

Supplementary Materials

Analysis of the Coupling Effects of Built and Environmental Factors on Researchers' Psychological Satisfaction with University Research Spaces Based on the Sparse Identification of Nonlinear Dynamics (SINDy) Algorithm

Hanyu Zhou, Junqi Li, Wenchang Wang and Changan Liu *

School of Architecture and Urban Planning, Shandong Jianzhu University, Jinan 250101, China

* Correspondence: liuchangan@sdjzu.edu.cn

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1. Common Sizes of Research Spaces in Universities

The study was conducted at Shandong Jianzhu University in Licheng District, Jinan City, Shandong Province. The climate features an annual average temperature of 14.7 °C and annual precipitation of 671.1 mm. Spring is characterized by frequent winds and dry conditions; summer is hot and rainy; autumn offers clear skies and pleasant weather; and winter is dry and cold for extended periods. Given that the university campus includes several newly constructed buildings, this survey focused primarily on older departmental buildings to ensure data generalizability. Additionally, certain disciplines were excluded due to specific requirements (e.g., light protection or controlled indoor temperatures required for particular reagents). The study covered 8 departmental buildings and 69 research spaces, with the following key findings (Table S1):

Table S1. Summary of research spaces survey at Shandong Jianzhu University.

Department Name	Room Number	Room Length: m	Room Width: m	Net Height of the Room (m):	Room Area (m ²)
Jianyi North Building	101	9	4.2	3.75	37.8
	102	9	4.2	3.75	37.8
	103	9	4.2	3.75	37.8
	104	9	4.2	3.75	37.8
	105	9	4.2	3.75	37.8
	106	9	4.2	3.75	37.8
	501	9	8.4	3.5	75.6
	502	9	8.4	3.5	75.6
	504	9	8.4	3.5	75.6
	505	9	8.4	3.5	75.6
	508	9	8.4	3.5	75.6
	509	9	8.4	3.5	75.6
	510	9	8.4	3.5	75.6
	511	9	8.4	3.5	75.6
	512	9	8.4	3.5	75.6
	50X	9	4.2	3.5	37.8
	ADA	14	3.5	3.5	49
Jianyi South Building	418-1	8.4	4.2	3.5	35.28
	418-2	8.4	4.2	3.5	35.28
	417-1	8.4	4.2	3.5	35.28
	417-2	8.4	4.2	3.5	35.28
	427-1	8.4	4.2	3.5	35.28
	427-2	8.4	4.2	3.5	35.28
	426-1	8.4	4.2	3.5	35.28
	426-2	8.4	4.2	3.5	35.28
	424	8.4	8.4	3.5	70.56
	425-1	8.4	4.2	3.5	35.28
	425-2	8.4	4.2	3.5	35.28
Jianyi South Building	419-1	8.4	4.2	3.5	35.28
	419-2	8.4	4.2	3.5	35.28
	420	8.4	4.2	3.5	35.28



Table S1. Cont.

Department Name	Room Number	Room Length: m	Room Width: m	Net Height of the Room (m):	Room Area (m ²)
science center	205(1)	7.2	3.6	3.5	25.92
	205(2)	7.2	3.6	3.5	25.92
	202	7.2	4.8	3.5	34.56
	203	7.2	4.8	3.5	34.56
	204	7.2	4.8	3.5	34.56
The passive south building of the complex	515(1)	8.8	5.2	3	45.76
	515(2)	9.6	5.6	3	53.76
	401(1)	12	4.8	3	57.6
	401(2)	5.8	5.2	3	30.16
	401(3)	5.8	3.4	3	19.72
	404	7.6	6.8	3	51.68
Thermal Energy Engineering Building	204	7.2	3.6	3.5	25.92
	206	7.2	3.6	3.5	25.92
	208	7.2	3.6	3.5	25.92
	210	7.2	3.6	3.5	25.92
	212	7.2	3.6	3.5	25.92
	214	7.2	3.6	3.5	25.92
	216	7.2	3.6	3.5	25.92
	218	7.2	3.6	3.5	25.92
	220	7.2	3.6	3.5	25.92
	310	10.8	7.2	3.5	77.76
Civil Building	308	10.8	7.2	3.5	77.76
	214	7.2	5.4	3.5	38.88
	216	7.2	5.4	3.5	38.88
	513	7.2	5.4	3.5	38.88
	514	7.2	5.4	3.5	38.88
	515	7.2	5.4	3.5	38.88
	516	7.2	5.4	3.5	38.88
Foreign Languages Building	517	3.6	5.4	3.5	19.44
	401	7.2	4.8	3.5	34.56
	402	7.2	4.8	3.5	34.56
	403	7.2	4.8	3.5	34.56
North Building of the Information Center	404	7.2	4.8	3.5	34.56
	201	8.4	4.2	3.5	35.28
	202	8.4	4.2	3.5	35.28
South Building of the Information Center	102	7.8	7.8	3.5	60.84
	104	7.8	7.8	3.5	60.84
	105	4.2	7.8	3.5	32.76

Based on the collected data, analysis of the size distribution of the surveyed research spaces reveals that their areas generally range from 20 to 80 square meters: two spaces under 20 m², eleven between 20–30 m², thirty-one between 30–40 m², two between 40–50 m², three between 50–60 m², two between 60–70 m², eight between 70–80 m², and four exceeding 80 m². The quantitative relationship is illustrated in Figure 1:

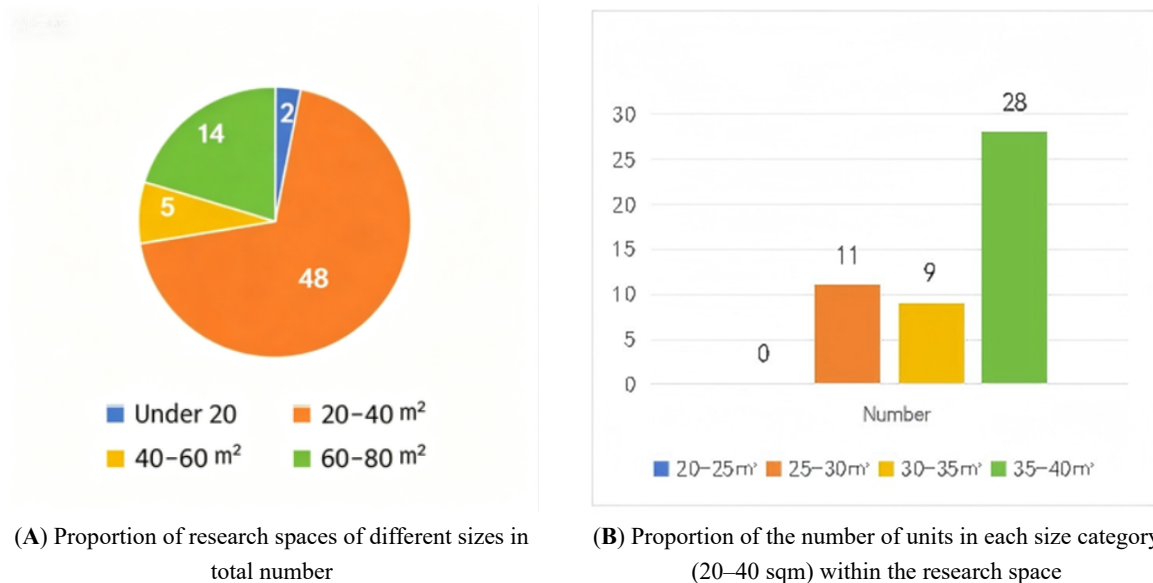


Figure 1. Analysis of the scale of scientific research spaces.

It is evident that at Shandong Jianzhu University, research spaces ranging from 20 to 40 square meters constitute the majority, accounting for 69.6% of all space categories, followed by those measuring 60–80 square meters (20.3%). Consequently, 23 such research spaces were selected for detailed investigation, with the findings presented below:

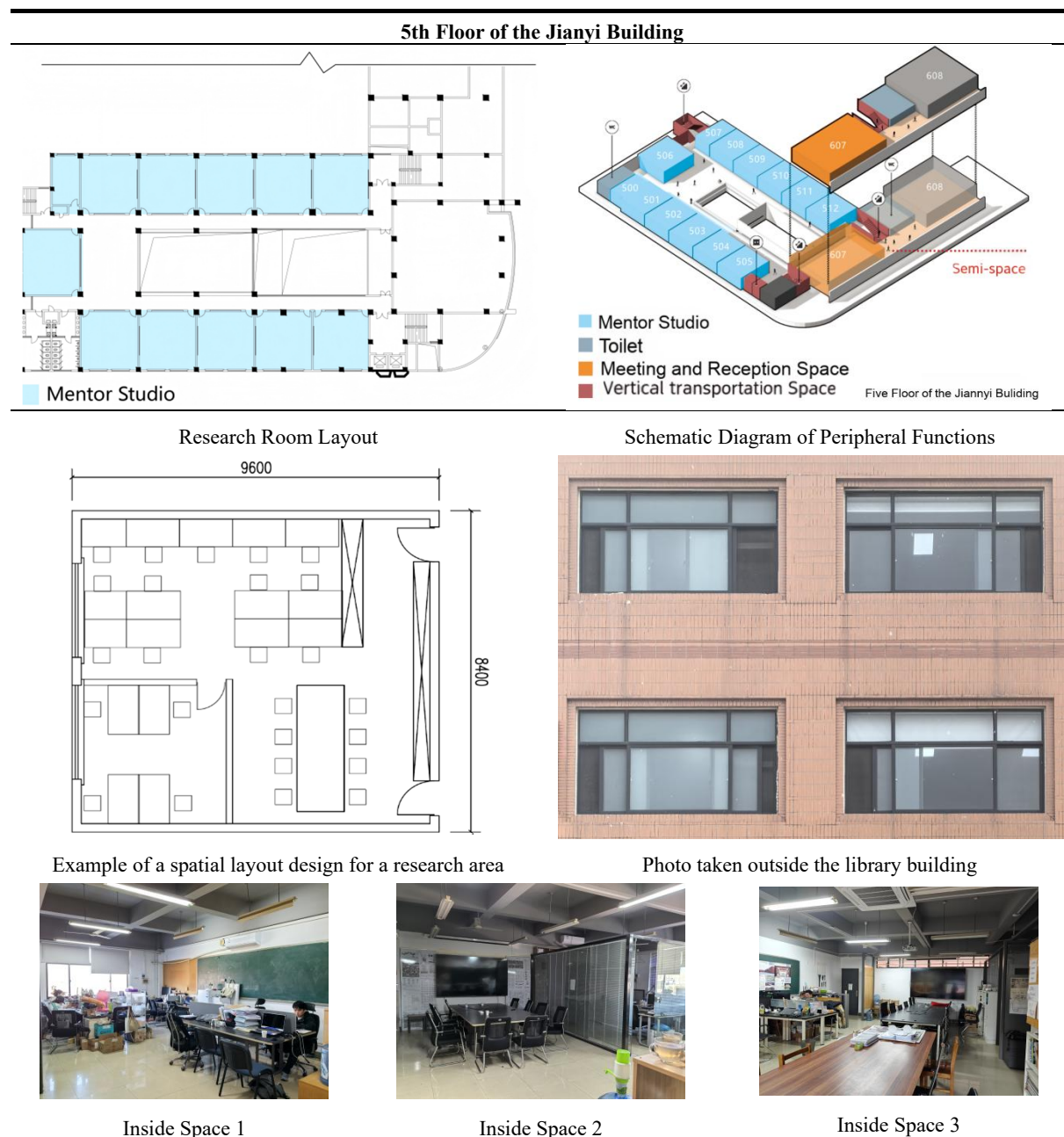
- (1) Jianyi building is located on the 1st floor of the building (there are 7 such halls in total).
 - (a) The primary resident population in the surveyed research space consists of graduate students and their supervisors.
 - (b) Average number of residents: 8
 - (c) Average depth: 9 m
 - (d) Average bay width: 4.2 m
 - (e) Average length-to-width ratio: 2.14:1
 - (f) Average net height: 3.75 m
 - (g) Average Area: 37.8
 - (h) Average window-to-floor ratio: 1/8
 - (i) View outside the window: Abundant natural surroundings
 - (j) Average number of supervisors per room: 2
 - (k) The average area allocated per indoor research space mentor is approximately 18.9 square meters per person.
 - (l) Per capita usable space in research laboratories (for supervisors and graduate students): approximately 4.725 m² per person
 - (m) Research Photo (Table S2):

Table S2. Photos of the research spaces survey on the first floor of Jianyi Building.



- (2) Jianyi Building is located on the 5th floor of the main building (there are 10 such floors).
- The primary resident population in the surveyed research space consists of graduate students and their supervisors.
 - Average number of permanent staff: 13
 - Average depth: 9 m
 - Average bay width: 7.98 m
 - Average length-to-width ratio: 1.1:1
 - Average net height: 3.5 m
 - Average Area: 71.82
 - Average window-to-floor ratio: 1/8
 - View outside the window: Abundant natural surroundings
 - Average number of supervisors per room: 4
 - The average area allocated per indoor research space mentor is approximately 17.96 square meters per person.
 - Per capita usable space in research laboratories (for supervisors and graduate students): approximately 5.52 m² per person
 - Research Photo (Table S3):

Table S3. Photos of the research spaces survey on the fifth floor of Jianyi Building.



- (3) Passive building units: floors 4–5 (total of 6 units)
- The primary resident population of the surveyed research space is graduate students.
 - Average number of residents: 9
 - Average depth: 8.2 m
 - Average bay width: 5.1 m
 - Average length-to-width ratio: 1.6:1
 - Average net height: 3 m
 - Average Area: 43.11 sqm
 - Average window-to-floor ratio: 1/8
 - View outside the window: Abundant natural surroundings
 - Per capita usable space in research laboratories (for graduate students): approximately 5.51 m² per person
 - Research Photo (Table S4):

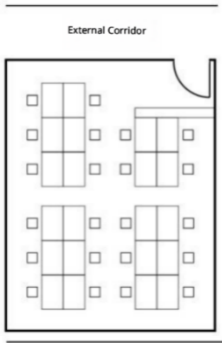
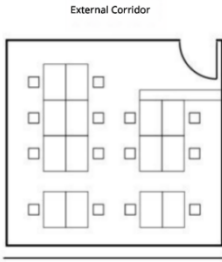
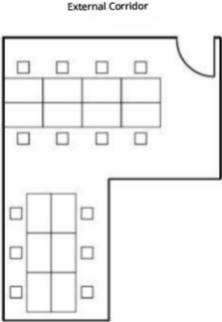
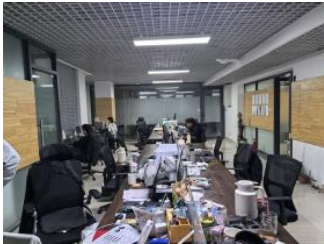
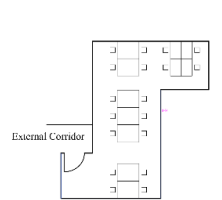
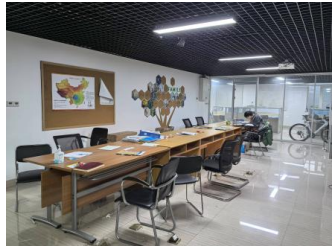
Table S4. Survey of floors 4–5 in the Passive Building.



2. The Spatial Location and Spatial Morphology of Research Spaces in Universities

The survey revealed that three primary planar configurations are used in research spaces: rectangular, square, and L-shaped. Among these, rectangular plans account for 82.6% of the total sample, making them the most common configuration (Table S5).

Table S5. Survey of location and spatial configuration of University Research Spaces.

Planar Form	Graphic	Merit	Shortcoming	Research Photo
Rectangular Plane		Facilitates furniture placement and space planning	Lack of innovation	
Square Plane		Balanced layout with uniform spatial distribution	Not flexible enough	
L-shaped plane		Provide flexibility in functional zoning	The corner may lead to inefficient use of space	
Combined Plane		Suitable for spaces with various functional combinations to meet different office needs	Low spatial utilization efficiency and poor furniture adaptability	

3. Internal Functional Layout of Research Spaces in Universities

Classification of Research Spaces: Based on the spatial distribution of supervisors' work areas within the building (Table S6).

Classification of Research Spaces: Based on the allocation of functional zones in supervisors' workspaces (Table S7).

Statistical analysis of the surveyed subjects revealed that research spaces primarily centered around supervisors' work areas accounted for 21.7%, while those predominantly dedicated to graduate students constituted 78.3%. Among these, only one case involved a research space located adjacent to a supervisor's work area.

Table S6. Classification of research spaces: Based on the spatial distribution of supervisors' work areas within the building.

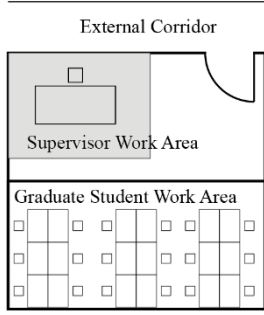
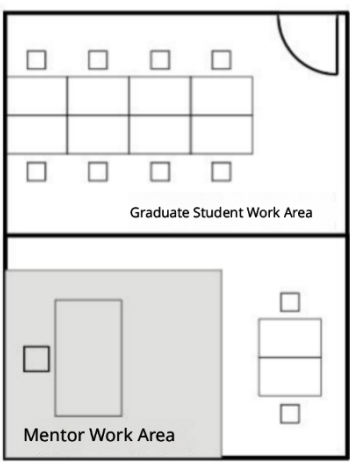
Type	Legend	Merit	Shortcoming
The mentor's workspace is located on the outside.		When a supervisor's workspace is externalized, it is typically designed with an open layout that prioritizes accessibility over privacy, enabling effective supervision of graduate students' work and enhancing their academic efficiency.	There may be significant noise interference near the corridor side, which could affect the supervisor's work efficiency.
The mentor's workspace is located inside.		If a mentor workspace is built-in, it typically features a private layout that prevents storage cabinets, bookshelves, or other furniture from dividing the space. This provides mentors with a better working environment and ensures higher productivity.	The built-in tutor workspace may limit interaction between tutors and students, and could also lead to inefficient space utilization due to its more enclosed layout.

Table S7. Classification of Research Spaces: Based on the allocation of functional zones in supervisors' workspaces.

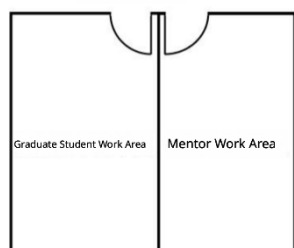
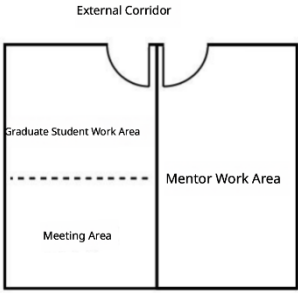
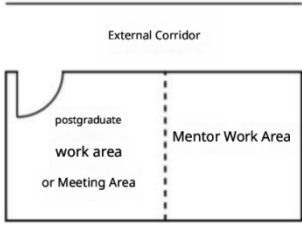
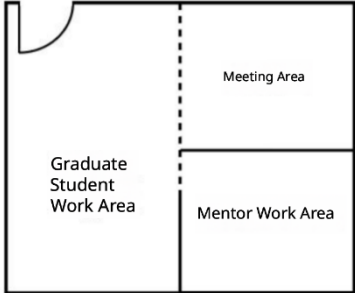
Type	Legend	Merit	Shortcoming
The graduate student workspace is separated from the supervisor's workspace.		It helps both supervisors and students maintain independent workspaces, enhancing focus and privacy during work.	This leads to reduced daily interactions between teachers and students, impairing timely communication and team collaboration efficiency.

Table S7. Cont.

Type	Legend	Merit	Shortcoming
The graduate student workspace and meeting area have been merged, while the supervisor's workspace remains independent.		It facilitates academic and competition-related exchanges among graduate students, providing supervisors with a quieter and more focused working environment.	Reducing the supervisory role of supervisors over graduate students and diminishing communication between teachers and students may lower their learning efficiency.
Combined workspace for graduate students (or meeting area) and supervisor's workspace		It helps enhance communication and guidance between teachers and students, facilitates resource sharing and timely problem resolution, enables effective supervision of graduate students, thereby improving their work efficiency.	This may compromise certain aspects of personal privacy, increase the risk of mutual interference, and potentially have adverse effects on tasks or studies requiring high levels of concentration.
Integrated workspace for graduate students, supervisors, and meetings		This facilitates quick meetings between supervisors and their graduate students for knowledge sharing and improved team collaboration efficiency.	Frequent meeting discussions may disrupt the progress of graduate students in certain academic years, causing some disruption.

4. The Interaction between Indoor and Outdoor of Research Spaces in Universities

4.1. Viewing Direction

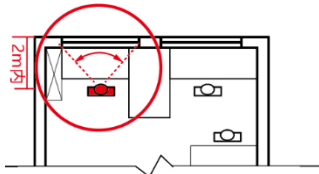
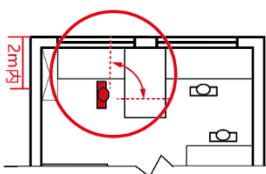
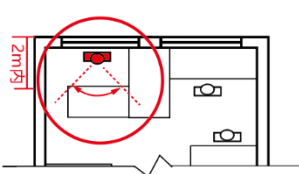
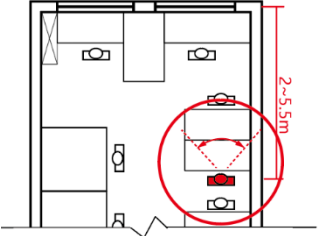
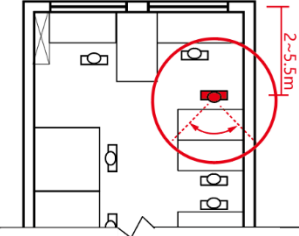
The research revealed three primary user positioning scenarios within the mentor studio relative to windows: line of sight parallel to the window, line of sight perpendicular to and away from the window, and line of sight perpendicular to and toward the window. Although viewing directions are not explicitly defined in window view design standards and guidelines (EN 17370, SLL, LEED v4, WELL v2)—likely due to the complexity of practical design scenarios—the viewing direction significantly impacts aspects of window views within the user's field of view, such as the percentage of visible window area and glare intensity.

4.2. Distance to the Window

The distance from workstation to window refers to the spatial separation between the work station and the window. During the research, this relationship was categorized into three scenarios: less than 2 m, 2–5.5 m, and above 5.5 m.

Schematic diagram of the relationship between researchers and windows, as well as perspective relationships, as shown in Table S8.

Table S8. Schematic diagram of the relationship between researchers and windows, as well as perspective relationships.

	From the Window Perspective (Sitting Facing the Window)	From the Window Perspective (Sitting by a Side Window)	From the Window Perspective (Sitting Back)
Distance between workstation and window <2 m			
Distance between workstation and window 2~5.5m			
Distance between workstation and window >5.5 m	