core areas and peripheral areas.	Characterizing an individual's activity and engagement in the network. Characterizing an individual's level of control over resources in the network. Characterizing the ease of individuals conveying information and resources in the network. Assessing the relative position of individuals in the network to identify core individuals and peripheral individuals.

Methodology for calculating indicators

1. Network Density

The range of network density is $[0, 1]$. A density value closer to one indicates that the connections between individuals in the network are closer, and the impact of network relationships on individuals is greater. The formula is:

$$D = \sum_{i=1}^k \sum_{j=1}^k d(n_i, n_j) / k(k-1) \quad (1)$$

where D represents network density, k stands for the number of nodes, and $d(n_i, n_j)$ indicates whether there is a direct link between nodes n_i and n_j . If there is a connection, it is represented by one (1), and if not, it is represented by zero (0).

2. Cohesive Subgroup Density

The CONCOR algorithm in Ucinet6.0 can be used to construct subgroups and obtain a subgroup density matrix. The values on the diagonal of the matrix represent the internal density of the subgroups, with a range of $(0, 1]$, where a value closer to one indicates a closer connection between the individuals in the subgroup. As close relationships are a prerequisite for subgroup formation, the internal density value cannot be zero.

The values outside the diagonal of the matrix represent the external density of the subgroups, that is, they represent the degree of closeness between a subgroup and other subgroups, with a range of $[0, 1)$. A value closer to one indicates relatively close intergroup communication among the individuals constituting these two subgroups. As external density cannot exceed internal density, the density value cannot be one. When the value is zero, it indicates that there is no communication between the individuals forming the two subgroups.

3. Degree centrality

A node with a high degree centrality can be considered to have a high level of participation in the network. Degree centrality can be divided into absolute degree centrality and relative degree centrality.

Absolute degree centrality is the number of other nodes directly connected to the node, and its magnitude is related to the number of nodes in the network. The range of values is $[0, +\infty)$. The formula is:

$$C_{ADi} = \sum_{j=1}^n X_{ij} \quad (2)$$

where C_{ADi} represents the absolute degree centrality of the node, X_{ij} indicates whether the nodes i and j are connected, and n stands for the number of nodes in the network.

The relative degree centrality is given by the ratio of a node's absolute degree centrality to its maximum possible degree centrality in a network. This index is commonly used to compare the degree centralities of nodes in networks of different sizes, with a value range of $[0, 1]$. The formula is:

$$C_{RD i} = \frac{C_{AD i}}{n-1} \quad (3)$$

where $C_{RD i}$ represents the relative degree centrality of a node, $C_{AD i}$ stands for the absolute degree centrality of a node, and n denotes the number of nodes in the network.

4. Betweenness centrality

Nodes with higher betweenness centrality are considered to have a stronger ability to control interactions between the other two nodes (Ping & Zong, 2010). Betweenness centrality can be divided into absolute betweenness centrality and relative betweenness centrality.

Assuming there are multiple shortcuts between a pair of nodes, and one of them passes through a third node, the betweenness centrality of the node being passed to this pair of nodes refers to the node's ability of the node to be on the shortcut between the pair of nodes, which is referred to as the "intermediary ratio" (Liu, 2019). The formula is:

$$b_{jk}(i) = \sum_{j < k} g_{jk}(i) / g_{jk} \quad (4)$$

where $b_{jk}(i)$ denotes the ability of the third node i to control the interaction between node j and node k , which is equal to the probability that node i is on a shortcut between node j and node k , (i.e., the degree of intermediation), g_{jk} represents the number of shortcuts from node j to node k , and $g_{jk}(i)$ denotes the number of shortcuts between node j and node k that exist through the third node i .

Based on the formula above, adding the betweenness centrality of the third node i with respect to all pairs of nodes in the network yields the absolute betweenness centrality of the node, which is related to the number of nodes in the network. Its value ranges from $[0, +\infty)$. The formula is:

$$C_{ABi} = \sum_j \sum_k b_{jk}(i) \quad (5)$$

where C_{ABi} represents the absolute betweenness centrality of a node, $b_{jk}(i)$ stands for the betweenness centrality of a node, and n denotes the number of nodes in the network.

The absolute betweenness centrality C_{ABi} of a node can reach a maximum value of $C_{\max} = (n^2 - 3n + 2) / 2$ when it is in a star-shaped network (Liu, 2019). Relative betweenness centrality is the ratio of the absolute betweenness centrality of a node in the network to its maximum possible betweenness centrality, which can be used to compare the betweenness centrality of nodes in networks of different scales, with a range of values ranging between $[0, 1]$. The formula is:

$$C_{RBi} = \frac{2C_{ABi}}{n^2 - 3n + 2} \quad (6)$$

where C_{RBi} represents relative betweenness centrality, C_{ABi} denotes absolute betweenness centrality, and n stands for the number of nodes in the network.

5. Closeness centrality

The larger the closeness centrality of a particular node, the greater the distance between this node and other nodes, which will correspondingly weakens its information resources, power, prestige, and influence (Liu, 2019). Closeness centrality can be categorized into absolute closeness centrality and relative closeness centrality.

Absolute closeness centrality is the sum of the shortcut distances of the point from all other nodes in the network, with its magnitude being dependent on the number of nodes in the network. The range of values range between $[0, +\infty)$. The formula is:

$$C_{APi}^{-1} = \sum_{j=1}^n d_{ij} \quad (7)$$

where C_{APi}^{-1} represents absolute closeness centrality and d_{ij} denotes the shortcut distance (i.e., the number of lines contained in the shortcut) between node i and node j .

The absolute closeness centrality of a node can reach a minimum value of $n-1$ in a star-shaped network containing n nodes. Relative proximity centrality is the ratio of the absolute proximity centrality of a node in the network to the minimum possible proximity centrality of the node, which can be used to compare the closeness centrality of nodes in networks of different sizes. The values range between $[0, +\infty)$. The formula is:

$$C_{RPi}^{-1} = \frac{C_{APi}^{-1}}{n-1} \quad (8)$$

where C_{RPi}^{-1} denotes the formula: C_{RPi}^{-1} is the relative closeness centrality, C_{APi}^{-1} stands for the absolute closeness centrality, and n represents the number of nodes in the network.

6. Core-periphery Structure: Core-ness

The range of core-ness values is $[0, 1]$, which can be obtained using the K-core algorithm in Ucinet 6.0. The closer the value is to one, the more tightly connected the node is to other nodes, indicating that it is in the core area of the network. Such nodes can rapidly disseminate information and resources, and play an important supporting role in the stability and functionality of the entire network. A core-ness value of one indicates that the node is directly connected to all other nodes in the network, often making it a leader or key decision-maker in the network. A core-ness value of zero indicates that the node has no connections to other nodes in the network, making it an isolated node.

Determination of Evaluation Criteria

Based on the selected indicators and the actual situation on the ground in the two regions, the following evaluation system of empirical indicators has been selected to facilitate the comparative analysis of the teaching practices and research exchanges between the two regions (Table 4).

Different types of networks have different density characteristics; therefore, the minimum standards for network density should be determined based on the specific network type and research background under investigation. Given the scale of the educational research and exchange networks in the two regions and the regular characteristics of local educational research and exchange activities, this study sets 0.15 as the minimum standard for network density because when 15% of teachers in a particular area communicate above the minimum standard, the overall connections in the educational research and exchange network are relatively close.

The subgroups obtained from cohesion subgroup analysis represent educational research communities. Educational research communities belong to the "small group" structure within the overall network, with a limited number of members, and as a result, a teacher's proportion within their respective educational research community is significant. Therefore, this study adopts 70% as the grading standard, considering that when the proportion of teachers from the same unit in a subgroup is less than 70%, there are clear differences among the unit affiliations of the subgroup members.

Because the size and quantity of subgroups in the two regions vary, when comparing the internal and external communication characteristics of the subgroups in the two regions, it is necessary to separately calculate the average values of internal and external density within the subgroups, representing the average level of communication closeness of all subgroups in that region. The density ratio of "average internal subgroup density" and "average external subgroup density" is then used to determine their communication characteristics. Because the communication tendency is significantly affected by the proportion of members from the same unit within the subgroups, this study suggests that when the internal density is greater than 0.7, the external density is less than 0.2, and the internal-external density ratio is greater than 3.5, there is a significant internal communication tendency.

Core teachers are classified based on their core-ness. The ideal structure of core teachers is characterized by the following: an appropriate number of teachers, a balanced gender ratio, a reasonable distribution of professional titles, and diverse educational levels. First, the number of core teachers should be able to meet the educational needs of the region, ensuring a balance between teaching quality and student numbers. The specific quantity depends on the scale and type of schools and on educational policies and needs. Generally, the number of core teachers should account for 20%–30% of the total number of teachers in the area. Second, a balanced gender ratio. Gender balance can provide diverse and wide-ranging perspectives, helping to create an inclusive and positive work environment in schools. In general, a male-to-female ratio of between 2:3 and 3:2 is considered an ideal range. Third, the proportion of professional titles in the core teacher group should be reasonably distributed and not overly concentrated on one title. This distribution can enhance the maintenance of a stable title structure and provide opportunities for development and promotion, serving as a motivating factor for teachers. The specific proportion can be determined based on the size and composition of the teacher group, but should be relatively balanced. Fourth, different educational backgrounds and levels lead to the input of diverse professional knowledge and teaching experiences, enhancing teaching quality and innovation capabilities. The specific proportion can be adjusted based on the size, responsibilities, and needs of the teaching team. Therefore, this study categorizes core teachers with a core-ness greater than 0.1 as core teachers in the region, those between 0.01 and 0.1 as semi-marginal teachers, and those with a core-ness less than 0.01 as marginal teachers, using the average core-ness to measure the dominance or weakness of the teacher group in the entire educational research and communication network.

Due to the different sizes of teaching and research exchange networks in the two regions, relative centrality values are required when comparing the centrality indicators of core and marginal teachers. Additionally, due to the quantitative differences between core and marginal teachers in the two regions, the average of the relative centrality values needs to be calculated to represent the average level of centrality. In this study, evaluation criteria were established for each of the three centrality indicators.

Table 4. Evaluation System of Indicators for Regional Teaching and Research Exchange Networks

Primary index	Secondary index	Evaluation criteria
Network density	/	≥0.15 Closely related <0.15 Loosely related
Ratio of subgroup members to the same unit	/	≥70% Essentially the same unit <70% Apparent difference in affiliation
Subgroup density	Average internal subgroup density	≥0.7 Close relationship 0.2–0.7 Moderate relationship <0.2 Loose relationship
	Average external subgroup density	≥0.7 Close relationship 0.2–0.7 Moderate relationship <0.2 Loose relationship
	Average internal–external density ratio	≥3.5 Significant propensity for internal communication 3.5–1 Balance of internal and external communication tendencies <1 Significant tendency towards external communication
Core–periphery structure	Core-ness	≥0.1 Core teachers 0.01–0.1 Semi-marginal teachers <0.01 Marginal teachers
	Average Core-ness	≥0.1 Play a leading role <0.1 Weak dominance
	Core–marginal teacher ratio	≥1:1 Well-structured faculty <1:1 Imbalance in teacher structure
Relative centrality	Average degree centrality	≥0.7 High level of participation 0.4–0.7 Moderate level of participation <0.4 Low participation
	Average betweenness centrality	≥0.02 Functioning 0.003–0.02 Weak effect <0.003 Almost no effect
	Average closeness centrality	>2.0 Low efficiency 1.0–2.0 Good efficiency <1.0 High efficiency

Results

1. Variations in the density of educational research exchanges between the two regions

To visually represent the differences in educational research exchanges between the two regions, the NetDraw function of Ucinet 6.0 was employed to generate community graphs for both regions (Figure 1 and Figure 2). In the graphs, black squares and codes represent individual teachers, and the connections between the squares represent the interactions between the teachers.

The results show that the network density of educational research exchanges in City A is 0.136, while County B has a higher density than City A, at 0.168. A value greater than 0.15 indicates that there are more closely-knit educational research exchange connections between teachers in County B than there are in City A (Table 5).

Both community graphs of the two regions show a dense middle section surrounded by a sparse area, indicating that teachers positioned in the center of the community graph are active and have high participation in the educational research exchange network, while those on the periphery have relatively few interactions with other teachers. Teachers with code X01 in both regions are educational

research coordinators positioned in the middle of the community graphs, which means that they have played an active role in their respective regions.

There are no isolated nodes in the community graphs of either location, indicating that geography teachers in both City A and County B have participated in the educational research exchange activities in their respective regions, and there are no isolated teachers.

Table 5. Density of Teaching and Research Exchange Networks between Geography Teachers in City A and County B

Indicator	Standard	City A	County B
Total theoretical relationships		2485	4656
Total actual relationship		339	780
Network density	>0.15	0.136	0.168

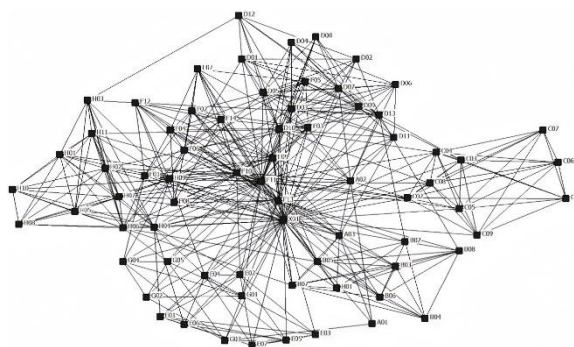


Figure 1. Community map in City A

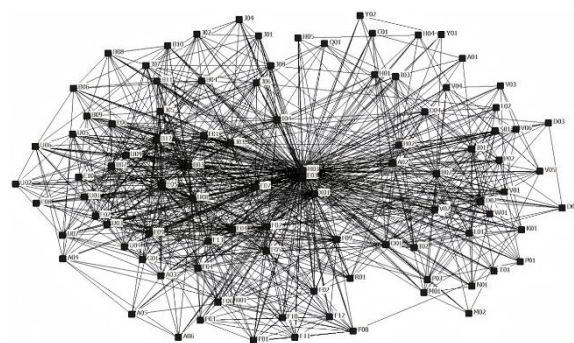


Figure 2. Community map in County B

2. Differences in patterns of teaching and research exchange between the two regions: City A has a pattern of exchanges within the same school, while County B has a pattern of exchanges between schools

In City A, 9 units participated in the study, forming 8 subgroups while in County B, 27 units participated in the study, forming 28 subgroups. The number of units and subgroups were similar, and the average ratio of colleagues from the same unit in subgroup A was 83%, with an average internal: external density ratio of 7.55 and both ratios far exceeded those of County B. This outcome indicates that compared to County B, City A engages more in educational and research exchanges within subgroups, forming a network of subgroups dominated by school-based educational and research exchanges. Simultaneously, County B exhibits a greater occurrence of inter-school exchanges than City A (Table 6).

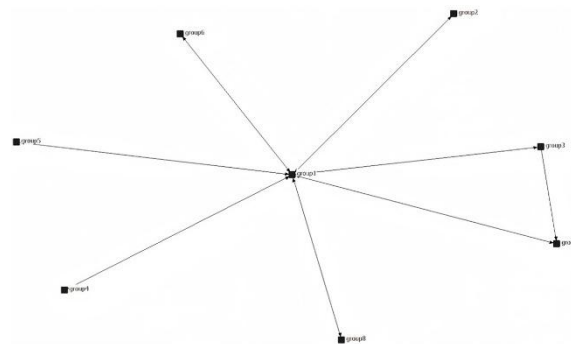
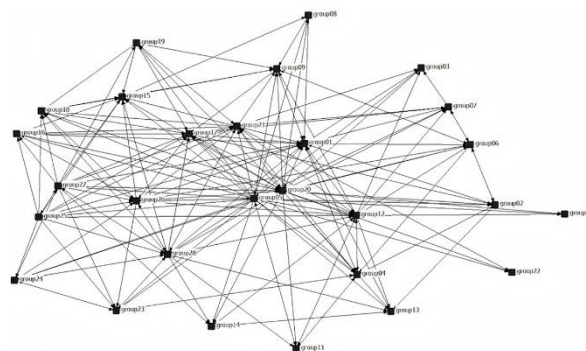
Table 6. City A and County B Subgroup Information Statistics

Indicator	Standard	City A	County B
Number of subgroups		8	28
Ratio of subgroup members from the same unit	<70%	83.0%↑	66.2%
Average subgroup internal density	>0.7	0.755	0.543↓
Average subgroup external density	>0.2	0.100↓	0.185↓
Average internal–external density ratio	<3.5	7.55↑	2.94

3. Differences in the structure of teaching and research exchanges between the two regions: City A's central–divergent pattern versus County B's network-interwoven configuration

To further assess the structural characteristics of the educational and research communities in the two regions, it is necessary to first binarize the subgroup exchange density matrix. Using the region's network density as a threshold, assigning a value of 0 to densities less than the network density is considered an indication of loose relationships that are below the average level, while assigning a value of 1 to densities greater than or equal to the network density is considered to be an indication of close relationships and frequent interactions. The resulting binarized matrix was imported into NetDraw to obtain subgroup structure diagrams of the two regions (Figure 3 and Figure 4).

From the subgroup structure diagram, it can be seen that City A has a central–divergent configuration, with a prominently central subgroup occupying a core position with connections to which all subgroups are related. In contrast, the remaining subgroups have very few connections among them. On the other hand, County B lacks a prominently central subgroup and exhibits several connections among the subgroups.

**Figure 3.** Structure of subgroups in City A**Figure 4.** Structure of subgroups in County B

4. Comparative Evaluation of Teacher Resource Structure and Role Dynamics: Core Teacher Influence and Marginal Teacher Characteristics in City A and County B

The proportion of core teachers in the two regions is the same, accounting for 26.8% of all teachers in the region. City A has fewer marginal teachers than County B. The proportion of marginal teachers in City A is 9.86%, while in County B it is 17.53%. The ratio of core teachers to marginal teachers in both regions is greater than 1:1, standing at 2.71:1 in City A and 1.53:1 in County B, indicating that the teacher structure in both regions is relatively reasonable and can meet the basic needs of daily teaching and ensure relatively stable teaching quality (Table 7).

The average centrality of core teachers in City A is greater than that of County B, indicating that the core teachers in City A have a more dominant role in the research and communication network than do those in County B.

Comparing the three types of centrality degree indicators, it can be observed that the average relative degree centrality of core teachers in County B is higher than that of core teachers in City A, indicating that the core teachers in County B have a higher level of participation in the research and communication network of the entire region than those in City A. Both regions have very low average relative betweenness centrality indicators. Nevertheless, these indicators in City A are slightly higher than they are in County B, indicating that communication between geography teachers in both areas is highly direct, and there are few instances of a need for other teachers as communication bridges. The average relative closeness centrality in City A is higher than it is in County B, indicating that the communication efficiency among core teachers in City A is lower than it is in County B. Marginal teachers in both regions have low participation in the research and communication network of their respective areas and almost no intermediary role. Consequently, there are very limited means for marginal teachers to obtain information or resources, resulting in low communication efficiency.

Table 7. Indicator Statistics for Core and Marginal Teachers in City A and County B

Primary index	Secondary index	Standard	City A		County B	
			Core teachers	Marginal teachers	Core teachers	Marginal teachers
Number of teachers	/		19	7	26	17
Percentage	/		26.8%	9.86%	26.8%	17.53%
Core-periphery structure	Core-periphery $\geq 1:1$ count ratio		2.71:1		1.53:1	
	Average Core-ness	≥ 0.1	0.207	0.005↓	0.171	0.006↓
Average degree Centrality	Absolute		19	8	42	15
	Relative	>0.4	0.271↓	0.114↓	0.438	0.156↓
Average Betweenness Centrality	Absolute		4.644	0.156	3.025	0.389
	Relative	>0.003	0.002↓	0.00006↓	0.001↓	0.00008↓
Average Closeness Centrality	Absolute		126.368	152.429	153.038	176.412
	Relative	<2.0	1.805	2.178↑	1.594	1.838

In terms of the personal attributes of core teachers, both in City A and County B, the predominant demographic is male middle-aged teachers with senior professional titles and undergraduate degrees. However, the gender ratio of core teachers in City A is more balanced than it is in County B. Additionally, the overall level of education among core teachers in City A is higher than it is in County B. Approximately 63.2% of core teachers in City A hold senior professional titles or higher, while in County B this proportion is 65.4%. Overall, the educational qualifications of core teachers in County B are slightly higher than those of teachers in City A. For marginal teachers in both City A and County B, the majority are young to middle-aged females with undergraduate degrees and first-grade or lower professional titles (Table 8).

Table 8. Statistics of the Personal Attributes of Core and Marginal Teachers in City A and County B

Primary index	Secondary index	City A		County B	
		Core teachers	Marginal teachers	Core teachers	Marginal teachers
Average age		43.9	37.1	44.6	39.9
Gender	Male	10	2	23	5
	Female	9	5	3	12
Education	Undergraduate	11	6	25	16
Background	Postgraduate	8	1	1	1
Professional Title	Full-time senior teacher	2	0	0	0
	Senior teacher	10	2	17	4
	First-grade teacher	3	1	6	6
	Second-grade teacher	2	4	2	6
	Something else	2	0	1	1

5. Differing main roles played by research coordinators in the two regions

The research coordinators in City A and County B are male teachers aged 51–55 and hold undergraduate degrees and senior teacher titles. The research coordinators in City A play a stronger leading role in the research and exchange network than their counterparts in County B (Table 9).

There are differences in the main roles played by the research coordinators in their respective regions. The degree centrality and betweenness centrality of research coordinators in City A are the highest in the research and exchange network in their region, while the closeness centrality is the lowest, indicating that research coordinators in City A are the most active participants in the research and exchange network and are responsible for facilitating communication and resource-sharing among teachers. The relative betweenness centrality of the research coordinator in County B is lower than the standard value, but it is the highest in their research and exchange network, indicating that the research coordinator in County B mainly acts as an intermediary in the research and exchange activities in the region. However, due to the advantage of the network's intertwined structure, the teachers in County B already have relatively extensive communication links, thus reducing the opportunity for the research coordinator to act as an intermediary.

Table 9. Statistics of the Centrality and Personal Attributes of Research Coordinators in City A and County B

Primary index	Secondary index	Standard	City A	County B
Concentricity			0.275	0.197
Degree centrality	Absolute		53	66
	Relative	>0.7	0.757	0.688↓
Betweenness centrality	Absolute		49.922	18.355
	Relative	>0.02	0.020	0.004↓
Closeness centrality	Absolute		87	126
	Relative	<2.0	1.24	1.31
Gender			Male	Male
Age			51–55	51–55
Education background			Undergraduate	Undergraduate
Professional Title			Senior teacher	Senior teacher

Discussion

1. Factors Contributing to Disparities in the Two Regions Between Teaching and Research Exchange Structures: Variances in Teacher Numbers and Modes of Teaching

The teacher community in City A is relatively concentrated: In addition to the regional teaching and research office where the research coordinators are located, each school in City A has at least 5 geography teachers—enough to meet most teaching requirements within the school. Combined with the convenience of communication within the same school, a close-knit teaching and research community is easily formed within the school, reducing the need for inter-school communication. Therefore, most subgroups in City A are formed by teachers from the same school, with very few connections between subgroups. These patterns are consistent with findings from other countries. For example, research in the United States has shown that intra-school teacher networks play a crucial role in professional development and resource sharing (Coburn & Russell, 2008). In Japan, the concept of 'lesson study' to foster teacher collaboration (Lewis et al., 2006). These cases underscore the importance of cultivating teacher networks, even within individual school settings. Research coordinators are professional curriculum leaders (Cui, 2009). In City A, the research coordinators are responsible for educational assessment and coordinating regional curriculum development. The subgroup where they are located plays a leading role in the research communication network, forming a central subgroup. In contrast, the distribution of teachers in County B is scattered: There are 18 schools in County B with less than 5 geography teachers, and 9 of them have only 1 geography teacher. The shortage of geography teachers has led to the need for schools to collaborate with teachers from other schools to compensate for the lack of internal communication. This frequent exchange has fostered connections among teachers and a pattern of formation of educational research communities. Consequently, subgroups in County B are mainly composed of teachers from multiple schools, resulting in a complex network of relationships between teachers from the same school and different schools. Although the connections between subgroups are not as close as internal connections, they serve to amplify the group effects. Correspondingly, the dominant role of the research coordinators' subgroup in County B is relatively weakened. Therefore, there is no clear central subgroup in County B.

From the perspective of the teaching and research modes of schools in the two regions, in City A, the teaching research groups are divided based on subjects, meaning that teachers of the same subject, regardless of grade, are categorized into the same teaching research group. This practice is conducive to promoting joint professional development among teachers of the same subject within a school and also facilitates the transition and integration of subject knowledge across different grades. While enhancing the cohesion of teachers of the same subject within a school, this categorization also

increases teaching efficiency, leading to the dual improvement in the professional qualities of teachers and the academic performance of students.

In conclusion, the internal connections within the subgroups in City A are sufficient to meet daily teaching needs, while there appears to be a low necessity for connections between subgroups due to factors such as competition among subjects. This teaching and research mode has led City A to form a central–divergent subgroup structure.

County B categorizes groups by grade level, meaning that teachers in the same grade level, regardless of subject, are divided into the same teaching and research group. Such a model of teaching and research facilitates a school's management of teachers, but it results in limited opportunities for communication between teachers of the same subject across different grade levels, leading to insufficient familiarity and difficulties in forming close teaching and research communication relationships within the school. Due to the insufficient internal connections within the subgroups in County B to meet daily teaching needs, teachers turn their attention to teachers of the same subject and grade level from other schools and develop teaching and research exchange relationships with them. This practice contributes to the synergistic development of schools within the region, leading County B to form a network-interwoven subgroup structure.

2. Main Factors Impacting Core Teachers' Centrality and Roles: Variances in Educational Research Community Membership and Teaching/Research Exchange Structures across the Two Regions

City A is characterized by a central–divergent subgroup structure, with most members of each subgroup coming from the same institution. Core teachers in this city tend to engage in communication activities within their institutions, resulting in low overall participation in the network and creating barriers to communication between teachers from different institutions. As coordinators of educational development in the area, research coordinators utilize their connections to act as bridges for facilitating communication and the transfer of educational resources between different schools and teachers, thereby changing the situation. As a result, research coordinators in City A stand out in terms of their participation, intermediary role, and communication efficiency.

In contrast, County B has a network-interwoven subgroup structure, where different schools and teachers spontaneously form collaborative relationships. Information and resources between schools and teachers are typically shared, and core teachers have many opportunities for communication. Research coordinators in County B only need to act as intermediaries between teachers or teaching and research communities that lack the conditions for communication, without excessively interfering with existing connections. Therefore, the research coordinators in County B excel specifically in the intermediary role. Furthermore, compared to City A, communication efficiency among core teachers in County B is higher due to the county's network-interwoven structure, which provides broad pathways for information and resource transmission.

3. Social factors and female psychological characteristics influencing the vulnerability of young to middle-aged female teachers to marginalization

These factors and characteristics can be analyzed through the perspective of two aspects: social and psychological attributes of women. Studies show that professional women in China experience significant levels of role stress and that female role stress is significantly higher than that of males (Su et al., 2011). Moreover, high-end professional groups exhibit gender differences in work–family conflict, with women experiencing more severe effects from these conflicts than men (Li & Sun, 2013). On one hand, young to middle-aged female teachers face high expectations from families, schools, and society and bear the burden of family life and the heavy pressure of teaching. On the other hand, as society and the education sector undergo significant changes, these teachers also encounter difficulties in adapting to and changing their professional roles. In summary, role stress and role conflict make it difficult for young to middle-aged female teachers to balance family and work, hindering their active participation

in teaching and research activities. This stress and conflict lead to a lag in updating teaching knowledge and improving teaching skills, resulting in arrested career development. A prolonged sense of poor achievement makes this group prone to professional burnout, which gradually leads to their marginalization.

4. Consequences of differences in teaching and research exchanges and the impact of these consequences on educational equity

The achievement of educational equity depends on the elimination of regional disparities in educational levels. However, differences in teaching and research exchanges in different regions can lead to disparities in education levels, resulting in educational inequality. Vescio et al. (2008) found that teacher collaboration within and across schools significantly improves student outcomes and reduces educational disparities. Similarly, in Germany, teacher networks have been shown to facilitate the sharing of innovative pedagogies and resources, thereby promoting more equitable education systems (Kolleck et al., 2021).

Differences in the density and structure of teaching and research exchanges are key factors in increasing the disparity in educational levels within regions, which is particularly evident in regions with a central–divergent structure. Due to the apparent pattern followed by internal exchanges, the overall network density of teaching and research communication in regions with a central–divergent structure is low, which is not conducive to the sharing of educational resources and makes it difficult to achieve collaborative development among schools. Furthermore, schools with superior teaching facilities and welfare conditions form a clear "centralization effect," attracting high numbers of well-qualified teachers, thus widening the gap between schools in the region.

In regions with a network-interwoven structure, the lack of internal exchange conditions makes teachers and schools closely connected, and it is easy for teachers to form partnerships, thus promoting the synergistic development of schools in these regions and preventing a significant disparity in education levels.

The effective role of key teachers in the teaching and research communication network is crucial in improving regional education levels. Both core teachers and research coordinators are key players in regions, occupying a central position in the entire teaching and research communication network and thus possessing great influence. The effective performance of duties by these players is of vital importance in narrowing the education gap in regions and promoting educational equity.

Conclusion

Research Findings

This paper utilizes social network analysis to compare the characteristics and disparities of geography teachers' teaching and research exchanges in two regions: City A and County B and identifies the factors influencing the characteristics and causes of the disparities. A standard system for evaluating the level of regional teaching and research exchange is initially established at three levels: overall, group, and individual, and focus is placed on the overall level, group performance, and individual characteristics. The results of the study indicate that there are differences in the level of teaching and research exchanges between regions A and B, which can be summarized as follows: Firstly, the number of teachers and teaching and research modes influence the internal and external tendencies and structural patterns of teaching and research exchanges. Secondly, the variability of teachers' personal qualities and the structure of teaching and research exchanges has an impact on the characteristics and roles of core teachers in a region. Additionally, the differences in the research and communication structure lead to different role positioning for research coordinators in a region.

In summary, this study examines the impact of teacher professional exchanges on educational equity from a regional disparity perspective, revealing the relationship between teaching and research network structures and educational achievement gaps. This approach provides new insights for educational equity research, highlighting the crucial role of teacher collaboration in narrowing educational disparities.

Practical Recommendations

Based on the key findings regarding regional network structures and teacher exchange patterns, the study propose the following actionable measures:

1. Promote cross-school teaching and research networks: Establish inter-school collaboration platforms, particularly in resource-limited areas, to facilitate resource sharing and exchange of pedagogical experiences among teachers. For instance, regional teaching and research activities or online collaborative platforms can be utilized to break down barriers between schools.
2. Enhance professional support for research coordinators: Provide specialized training programs to improve coordinators' organizational and coordination skills, enabling them to better serve as bridges in teaching and research activities.
3. Encourage discipline-specific collaboration: Given geography's unique characteristics (e.g., interdisciplinary knowledge integration, field investigation requirements), schools should support geography teachers in developing cross-school and cross-disciplinary collaborative research activities.
4. Support career development of early/mid-career female teachers: Implement measures such as reasonable workload reduction and career development opportunities (e.g., mentorship programs) to better integrate this group into teaching and research networks and prevent marginalization. In summary, this study suggests that a region should prioritize teachers' research and communication to improve their teaching levels.

Study Limitations

The current research design presents two primary constraints:

1. Limited sample scope: The study focused solely on two regions in Jiangsu Province, which may not fully represent conditions in other areas (particularly regions with significant disparities in educational resource distribution).
2. Narrow disciplinary perspective: The research exclusively examined geography teachers without comparative analysis of other subject areas.

Future Research Directions

Building upon these limitations, the following research trajectories emerge as particularly valuable:

1. Expand the research scope: Incorporate additional regions (including other areas in China or international cases) to examine variations in teacher professional exchange patterns across different socioeconomic contexts.
2. Compare multidisciplinary collaboration models: Conduct comparative analyses between single-discipline and cross-disciplinary teacher collaboration approaches to identify discipline-specific challenges and opportunities.

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