

Network structure of education quality elements for Chinese Master of Nursing Specialist students: a GLASSO network analysis of interaction effects and core hub identification

rong zhao

fyzhaorong@sdsu.edu.cn

Affiliated Hospital of Shandong Second Medical University

Liyan Jia

Affiliated Hospital of Shandong Second Medical University

Cuiping Wang

Affiliated Hospital of Shandong Second Medical University

Fenglin Wang

Affiliated Hospital of Shandong Second Medical University

Ying Wang

School of Health and Life Sciences, University of Health and Rehabilitation Sciences

Research Article

Keywords: Master of Nursing Specialist, education quality, network analysis, supervisor support, interaction effect

Posted Date: October 23rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11019836/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background and aims Globally, master's-level nursing education faces the challenge of simultaneously cultivating high-level clinical competence and research capacity. China's distinctive dual-mentorship and dual-site training model provides a unique context for examining this issue. This study aimed to investigate interaction effects among dimensions of education quality in Master of Nursing Specialist (MNS) programmes and to identify core hub nodes within the education quality network.

Methods A cross-sectional survey was conducted among 130 full-time MNS students who had completed at least 12 months of clinical rotations, across 24 tertiary hospitals in China. Hierarchical linear regression assessed the interaction effect of management service and supervisor support on output quality. Quantile regression (25th, 50th, and 75th percentiles) examined whether the association between process quality and output quality varied by output level. A regularised graphical LASSO (GLASSO) network analysis was used to identify the core nodes and network structure of education quality; network stability was evaluated using bootstrap resampling (1,000 iterations, 80% subsamples), with a correlation stability coefficient (CS-coefficient) > 0.25 considered acceptable.

Results Hierarchical regression showed a significant positive interaction between management service and supervisor support ($\beta = 0.159, p = 0.015$). Quantile regression indicated that the slope difference between the 25th and 75th percentiles was -0.142 (95% CI: -0.299 to 0.015), which was not statistically significant, suggesting that the positive effect of process quality was consistent across students at different output levels. GLASSO network analysis identified three core hub nodes—supervisor support, research ability, and clinical practice ability (degree centrality = 6)—with a multi-centre, flat network structure and acceptable stability (CS-coefficient = 0.515).

Conclusions The MNS education quality network exhibits a multi-centred, flat architecture, with supervisor support, research ability, and clinical practice ability as the three core hubs. There is a synergistic gain between management service and supervisor support. The positive effect of process quality was consistent across students at different output levels, with no statistically significant evidence of a differential compensatory effect. These findings suggest that quality management in MNS programmes should target the coordinated development of the three core hubs rather than uniformly improving all dimensions.

Introduction

Globally, the expansion of advanced nursing practice education has consistently been accompanied by a central dilemma: how to balance the cultivation of high-level clinical competence and research capacity within the same programme. This is not merely a curriculum design issue—it more fundamentally reflects a structural integration challenge between academic training at universities and clinical practice learning. Whether in Doctor of Nursing Practice (DNP) programmes in the United States [1], advanced practice nursing education in the United Kingdom [2], or comparable master's programmes across Asia, educators confront the same fundamental question: how do the structural elements of the educational process

interact to jointly shape student outcomes? This global training dilemma has received sustained attention in recent international nursing education literature [3].

Since 2010, China has formally established Master of Nursing Specialist (MNS) education. This programme employs a dual-mentorship model (academic and clinical mentors co-supervising) [4, 5] and a dual-site training model (alternating between university and hospital) [6, 7]. This educational design is not an isolated case but a strengthened version of the global challenge of integrating theory and practice in clinical nursing education. Therefore, it constitutes a valuable educational practice case for examining how different dimensions of process quality (e.g. institutional support, interpersonal guidance, and curriculum design) jointly influence student outcomes within a complex, multi-site educational system.

In recent years, notable progress has been made in the evaluation of master's nursing education quality. Internationally, the student success model developed by Sanderson et al. [8] emphasises that quality assurance should simultaneously address the integration of institutional support, instructional delivery, and personal development. The concept analysis by Flott and Linden [9] identified four attributes of the clinical learning environment: physical space, psychosocial and interaction factors, organisational culture, and teaching and learning elements; these attributes jointly shape students' learning outcomes and professional confidence. A multicentre study by Papastavrou et al [10] confirmed that students with a named mentor were more satisfied with the clinical learning environment, and the named mentor relationship was considered the most successful mentorship model. In China, Zhao et al [11] developed a three-dimensional evaluation framework comprising input quality, process quality, and output quality; weighting analysis showed that process quality had the highest weight (0.608). Based on this framework, they developed a process quality evaluation scale comprising four dimensions: management service, supervisor support, curriculum and instruction, and learning engagement [12]. Huang et al [13] further confirmed that the construction of clinical practice bases is a weak link in MNS education quality assurance.

Although the above studies have laid the foundation for understanding MNS education quality, three notable gaps remain in the existing literature. First, there is a lack of an “interaction effects” perspective. Most studies have employed linear regression, treating each dimension as an independent predictor and overlooking potential synergistic effects among dimensions. Tinto's student integration theory [14] explicitly states that the synergistic effects of academic and social integration can effectively promote student development. Hobfoll's conservation of resources theory [15] likewise indicates that resource acquisition is cumulative, with initial resource gains triggering a further resource gain spiral. Together, these two theories suggest that significant interaction effects may exist among process quality dimensions, yet this has not been empirically tested in the field of MNS education quality. Second, there is a lack of a “systemic structure” perspective. Existing research cannot answer a key question: within the overall system of MNS education quality, which elements serve as the core hubs connecting the whole? Network analysis [16] provides a methodological tool for this purpose, identifying core and peripheral nodes in a network by estimating regularised partial correlations among variables. This method has seen preliminary application in nursing education, such as Wu et al [17] network analysis of self-reflection and

empathy among nursing students and Miao et al [18] network analysis of interpersonal sensitivity and self-efficacy, both of which have demonstrated its unique value; however, it has not yet been introduced into the field of MNS education quality. Third, student heterogeneity has been neglected. Does the effect of process quality on students at different output levels differ across individuals? If process quality has a stronger positive effect on low-output students, educational administrators should adopt differential intervention strategies; otherwise, they should focus on system-wide enhancement. Sanderson et al [8] student success model emphasises that institutional support (e.g. cocurricular student support systems) plays an important protective role in student success.

In summary, building on the four-dimensional process quality framework developed by Zhao et al [12], this study adopts dual perspectives of “variable interaction” and “system structure” to address the following three research questions: (1) Is there a significant interaction effect between management service and supervisor support? (2) Does the relationship between process quality and output quality differ across students at different output levels? (3) What network structure is formed by MNS education quality elements, and what are the core hub nodes?

Methods

Study design

This study employed a cross-sectional survey design and was reported in accordance with the STROBE guidelines.

Ethical considerations

This study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the Ethics Committee of the Affiliated Hospital of Shandong Second Medical University (Approval No. SDSMU-2026-at-45). All participants provided written informed consent and were informed of the study objectives, data use, and confidentiality principles. Participation was voluntary, and participants could withdraw at any time.

Setting and background

The study was conducted across 24 tertiary hospitals in China. MNS education in China employs a distinctive dual-mentorship model—academic mentors are responsible for cultivating research ability, while clinical mentors are responsible for developing clinical practice ability—and a dual-site training model, in which students complete theoretical coursework at the university and undertake no less than 12 months of clinical rotations at clinical practice bases. This institutional design constitutes the background of this study and an important boundary condition for the generalisability of the findings. Given differences in specific rotation arrangements across training institutions, this study did not perform stratified sampling by hospital type or region. The findings therefore reflect the overall characteristics of

multi-centre collaborative training within this institutional framework and are generalisable to MNS programmes with similar dual-track training models.

Participants

A convenience sampling approach was used to recruit full-time MNS students who had completed clinical rotations between December 2020 and January 2021. The inclusion criteria were as follows: (1) full-time enrolled MNS students; (2) at least 12 months of clinical practice completed; (3) voluntary participation. The exclusion criteria were as follows: (1) absence from study or withdrawal during the survey period; (2) incomplete questionnaires or patterned responding. A total of 158 questionnaires were distributed, and 130 valid responses were collected (valid response rate = 82.3%). The a priori sample size was estimated using G Power 3.1: statistical power ($1 - \beta$) = 0.80, significance level α = 0.05, medium effect size f^2 = 0.15, with up to eight predictors in the maximum regression model; the minimum required sample size was 107. The final sample of 130 met this requirement.

Variables and measurement tools

Based on the MNS education quality evaluation framework developed by Zhao et al [11], an education quality questionnaire was developed for this study, comprising three modules: input quality, process quality, and output quality. The process quality module used the previously published MNS student education process quality scale developed by Zhao et al [12]. The remaining components—the input quality module, the objective output indicators, and the Personal Development Self-Evaluation Scale—were developed for this study, and their English version is provided in Additional file 1. The input quality module collected demographic characteristics (age, sex, grade, and highest educational level), clinical work experience (yes/no), and motivations for pursuing graduate study (intrinsic and extrinsic motivation; binary variables: 1 = yes, 0 = no). The process quality module used the MNS student education process quality scale developed by Zhao et al [12], covering four dimensions—management service, supervisor support, curriculum and instruction, and learning engagement—with a total of 44 items. A five-point Likert scale was used (1 = strongly disagree, 5 = strongly agree). In this study, Cronbach's α for this scale was 0.979. In addition, daily study time (hours/day; open-ended) and frequency of participation in academic activities (times/semester; open-ended) were collected as behavioural indicators. The output quality module comprised objective indicators (theory knowledge examination scores, number of publications, and number of patents) and subjective evaluation. The subjective evaluation used a self-developed Personal Development Self-Evaluation Scale, covering four dimensions—research ability, clinical practice ability, career preparation, and motivation transfer—with 20 items rated on a five-point Likert scale. In this study, Cronbach's α for this scale was 0.971.

Data collection

Data were collected using the Wenjuanxing (Questionnaire Star) online survey platform. The survey homepage provided standardised instructions describing the study purpose, data use, and confidentiality, and included an informed consent form. Participants read the information and provided informed consent online before completing the survey. Data collection followed the principles of anonymity and voluntary participation. Each IP address was permitted to submit only once, and questionnaires completed in less than 180 seconds were considered invalid and excluded. The survey data were exported and cross-checked by the research team to form the final analysis dataset.

Statistical analysis

Data were analysed using Python 3.12 and R 4.6.1. Continuous variables are presented as mean $\pm$ standard deviation, and categorical variables as counts (percentages). Network analysis. The network was constructed with eight core variables as nodes, and the network structure was estimated using the GLASSO regularised partial correlation algorithm. The regularisation parameter was fixed at $\alpha = 0.050$ [16]. Node centrality was assessed using degree, betweenness, and closeness centrality. Network stability was evaluated using bootstrap resampling [19] (1,000 resamples, 80% subsamples), with a CS-coefficient > 0.25 considered acceptable [16]. Hierarchical regression. Hierarchical regression was used to test the main effects of process quality dimensions on output quality and the interaction effect between management service and supervisor support, controlling for sex, grade, and clinical work experience [20]. ΔR^2 and effect size f^2 were reported, with 95% CIs estimated via bootstrap (1,000 resamples) [19]. When the interaction term was significant, simple slope analysis (standard errors estimated using the delta method) and Johnson–Neyman threshold analysis were conducted [21]. Quantile regression. Quantile regression (25th, 50th, and 75th percentiles) was used to examine differential associations between process quality and different levels of output quality [22]. Differences between quantile slopes were tested by estimating the 95% CI of the slope difference via bootstrap (1,000 resamples) [19]. Common method bias and robustness checks. Harman's single-factor test was used to assess common method bias, with dimension-level means as the primary analytical approach and item-level data as the sensitivity analysis approach [23]. Robustness was evaluated using bootstrap [19] (1,000 resamples) and outlier removal, with outliers defined as observations exceeding the mean ± 3 standard deviations [24]. All tests were two-tailed, with $p < 0.05$ considered statistically significant.

Results

General characteristics of the study participants

A total of 130 Master of Nursing Specialist (MNS) students were enrolled in this study. Regarding demographic characteristics, there were 8 male (6.2%) and 122 female (93.8%) participants; 78 were in the second year (60.0%) and 52 in the third year (40.0%); 20 had clinical work experience (15.4%) and 110 did not (84.6%); the mean age was 24.32 ± 1.72 years. Regarding motivations for pursuing graduate study, “grow my knowledge” and “obtain higher economic returns” were the most frequently reported (both 62.3%). Regarding behavioural indicators, the mean daily study time was 6.29 ± 3.04 hours/day, and the two most frequently reported academic activities were attending hospital-organised academic

conferences (79.2%) and participating in supervisors' research projects (71.5%). The mean scores of the process quality dimensions ranged from 3.70 to 4.09, with supervisor support scoring highest (4.09 ± 0.72), followed by management service (3.86 ± 0.69) and learning engagement (3.83 ± 0.74), while curriculum and instruction scored relatively lower (3.70 ± 0.73); the overall process quality score was 3.90 ± 0.61 . The mean scores of the output quality dimensions ranged from 3.76 to 4.05, with research ability scoring highest (4.05 ± 0.63), followed by career preparation (3.98 ± 0.71) and clinical practice ability (3.93 ± 0.70), while motivation transfer scored relatively lower (3.76 ± 0.76); the overall output quality score was 3.96 ± 0.61 . Regarding objective indicators, 48 participants had published papers (36.9%), with a total of 77 publications; 13 participants held granted patents (10.0%), with a total of 10 granted patents.

Between-group differences in education quality scores

No statistically significant between-group differences in process quality or output quality were found for demographic characteristics (all $p > 0.05$). Correlations of age with process quality and output quality were $r = -0.064$ ($p = 0.468$) and $r = 0.113$ ($p = 0.202$), respectively. See Table 1.

Table 1

Between-group differences in process quality and output quality by demographic characteristics ($n = 130$)

Grouping variable	Comparison category	Statistic	Process quality total score			Output quality total score		
			Test statistic	P value	Cohen's d	Test statistic	P value	Cohen's d
Gender	Male vs. Female	t	0.809	0.420	0.295	0.656	0.513	0.239
Grade	Second year vs. Third year	t	-1.425	0.156	-0.255	-1.574	0.118	-0.282
Clinical experience	Yes vs. No	t	0.344	0.731	0.084	0.793	0.429	0.193
Age	Continuous variable	r	-0.064	0.468	—	0.113	0.202	—

Note: t= independent samplest-test;r= Pearson correlation coefficient; — = not applicable.pvalues are two-tailed, with $p < 0.05$ considered statistically significant. Cohen'sdis reported as a measure of effect size.

Main and interaction effects of process quality dimensions on output quality

Using sex, grade, and clinical work experience as control variables, hierarchical regression analysis was conducted. Model 1 (main effects model) explained 71.4% of the variance in output quality ($R^2 = 0.714$). Management service ($\beta = 0.477, p < 0.001$), supervisor support ($\beta = 0.269, p < 0.001$), and learning engagement ($\beta = 0.154, p = 0.001$) were significantly positively associated with output quality; the independent association of curriculum and instruction was not significant ($\beta = -0.067, p = 0.345$). Model 2

added the interaction term between management service and supervisor support to Model 1, and the results showed a significant interaction effect ($\beta = 0.159, p = 0.015$), $\Delta R^2 = 0.014$, effect size $f^2 = 0.051$. Bootstrap 95% confidence intervals showed that the CI for ΔR^2 was [0.001, 0.038] and the CI for the interaction β was [0.032, 0.261], neither of which included zero, indicating a significant positive interaction effect between management service and supervisor support. After removing the control variables, the interaction coefficient remained significant, consistent in direction with the main results, further supporting the robustness of the interaction effect. See Table 2 for details.

Table 2
Hierarchical regression analysis of process quality dimensions on output quality (n = 130)

Variable	Model 1 (β)	Model 2 (β)	pvalue
Management service	0.477	0.444	< 0.001
Supervisor support	0.269	0.310	< 0.001
Curriculum and instruction	-0.067	-0.069	0.325
Learning engagement	0.154	0.139	0.003
Management service $\times$ Supervisor support	—	0.159	0.015
R ²	0.714	0.728	
ΔR^2		0.014	

Note: All variables were mean-centred. Mean-centring only changes the interpretation of the intercept and does not change the magnitude or sign of the regression coefficients.

Simple slope analysis of the effect of management service on output quality at different levels of supervisor support

Simple slope analysis showed that the slope of management service on output quality increased across low, mean, and high levels of supervisor support: 0.341 ($p = 0.001$, 95% CI [0.148, 0.535]) at the low level (-1 SD), 0.449 ($p < 0.001$, 95% CI [0.290, 0.608]) at the mean level, and 0.556 ($p < 0.001$, 95% CI [0.387, 0.726]) at the high level ($+1$ SD). Johnson–Neyman threshold analysis indicated that the effect of management service was non-significant below a raw score of 2.832 of supervisor support and became significant above this threshold, suggesting that the association between management service and output quality became stronger as supervisor support increased. Given that the observed range of supervisor support in the present sample exceeded this threshold, the positive effect of management service on output quality was statistically significant across the entire observed range of supervisor support. See Table 3 and Fig. 1 for details.

Table 3
Simple slope analysis of the effect of management service on output quality at different levels of supervisor support

Level of supervisor support	Raw score	Slope	SE	t	p	95% CI
Low (– 1 SD)	3.37	0.341	0.098	3.490	0.001	[0.148, 0.535]
Mean	4.09	0.449	0.080	5.582	< 0.001	[0.290, 0.608]
High (+ 1 SD)	4.80	0.556	0.086	6.491	< 0.001	[0.387, 0.726]
Note: Calculated based on mean-centred variables. J–N (Johnson–Neyman) threshold = 2.832 (raw score).						

Nodes: The slope of management service on output quality at three levels of mentor support (– 1 SD, Mean, + 1 SD). Error bars represent 95% CI. The dashed vertical line indicates the Johnson–Neyman threshold (2.832); the green shaded region indicates where the slope is significant ($p < 0.05$), and the red shaded region indicates non-significance.

Quantile regression analysis of the effect of process quality on output quality

Quantile regression analysis showed that the slopes of process quality at the 25th, 50th, and 75th percentiles were 0.868, 0.962, and 0.744, respectively. The difference in slopes between the 25th and 75th percentiles was – 0.142 (bootstrap 95% CI [– 0.299, 0.015]). The CI included zero, indicating that the gradient difference was not statistically significant: the positive effect of process quality was consistent across students at different output levels, without evidence of a differential compensatory effect. See Table 4 and Fig. 2 for details.

Table 4
Quantile regression analysis of the effect of process quality on output quality

Percentile	Slope	Bootstrap 95% CI
25th	0.868	[0.763, 0.974]
50th	0.962	[0.851, 1.074]
75th	0.744	[0.583, 0.905]
Difference in slopes (75th – 25th)	–0.142	[– 0.299, 0.015]
Note: CI, confidence interval. The 95% CI for the difference in slopes was estimated using bootstrapping with 1,000 resamples.		

Nodes Gray dots represent individual samples ($n = 130$). Red, blue, and green lines represent the 25th, 50th, and 75th quantile regression lines, respectively. The text box in the lower right corner reports the difference in slopes between the 25th and 75th percentiles (– 0.142) and its 95% confidence interval ([– 0.299, 0.015]).

Construction and centrality identification of the education quality network

GLASSO regularised network analysis identified 20 edges (density = 0.714). Centrality analysis showed that the network exhibited a multi-centre, flat structure, in which supervisor support, research ability, and clinical practice ability were the three core hubs (degree centrality = 6), followed by management service, career preparation, and motivation transfer (degree centrality = 5), curriculum and instruction (degree centrality = 4), and learning engagement (degree centrality = 3). Stability analysis (CS-coefficient =) indicated that the centrality estimates were reliable. See Table 5 and Fig. 3.

Table 5

Centrality rankings of nodes in the MNS education quality network (based on 8 core variables,n = 130)

Rank	Node	Degree centrality	Normalised degree centrality	Betweenness centrality	Closeness centrality	Role
1	Supervisor support	6	0.857	0.056	0.875	Core hub
1	Research ability	6	0.857	0.091	0.875	Core hub
1	Clinical practice ability	6	0.857	0.056	0.875	Core hub
4	Management service	5	0.714	0.028	0.778	Important node
4	Career preparation	5	0.714	0.056	0.778	Important node
4	Motivation transfer	5	0.714	0.012	0.778	Important node
7	Curriculum and instruction	4	0.571	0.056	0.700	Second-tier node
8	Learning engagement	3	0.429	0.028		

Note:Role classification was based on degree centrality values: degree centrality = 6 was classified as a core hub, degree centrality = 5 as an important node, degree centrality = 4 as a second-tier node, and degree centrality ≤ 3 as a peripheral node. CS-coefficient (correlation stability coefficient) =, indicating that the network structure was stable.

Nodes: represent the eight core variables; edges represent regularised partial correlations. Node colours indicate hierarchical levels: red = core hubs (degree = 6), orange = important nodes (degree = 5), yellow = second-tier nodes (degree = 4), and grey = peripheral nodes (degree ≤ 3). Edge thickness is proportional to the absolute value of the regularised partial correlation.

Testing for common method bias

Because this study used a cross-sectional design and all variables were obtained from student self-report questionnaires, there was a potential risk of common method bias (CMB). To assess this threat, Harman's single-factor test was used. At the dimensional level, the first unrotated principal component accounted for 68.9% of the variance, exceeding the conventional threshold of 40%, suggesting some degree of CMB in the dimensional-level data. However, aggregation at the dimensional level may itself inflate estimates of CMB because it eliminates item-level measurement error and within-dimension unique variance. To further examine this finding, a supplementary analysis was conducted at the original item level (75 items). The results showed that the first unrotated principal component accounted for 41.8% of the variance, which was close to but slightly above the commonly accepted threshold of 40%, indicating that the threat of CMB at the item level was at the margin of the acceptable range.

Nevertheless, the key findings of this study—the interaction effect between management service and supervisor support ($\beta = 0.159, p = 0.015$) and the GLASSO network partial correlation structure—are higher-order statistical relationships. Such relationships involve complex patterns among variables and are unlikely to be fully explained by a single common method factor. In addition, the interaction effect remained significant after the control variables were removed ($\beta = 0.150, p = 0.017$), further ruling out a method factor as the primary explanation.

Robustness checks

To assess the robustness of the core results, several sensitivity analyses were conducted. First, bootstrap 95% confidence intervals (CIs) for the interaction effect showed that the CI for ΔR^2 was [0.001, 0.038], the CI for f^2 was [0.002, 0.155], and the CI for the interaction β was [0.032, 0.261]; none of which included zero, indicating that the interaction effect remained stable under resampling. Second, after removing the control variables (sex, grade, and clinical work experience), the interaction coefficient remained significant ($\beta = 0.150, p = 0.017, \Delta R^2 = 0.013$), with a direction consistent with the main results, indicating that the inclusion of demographic control variables did not substantially affect the interaction effect. Third, no extreme values exceeding the mean ± 3 standard deviations were detected in the data, ruling out potential interference from outliers. Fourth, post hoc power analysis showed that the post hoc statistical power for the interaction effect was 0.857, above the recommended threshold of 0.80, indicating that the current sample size ($n = 130$) was sufficient to support the reliability of the interaction effect estimate.

In summary, although the dimensional-level Harman test suggested that common method bias posed some threat, the item-level test results, the nature of the higher-order statistical relationships, and a series of robustness checks collectively indicated that the core conclusions of this study were reasonably robust.

Discussion

This study is the first to introduce GLASSO regularised partial correlation network analysis into the field of Master of Nursing Specialist (MNS) education quality evaluation [17], systematically addressing three research questions: (1) Is there a significant interaction effect between management service and

supervisor support? (2) Does the relationship between process quality and output quality differ across students with different output levels? (3) What network structure is formed by the MNS education quality elements, and what are the core hub nodes? The results showed that the MNS education quality network exhibited a multi-centre, flat structure [16], with supervisor support, research ability, and clinical practice ability forming three equally prominent core hubs; there was a significant but small positive interaction effect between management service and supervisor support ($\beta = 0.159, p = 0.015$); and quantile regression showed that the difference in slopes between the 25th and 75th percentiles was -0.142 (95% CI: -0.299 to 0.015), which did not reach statistical significance, indicating that the positive effect of process quality was consistent across students at different output levels, without evidence of a differential compensatory effect. These findings collectively depict the structural characteristics and operating mechanisms of the MNS education quality system and provide empirical evidence from the Chinese institutional context for the international nursing education community to understand the “clinical–research” tension in professional master's education in nursing.

The sample characteristics of this study were as follows: 93.8% of participants were female, the mean age was 24.32 years, second-year students predominated (60.0%), and only 15.4% had clinical experience before enrolment. The process quality dimension showed a gradient pattern in which interpersonal support was superior to teaching implementation; supervisor support had the highest score (4.09), whereas curriculum and instruction had the lowest score (3.70). Zhao et al [11] found that process quality had the highest weight (0.608) in the MNS evaluation framework. This study further revealed that dimensions with high weights do not necessarily receive high perceived scores. Clinical practice teaching occupied an important position in the weight analysis but received the lowest student perceived score, forming a “high importance–low satisfaction” gap that should be treated as a priority improvement target. It is recommended that regular training in teaching competence for clinical preceptors be conducted, a feedback mechanism for preceptorship quality be established, and horizontal exchange of teaching experience between institutions be promoted. In the output quality dimension, research ability had the highest score (4.05), followed by career preparation (3.98), and motivation transfer had the lowest score (3.76). This marked gap suggests that MNS education has been effective in cultivating “hard skills”, but the enhancement of “soft skills”—such as professional identity and career intrinsic motivation—has lagged notably. Motivation transfer is an attitudinal outcome, and its formation requires longer-term emotional investment and value internalisation, which is difficult to achieve through short-term courses. It is recommended that the cultivation of professional identity be embedded throughout the entire clinical rotation process and that attitude change be gradually accumulated through low-intensity, high-frequency interventions such as narrative reflection, role-model dialogue, and role experience. Between-group difference analysis showed that sex, year of study, clinical experience, and age did not differ significantly in quality perception ($p > 0.05$), with effect sizes all less than 0.50. This finding has three implications: first, demographic variables are not the main factors influencing perception; second, quality perception is consistent across different groups, and overly differentiated intervention designs are unnecessary; third, although the difference between second- and third-year students in output quality was not statistically significant ($p = 0.118$, Cohen's $d = -0.282$), the direction of the effect suggests that further longitudinal research is warranted to examine whether training duration influences students' evaluations of their own

ability development. Implications for practitioners: quality improvement should not be based solely on weight analysis results but should also take student perceived evaluations into account. Dimensions with high weights but low scores (e.g., clinical practice teaching) are the most cost-effective directions for investing improvement resources. Systematic overall improvement strategies are more efficient than differentiated designs targeting specific populations.

Beyond the descriptive findings above, the most central breakthrough of this study lies in the systemic structure revealed by network analysis—supervisor support, research ability, and clinical practice ability constitute three core hubs. This finding directly challenges a deeply rooted assumption in professional master's education: that clinical training and research training are competing priorities and that curriculum design must choose between them. The network analysis in this study indicates that, within students' subjective perception system, the two are not zero-sum opposites but mutually reinforcing structural anchors. This finding forms a valuable dialogue with previous network analysis studies in nursing education. Wu et al [17] conducted a network analysis of self-reflection and empathy among nursing students and found that empathy and self-reflection formed dual cores; Miao et al [18] conducted a network analysis of interpersonal sensitivity and self-efficacy among nursing students and found that interpersonal sensitivity-related nodes occupied central positions in the network. Wu et al [17] explicitly used undergraduates as the sample, and the study population of Miao et al [18] was nursing students (predominantly undergraduates). Both studies focused on psychological trait variables and did not address the core “clinical–research” tension in professional education at the postgraduate level. This study extends the scope of network analysis to the master's level, revealing that in higher-level professional education, the structural relationships among competence elements have undergone a qualitative change: from associations among psychological traits to systemic integration among professional competencies. How can the equally central status of these three be explained? This study offers explanations at three levels. At the institutional design level, the dual-mentorship model in Chinese MNS education provides differentiated but interlocking sources of support: academic mentors focus on cultivating research ability, while clinical mentors focus on forging practical ability [4]. For students who receive strong support from both, the two domains are not perceived as separate—this is consistent with Hobfoll's conservation of resources theory [15], which posits that the combined gain of different resources exceeds the simple sum of their individual effects. At the cognitive mechanism level, research outputs (publication, project participation) and clinical skills (procedural ability, case management) are observable, quantifiable, and competence-based, making them more “visible” and “connected” in students' subjective evaluation networks than attitudinal outcomes (e.g., motivation transfer) [25]. At the level of cultural–institutional co-construction, the hard requirement in the Chinese nursing education system that “graduate students must publish papers before graduation” objectively reinforces students' emphasis on research ability, placing it in a central position in the education quality perception network.

It is noteworthy that although supervisor support was the only element in the process quality dimension to enter the core tier, in master's-level students' perceptions, research ability and clinical practice ability are no longer merely “output indicators” but have acquired a structural bridging function that integrates the various elements of the educational process [26]. The implication for nursing educators in

professional master's programmes is that, in curriculum design, research training should not be regarded as a burden that “crowds out clinical time”, but should be repositioned as a systemic hub connecting the various stages of the educational process [16]. Curriculum design should not pursue a quantitative balance between “clinical hours versus research hours”, but should pursue their deep integration in students' learning experience—for example, by embedding research training into clinical rotations (e.g., requiring students to complete a literature review based on clinical questions after each specialty rotation), so that research activities become a natural extension of clinical learning rather than an additional burden. For nursing education administrators, strengthening research capacity building does not deviate from the “clinical orientation” of the training goal—on the contrary, it may indirectly enhance the effectiveness of clinical competence development by strengthening the internal connectivity of the education quality system.

In addition to the three core hubs, management service plays a dual role in the MNS education quality system [27]. In the network analysis, its degree centrality (5) ranked fourth among all nodes, with a normalised degree centrality of 0.714, making it a key institutional connecting node second only to the three core hubs—this means that, in students' perceptions, management service is not an administrative concept isolated from the educational process, but a core element embedded in the education quality network. In the regression analysis, it showed a significant positive interaction effect with supervisor support ($\beta = 0.159, p = 0.015$)—that is, the association between management service and output quality became stronger as the level of supervisor support increased. However, the effect size of this interaction effect was small ($f^2 = 0.051$), and Johnson–Neyman analysis showed that the effect of management service was significant across the entire observed range of supervisor support (threshold = 2.832, below the sample minimum). This pattern suggests that management service performs a foundational institutional safeguard function—it creates the necessary conditions for the effective functioning of interpersonal resources (supervisor support) rather than replacing supervisor support. This finding is highly consistent with the core proposition of conservation of resources theory [15]. the combination of institutional resources and interpersonal resources can produce synergistic gains, but the former plays the role of the “foundation”, while the latter is the “superstructure”. Translating this theoretical insight into practical implications: in MNS education quality management, the goal of institutional development should not be to replace supervisors' individualised guidance, but to create institutional conditions for supervisors to perform their duties effectively—such as simplifying administrative processes, clarifying rotation management standards, and establishing support systems for workload recognition and supervisor training [28]. Notably, Zhao et al [11] previously found that process quality had the highest weight (0.608). This study further revealed the internal differentiation of process quality through network analysis—management service (degree centrality = 5, normalised degree centrality = 0.714) belonged to the important node tier, whereas supervisor support (degree centrality = 6, normalised degree centrality = 0.857) belonged to the core tier, and curriculum and instruction (degree centrality = 4, normalised degree centrality = 0.571) ranked in the second tier. This differentiation suggests that even within the same dimension, the “systemic importance” of different elements differs significantly, and precise interventions should target core nodes and important nodes rather than applying equal effort across the board. The implication for nursing administrators is that when the level of supervisor support is low, merely

improving management systems has limited effect—the finding that the Johnson–Neyman threshold is below the sample minimum clearly indicates that when supervisor support is extremely low, the “marginal effect” of management service in students' perceptions may approach zero. Therefore, the focus of improving management service should not be “adding more rules and regulations”, but “reducing supervisors' administrative burden”—simplifying processes, reducing paperwork, and freeing supervisors from routine tasks so that they can devote more energy to substantive guidance. Under conditions of limited resources, rather than creating a new set of supervisor assessment indicators, it is better to first “subtract”: assessing which steps in existing management processes are inefficient for supervisors, which tasks can be merged, and which meetings can be streamlined—these seemingly minor improvements are precisely the key entry points for activating the synergistic effect of institutional resources and interpersonal resources.

This study's quantile regression analysis [22] examined whether the association between process quality and output quality varied across students at different output levels. The results showed that the difference in slopes between the 25th and 75th percentiles was -0.142 (95% CI $[-0.299, 0.015]$), which did not reach statistical significance. This indicates that the positive effect of process quality was consistent across students at different output levels, without evidence of a differential compensatory effect. Overall, process quality had a positive promoting effect for all types of students, and the marginal gain did not differ significantly across output levels. This finding can be interpreted from the following perspectives. At the theoretical level, Tinto's student integration theory [14] posits that the synergistic effect of academic and social integration can effectively promote student development. The present finding suggests that this integration effect operates broadly across students rather than disproportionately benefiting those with lower levels of integration. Sanderson et al [8] student success model likewise indicates that institutional support has foundational safeguard value for all students, and the present results are consistent with this universal protective role. At the mechanism level, improvements in process quality may provide baseline support that benefits students across the output distribution, rather than producing a steeper marginal return for any particular subgroup. Although the direction of the slope difference (lower at the 75th percentile than at the 25th) hints at a possible tendency toward stronger effects among lower-output students, this tendency was not statistically reliable in the present sample. This suggests that in clinical teaching and preceptorship resource allocation, priority should be given to ensuring the baseline quality of all dimensions of the educational process, so that all students receive adequate institutional support. Given the absence of a significant gradient difference, differentiated intervention strategies (e.g., designing additional tutoring programmes specifically for “low-output” students) are not supported by the present data. On the contrary, systematically improving the baseline safeguard level of the educational process—especially for relatively peripheral dimensions such as curriculum and instruction (degree centrality = 4, normalised degree centrality = 0.571)—should remain the primary task of quality improvement. In other words, in MNS education quality assurance, system-wide improvement of the “rising tide lifts all boats” type should be the primary strategy, while targeted compensatory support of the “precision irrigation” type should be treated with caution and reserved for situations where future longitudinal or larger-sample studies confirm a genuine differential effect.

The methodological pathway of this study itself has independent academic value. GLASSO regularised partial correlation network analysis was proposed by Friedman et al [29] and has since been widely applied in fields such as psychology and public health. In nursing education research, this method has seen preliminary exploration [17, 18], but it is the first time it has been applied in research on master's nursing education quality. The core advantage of this method is that it shrinks weak correlations to zero through lasso regularisation, thereby producing sparse and robust network structure estimates in limited samples. Traditional regression models focus on “whether a certain variable significantly predicts the outcome”, whereas network analysis focuses on “which variables occupy core connecting positions in the system”—Borsboom and Cramer [30] pointed out that network analysis encourages researchers to think about relationships among variables in a way different from traditional reductionism; Costantini et al [31] further provided specific methods for identifying core nodes through centrality indicators. Notably, under the condition of a relatively limited sample size ($n = 130$), the CS-coefficient for strength obtained from bootstrap resampling (1,000 resamples) was 0.515, well above the 0.25 safety threshold recommended by Epskamp and Fried [16], demonstrating that the centrality estimates were stable. This means that even in exploratory research, as long as rigorous methodological design is followed and adequate stability testing is conducted, network analysis can still yield reliable inferences about systemic structure [32]. The implication for nursing researchers is that when the research question shifts from “which variable is significant” to “which elements are core hubs”, network analysis provides a cognitive tool that transcends the traditional regression framework [32]. Especially for complex systems such as nursing education (multi-site rotations, multi-stakeholder involvement, multidimensional outputs), the value of network analysis lies in the fact that it does not require presupposing linear relationships among variables, but instead lets the data “speak”—automatically revealing the association patterns among variables through regularised partial correlation network analysis. This provides a feasible technical pathway for nursing education research to move from “reductionism” to “systems theory”.

This study has the following strengths. First, it is the first to introduce GLASSO network analysis into the field of MNS education quality, providing a new perspective for understanding the structural characteristics of the education quality system. Second, it simultaneously employs hierarchical regression, quantile regression, and network analysis to triangulate the same research question across two dimensions—“variable interaction” and “system structure”—thereby enhancing the reliability of the conclusions [29]. Third, the stability of the network structure was rigorously tested through bootstrap resampling [19]; the CS-coefficient for strength was 0.515, exceeding the recommended threshold of 0.25 and providing statistical support for the stability of the centrality estimates and the robustness of the conclusions [16].

At the same time, this study has several limitations. The cross-sectional design limits causal inference—the hub status of research ability is an association pattern observed at the perceptual level and cannot be equated with the causal conclusion that “improving research ability will automatically enhance other dimensions”. Future studies should adopt longitudinal designs to examine the dynamic evolution of the network structure over the training process. Regarding common method bias, although the item-level variance explained by the first unrotated principal component in Harman's single-factor test was 41.8%,

which was close to the acceptable threshold, common method bias may still have been present [23]; however, the core findings of this study—the interaction effect and the GLASSO network partial correlation structure—are higher-order statistical relationships and are highly unlikely to be fully explained by a common method factor [23]. Future studies should incorporate multi-source data (supervisor evaluations, clinical assessments, objective grades) for triangulation. The sample size ($n = 130$) constrains the absolute precision of edge weight estimation in the network analysis, but the bootstrap stability test showed that the strength centrality was stable (CS-coefficient = 0.515), exceeding the recommended threshold of 0.25 and supporting the reliability of inferences about the core topological structure [8]. Future multi-centre collaborative studies could further increase the sample size. Regarding sample representativeness, the sample was drawn only from MNS students in tertiary hospitals in selected provinces of China; future cross-national comparisons are needed to test whether the "multi-centre, flat network" has cross-system generalisability. The selection of network nodes was based on an existing theoretical framework, which may have omitted other important variables such as self-efficacy, learning motivation, and professional identity; future studies could include a broader set of variables to construct a more comprehensive map of education quality.

In summary, this study revealed the structural characteristics of the MNS education quality system through GLASSO network analysis: a multi-centre, flat network with supervisor support, research ability, and clinical practice ability as the three core hubs. Management service performs a foundational institutional safeguard function and produces synergistic gains with supervisor support; the positive effect of process quality was consistent across students at different output levels, with no statistically significant evidence of a differential compensatory effect. The core implication for nursing education practice is that precise interventions in quality management should target the "three core hubs"—the synergistic development of supervisor support, research ability, and clinical practice ability—rather than applying equal effort across all dimensions.

Abbreviations

CI

confidence interval

CMB

common method bias

CS-coefficient

correlation stability coefficient

DNP

Doctor of Nursing Practice

GLASSO

graphical least absolute shrinkage and selection operator

J–N

Johnson–Neyman

MNS

Master of Nursing Specialist

SD

standard deviation

SE

standard error

STROBE

Strengthening the Reporting of Observational Studies in Epidemiology

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Medical Ethics Committee of the Affiliated Hospital of Shandong Second Medical University (Approval No. SDSMU-2026-at-45). All participants provided written informed consent before taking part in the study.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to privacy and ethical restrictions, but are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests.

Funding

This work was supported by:

University-level Project of University of Health and Rehabilitation Sciences: Research on the Construction of Medical Education Community under the Background of New Medical Science Development.

2025 Teaching Case Grant of Shandong Provincial Undergraduate Universities on Labor Education: Research on the Inter-embedded Education of Labor Education and Intangible Cultural Heritage Inheritance under the Background of Developing New Quality Productive Forces.

Development and Psychometric Validation of a Self-Rating Scale for Smart Literacy in Clinical Nursing Staff (Grant No. 2024HLB001), Affiliated Hospital of Shandong Second Medical University.

Authors' contributions

Rong Zhao: Conceptualization, Methodology, Writing original draft, Visualization.

Liyan Jia: Investigation, Data curation, Writing review & editing.

Cuiping Wang: Investigation, Formal analysis, Validation.

Fengling Wang: Investigation, Data collection, Literature search.

Ying Wang: Supervision, Project administration, Writing review & editing, Funding acquisition, and serves as the corresponding author.

All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

Acknowledgements

We would like to express our sincere gratitude to all the Master of Nursing Specialist students who participated in this study for their valuable time and cooperation. We also extend our heartfelt thanks to the clinical mentors and nursing administrators at the 24 participating hospitals for their support and assistance during the data collection process.

References

1. Chism LA. The Doctor of Nursing Practice: a guidebook for role development and professional issues. 4th ed. Burlington, MA: Jones & Bartlett Learning; 2019.
2. Author(s). A multidisciplinary learning approach: training, preparation and role transition. *Br J Nurs*. 2022;31(8):430–40.
3. Vinette B, Lapierre A, Lavoie A, Leclerc-Loiselle J, Charette M, Deschênes MF. Educational strategies used in master's and doctoral nursing education: a scoping review. *J Prof Nurs*. 2023;48:84–92.
4. Yang YG, Yang QJ, Guan JY, et al. Challenges and strategies in implementing the dual mentor system for master of nursing specialist students. *Int J Nurs*. 2026;45(11):1930–3.
5. Zheng YX, Liu YL, Jin ZY, et al. A qualitative study of the experiences of teachers and students in the dual-mentorship model of master of nursing specialist education. *Mod Clin Nurs*. 2025;24(8):73–9.
6. Yang JS, Wang Y, Wang HY et al. Construction of a combined clinical practice teaching and assessment training programme for master of nursing specialist students based on core competency needs. *Chin J Mod Nurs*. 2024;30(29).
7. Li DY, Chen OY, Ni J, et al. Practice of the school–hospital–community three-party classroom in traditional Chinese medicine nursing technology courses for master of nursing specialist students. *Chin J Nurs Educ*. 2021;18(1):8–12.
8. Xiao HM, Li SY, Su QC, et al. Construction and practice of the one student, multiple mentors guidance model for master of nursing specialist students. *Chin Nurs Res*. 2025;39(3):396–400.
9. Sanderson CD, Hollinger-Smith L, Cox K. A model for student success. *J Nurs Educ*. 2022;61(2):101–4.
10. Flott EA, Linden L. The clinical learning environment in nursing education: a concept analysis. *J Adv Nurs*. 2016;72(3):501–13.
11. Papastavrou E, Lambrinou E, Tsangari H, Saarikoski M, Leino-Kilpi H. Student nurses experience of learning in the clinical environment. *Nurse Educ Pract*. 2010;10(3):176–82.

12. Zhao R, Yu WZ, Wang Y. Construction and weight analysis of an education quality evaluation framework for master of nursing specialist students. *Chin Nurs Res.* 2023;37(14):2493–500.
13. Zhao R, Yu WZ, Wang Y. Development of a process quality evaluation scale for master of nursing specialist education. *Chin Nurs Res.* 2022;36(15):2655–9.
14. Huang XT, Wang ZY, Yang XY, et al. Identification of key issues in master of nursing specialist education in China. *Mil Nurs.* 2024;41(12):109–12.
15. Tinto V. *Leaving college: rethinking the causes and cures of student attrition.* 2nd ed. Chicago: University of Chicago Press; 1993.
16. Hobfoll SE. Conservation of resources. A new attempt at conceptualizing stress. *Am Psychol.* 1989;44(3):513–24.
17. Epskamp S, Fried EI. A tutorial on regularized partial correlation networks. *Psychol Methods.* 2018;23(4):617–34.
18. Wu W, Lian C, Yang Y. Self-reflection and empathy in undergraduate nursing students: a network analysis. *BMC Med Educ.* 2025;25(1):1753.
19. Miao J, Wu Y, Yuan J, et al. Network analysis of interpersonal sensitivity and self-efficacy in nursing students. *BMC Nurs.* 2025;24(1):63.
20. Efron B, Tibshirani RJ. *An introduction to the bootstrap.* New York: Chapman & Hall; 1993.
21. Cohen J, Cohen P, West SG, Aiken LS. *Applied multiple regression/correlation analysis for the behavioral sciences.* 3rd ed. Mahwah, NJ: Lawrence Erlbaum Associates; 2003.
22. Bauer DJ, Curran PJ. Probing interactions in fixed and multilevel regression: inferential and graphical techniques. *Multivar Behav Res.* 2005;40(3):373–400.
23. Koenker R. *Quantile regression.* New York: Cambridge University Press; 2005.
24. Podsakoff PM, MacKenzie SB, Lee JY, Podsakoff NP. Common method biases in behavioral research: a critical review of the literature and recommended remedies. *J Appl Psychol.* 2003;88(5):879–903.
25. Field A. *Discovering statistics using IBM SPSS Statistics.* 4th ed. Los Angeles: SAGE; 2013.
26. Sun XH, Li L, Liao TT, et al. Research progress on core competencies of master of nursing specialist students. *J Nurs Sci.* 2019;34(5):92–5.
27. Li MY, Luo YH. Research progress on education quality evaluation of master's nursing students in China and the United States. *J Nurs Sci.* 2019;34(15):104–7.
28. Ge W, Xu SS, Cao BH, et al. Evaluation of the current status of education quality assurance by master of nursing specialist students in China. *Chin Nurs Res.* 2017;31(31):3989–91.
29. Guo Y, Li XM, Li J, et al. Construction of an indicator system for mentor admission and position competency evaluation for master of nursing specialist students. *Chin J Nurs Educ.* 2021;18(8):695–9.
30. Friedman J, Hastie T, Tibshirani R. Sparse inverse covariance estimation with the graphical lasso. *Biostatistics.* 2008;9(3):432–41.

31. Borsboom D, Cramer AO. Network analysis: an integrative approach to the structure of psychopathology. *Annu Rev Clin Psychol.* 2013;9:91–121.
32. Costantini G, Epskamp S, Borsboom D, et al. State of the aRt personality research: a tutorial on network analysis of personality data in R. *J Res Pers.* 2015;54:13–29.
33. Dalege J, Borsboom D, van Harreveld F, van den Berg H, Conner M, van der Maas HL. Toward a formalized account of attitudes: the Causal Attitude Network (CAN) model. *Psychol Rev.* 2016;123(1):2–22.

Figures

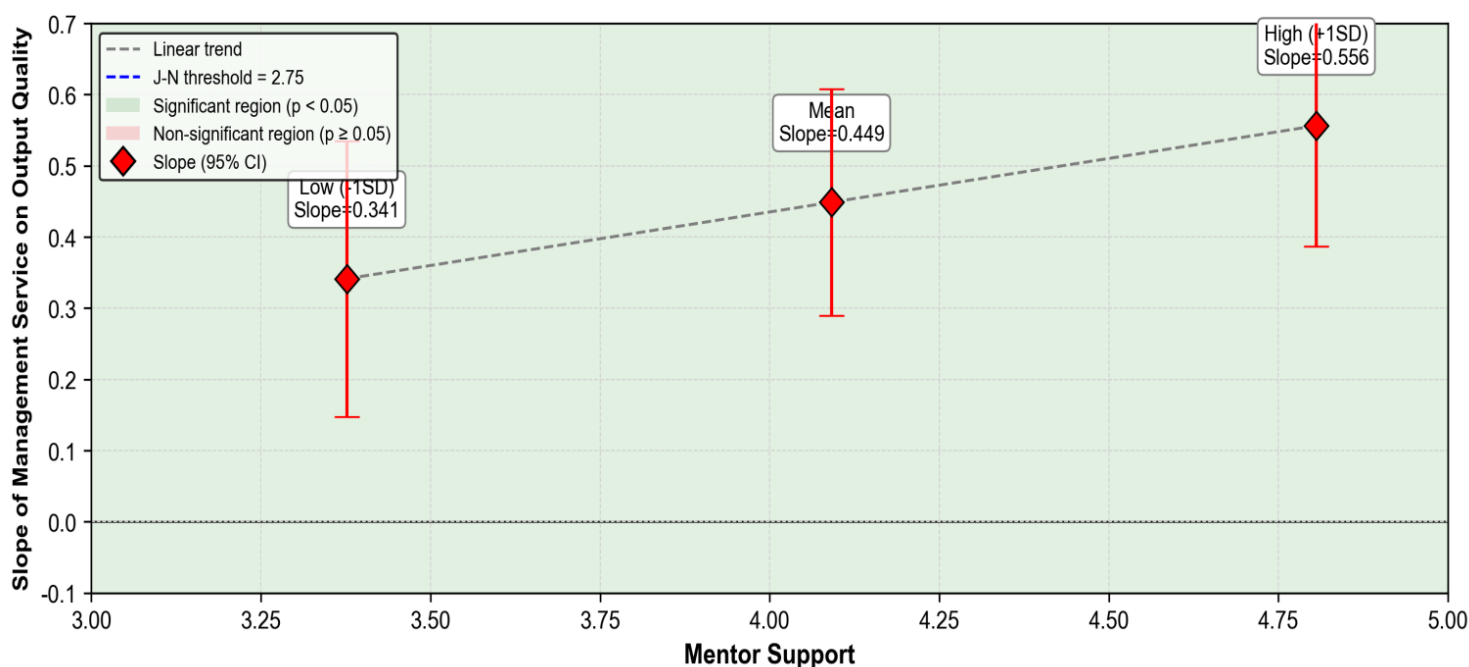


Figure 1

Simple Slope and Johnson-Neyman Analysis

Nodes: The slope of management service on output quality at three levels of mentor support (-1 SD, Mean, +1 SD). Error bars represent 95% CI. The dashed vertical line indicates the Johnson–Neyman threshold (2.832); the green shaded region indicates where the slope is significant ($p < 0.05$), and the red shaded region indicates non-significance.

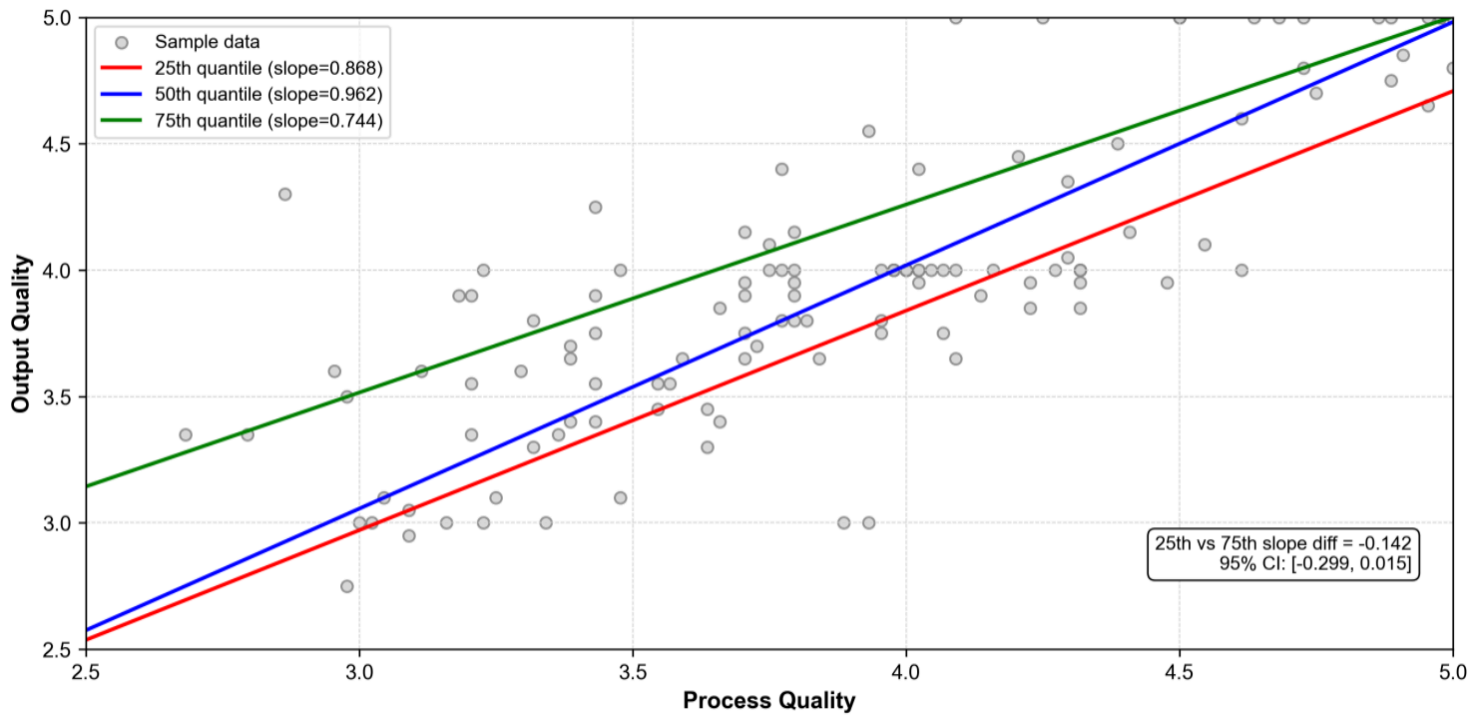


Figure 2

Quantile Regression: Process Quality on Output Quality

Nodes Gray dots represent individual samples ($n=130$). Red, blue, and green lines represent the 25th, 50th, and 75th quantile regression lines, respectively. The text box in the lower right corner reports the difference in slopes between the 25th and 75th percentiles (-0.142) and its 95% confidence interval ($[-0.299, 0.015]$).

■ Core hub (degree = 6)
■ Important node (degree = 5)
■ Second-tier node (degree = 4)
■ Peripheral node (degree ≤ 3)

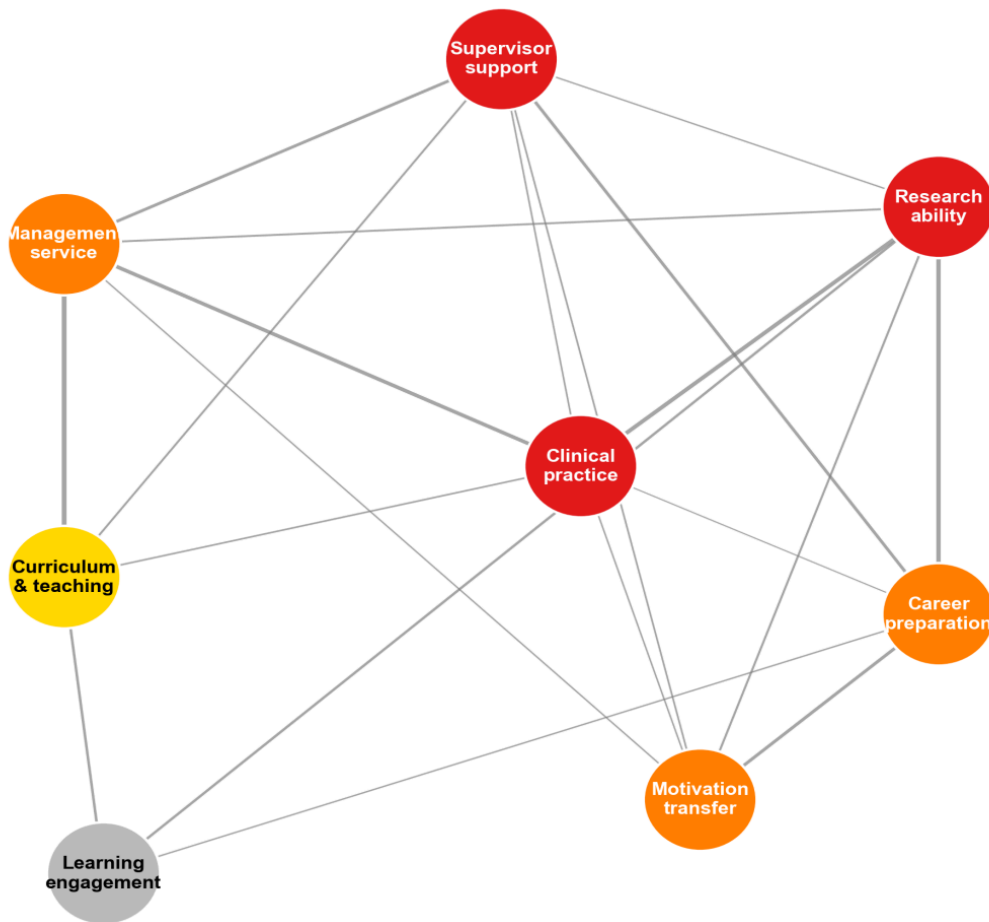


Figure 3

MNS Education Quality Network Structure (GLASSO, $\alpha=0.050$)

Nodes: represent the eight core variables; edges represent regularised partial correlations. Node colours indicate hierarchical levels: red = core hubs (degree = 6), orange = important nodes (degree = 5), yellow = second-tier nodes (degree = 4), and gray = peripheral nodes (degree ≤ 3). Edge thickness is proportional to the absolute value of the regularised partial correlation.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Additionalfile1.docx](#)