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Article

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Posted Date: October 20th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10923606/v1>

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Additional Declarations: No competing interests reported.

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Abstract

Innovative practice competence has become a defining objective of professional degree education, yet its development is often understood through fragmented accounts of student ability, mentoring, or practice conditions. This study moves beyond these isolated perspectives by developing an integrated student–dual-mentor–practice-base framework that conceptualizes competence development as an outcome of interactions between learner agency, mentoring capability, and organizational affordances. Drawing on social cognitive theory, mentoring research, and the affordance perspective of workplace learning, the study further proposes an embedded dual-mentor mechanism to explain how mentoring capability is translated into training quality through the practice environment. Survey data from 184 university-based and practice-base mentors, predominantly from Jiangsu Province, China, were analyzed using formative composite measurement, robust path analysis, and bootstrap estimation of indirect associations. The findings show that students' innovative practice ability has the strongest independent association with perceived training quality, while dual mentor guidance competence and the practice-base support environment also show positive associations. More importantly, part of the association between dual mentor guidance competence and perceived training quality operates through the practice-base support environment, while a positive direct association remains. This finding challenges an individual-centered view of mentoring effectiveness and shows that mentor competence becomes educationally consequential when embedded in authentic projects, institutional support, resource access, feedback, and quality-assurance arrangements. The study contributes an ecological and relational explanation of innovative practice competence development by revealing how student, mentoring, and organizational resources operate as an interconnected educational system. Practically, the findings suggest that improving professional degree education

requires institutions to move beyond mentor development alone and strengthen the organizational conditions that enable mentoring expertise to be converted into meaningful practice-based learning.

Keywords: innovative practice competence; professional degree education; dual-mentor system; practice-base environment; workplace learning

1 Introduction

Professional degree education is expected to do more than transmit disciplinary knowledge. Its distinctive purpose is to prepare students to exercise professional judgment, integrate knowledge with practice, collaborate across organizational boundaries, and address complex problems in authentic occupational settings. This challenge has become increasingly important as universities seek to narrow the persistent gap between academic preparation and workplace capability. Research on work-integrated learning (WIL) similarly shows that professional competence develops most effectively when curricula, authentic tasks, industry engagement, and reflective learning are deliberately connected, allowing students to transfer knowledge and capabilities between university and workplace contexts (Sunnemark et al., 2024; Ferns et al., 2025; Curto-Reverte et al., 2025). Accordingly, the quality of professional degree education cannot be adequately understood through academic outputs alone; it also depends on whether educational arrangements enable students to develop transferable and demonstrable innovative practice competence (Ruitenbeek et al., 2024). This issue is particularly salient in China, where the expansion of postgraduate professional degree education since 2009 has been accompanied by the institutionalization of dual-mentor arrangements and external practice bases. These arrangements are intended to connect academic learning with professional practice: university-based mentors contribute theoretical knowledge, research methods, and academic guidance, while practice-base mentors provide access to authentic problems, technical processes, professional standards, and workplace feedback. Practice bases, in turn, provide the organizational setting in which these forms of guidance can be translated into experiential learning. Yet the formal presence of mentors and practice bases does not necessarily ensure that these resources function as an integrated educational system. The more consequential question is therefore not simply whether these components exist, but how student capability, mentoring competence, and the practice environment work together to shape the quality of professional competence development.

Existing research provides important insights into each component but offers a fragmented account of their combined operation. At the student level, research has linked self-efficacy, learning engagement, knowledge integration, and innovation capability to academic achievement, employability, and innovative performance (Li et al., 2022; Han et al., 2024; Miao et al., 2025). At the mentoring level, effective guidance has been associated with academic, career, psychological, and reflective support, while its effectiveness depends on sustained interaction, role clarity, timely feedback, and appropriate institutional support (Dias et al., 2022; Mojab et al., 2023; Penman et al., 2024; Nuis et al., 2026). Research on workplace and practice-based learning further demonstrates that authentic tasks, access to resources, industry feedback, university–enterprise collaboration, and alignment between curricula and occupational roles can strengthen employability, professional identity, problem-solving, and practice competence (Kligyte et al., 2024; Crawford et al., 2024; Jackson & Cook, 2025). Although these streams are complementary, they have largely developed in parallel. Consequently, we know considerably more about the individual ingredients of professional learning than about how they operate together within the same educational ecosystem. This fragmentation is particularly consequential for understanding the role of dual mentors. Much of the conventional logic surrounding mentoring assumes that stronger mentor competence should translate relatively directly into better educational outcomes. Such an assumption may overlook the organizational conditions through which mentoring is enacted. A highly competent mentor can provide expertise and guidance, but students' opportunities to convert that guidance into professional competence depend on whether the practice environment provides authentic projects, resources, data, collaboration, feedback, and opportunities for experimentation. From this perspective, mentor competence may be valuable not simply as an individual educational resource, but because it helps activate and utilize the affordances available within the practice environment. The effectiveness of dual mentoring may therefore be embedded in the practice-base environment rather than operating independently of it. This possibility remains insufficiently examined in existing professional degree research.

A second limitation concerns how training quality itself is conceptualized. Evaluations of professional degree education can become overly dependent on conventional academic outputs,

despite the broader purposes of professionally oriented postgraduate education. Innovative practice competence encompasses the capacity to integrate knowledge, engage with authentic professional problems, generate technical or practical solutions, contribute to organizational improvement, and develop professionally recognized capabilities. Training quality should therefore capture multiple forms of value generated through professional learning rather than being reduced to a single academic outcome. Understanding such quality requires a framework capable of connecting the learner, the mentoring relationship, and the organizational environment in which professional learning occurs. To address these limitations, this study develops an integrated student–dual-mentor–practice-base framework that brings together three interdependent pillars of professional competence development: students' innovative practice ability (SIPA), dual-mentor guidance competence (DMGC), and the practice-base support environment (PBSE). Drawing on social cognitive theory, mentoring research, and the affordance perspective of workplace learning, the framework conceptualizes SIPA as a learner-level capability, DMGC as a relational mentoring resource, and PBSE as the organizational environment through which opportunities for authentic professional learning are enabled. The study examines their associations with perceived training quality (PTQ) and, more specifically, tests an embedded dual-mentor mechanism in which part of the association between mentor competence and training quality operates through the practice-base environment.

By integrating these previously separated levels of explanation, the study makes three contributions. First, it shifts the analysis of innovative practice competence from isolated educational inputs toward an ecological account of professional learning in which learner, relational, and organizational resources operate as an interconnected system. Second, it reconceptualizes dual-mentor effectiveness as environmentally embedded, providing an explanation for why mentor competence may not independently translate into higher training quality unless it is supported by an enabling practice environment. Third, it advances a multidimensional understanding of professional training quality that extends beyond conventional academic outputs to encompass the broader practical and professional value generated through competence development. In doing so, the study offers both a theoretical framework for understanding how innovative practice competence is developed and a practical basis for designing more effective university–industry professional degree education.

2 Theoretical Background and Hypotheses

2.1 Social Cognitive Theory and the Student–Mentor–Practice Base Model

Social Cognitive Theory (SCT) provides the overarching theoretical foundation for explaining professional learning as a process shaped by the reciprocal relationship between individual agency, behaviour, and environmental conditions. Bandura (1986, 2001) conceptualises individuals as active agents who exercise intentionality, forethought, self-regulation, and self-reflection while operating within broader social and structural environments. The theory therefore does not treat either personal capability or environmental conditions as sufficient in isolation. Rather, learning and performance emerge as individuals interpret opportunities, regulate their participation, and act within environments that provide resources, constraints, and social support (Bandura, 1986, 2001; van Dinther et al., 2011). This perspective is particularly applicable to professional degree education because learning extends beyond formal instruction into authentic professional activities in which students interact with mentors, organisational arrangements, resources, and workplace practices (Billett, 2001, 2004; Curto-Reverte et al., 2025). Within the present model, students' innovative practice ability represents the agentic dimension of SCT, dual mentor guidance competence represents the social and instructional dimension, and the practice base support environment represents the contextual dimension. The model consequently examines how these dimensions relate to perceived training quality and how mentor competence becomes connected to training quality through the practice environment (Bandura, 2001; Nuis et al., 2023; Ferns et al., 2025).

2.2 Students' Innovative Practice Ability and Perceived Training Quality

SCT places individual agency at the centre of learning because individuals do not simply receive environmental influences; they interpret opportunities, set goals, regulate their actions, and reflect on their experiences (Bandura, 2001). In higher education, self-efficacy and related agentic capabilities have been associated with students' motivation, learning behaviour, persistence, and performance, indicating that students' personal capabilities influence how effectively they engage with educational opportunities (van Dinther et al., 2011). This proposition is especially relevant to professional learning, where students must move beyond receiving knowledge to participating in practical activities,

identifying problems, seeking feedback, collaborating with others, and applying knowledge to authentic situations (Billett, 2001, 2004; Ceelen et al., 2025). Recent workplace-learning research further shows that student agency is expressed through active participation, negotiated involvement, and increasingly independent engagement with workplace affordances, while supervisors and students jointly shape the opportunities available for learning (Ceelen et al., 2025). Empirical evidence from higher education also links innovation capability with employability and indicates that self-efficacy forms part of the mechanism through which innovation-related capabilities become consequential for student outcomes (Li et al., 2022). Accordingly, SIPA captures agentic capabilities that enable students to make purposeful use of professional learning opportunities. When students demonstrate initiative, goal orientation, practical capability, collaboration, innovative thinking, and persistence, they are better positioned to engage with the training process and convert available opportunities into meaningful learning experiences (Bandura, 2001; Billett, 2001; Ceelen et al., 2025).

H1: Students' innovative practice ability is positively associated with perceived training quality.

2.3 Dual Mentor Guidance Competence and Perceived Training Quality

Mentoring provides a social and instructional mechanism through which students receive guidance, feedback, developmental support, and opportunities to connect academic knowledge with professional practice. A systematic review of 106 studies shows that mentoring in higher education encompasses multiple purposes and characteristics and that its educational contribution cannot be adequately represented by a single mentoring function (Nuis et al., 2023). This multidimensional character is important in professional degree education because students operate across academic and practice settings and consequently require complementary forms of guidance. Academic mentors can support disciplinary knowledge, research methods, academic standards, and reflective learning, whereas practice-based mentors can support professional judgement, authentic tasks, technical processes, and workplace feedback (Nuis et al., 2023; Nuis et al., 2024a). Evidence from China also indicates that mentoring is positively associated with university students' perceived employability, while the duration, frequency, and characteristics of mentoring relationships shape this association (Niu et al., 2025). Nuis et al. (2024a) further show that mentoring can support employability competence through students' critical reflection, highlighting the role of guidance in helping students interpret and learn from their experiences. The dual-mentor arrangement considered here brings academic and practice-based guidance into the same professional learning process. DMGC captures mentors' capacity to provide professional knowledge, instructional support, interaction, feedback, methodological guidance, and connections between theory and practice. From an SCT perspective, these social sources of guidance can shape how students interpret and use learning opportunities within their environment (Bandura, 2001; Nuis et al., 2023). The literature therefore supports the expectation that competent and coordinated dual mentoring should be associated with more favourable perceptions of professional training quality.

H2: Dual mentor guidance competence is positively associated with perceived training quality.

2.4 Practice Base Support Environment and Perceived Training Quality

Professional learning depends not only on what students and mentors bring to the learning process but also on whether the practice environment provides meaningful opportunities for participation. Workplace-learning research conceptualises the workplace as a learning environment in which organisational affordances interact with individual agency. Billett (2001, 2004) argues that access to activities, guidance, resources, and participation opportunities shapes what learners can experience and learn, while learners' engagement determines whether those affordances are taken up. This interaction is consistent with SCT, which recognises that personal agency operates within sociostructural conditions that enable or constrain action (Bandura, 2001). Contemporary WIL research similarly positions authentic workplace participation, institutional coordination, and purposeful curriculum design as central conditions for connecting academic learning with professional practice (Ferns et al., 2025; Curto-Reverte et al., 2025). Kligyte et al. (2024) further emphasise collaborative and transdisciplinary engagement in work-integrated professional learning. The practice base is consequently more than a physical placement location. It provides projects, equipment, learning materials, funding, organisational arrangements, incentives, academic climate, management support, and quality-assurance processes through which professional learning can be enacted. WIL assessment research also shows that assessment can support learning, self-regulation, and lifelong capability development, highlighting the importance of organisational processes rather than participation alone (Luk & Chan, 2024). Research on organisational support in WIL likewise indicates that workplace support is connected with students' engagement and development in host

organisation. These findings suggest that a practice base with stronger learning affordances and organisational support should provide more favourable conditions for professional training and should therefore be associated with higher perceived training quality.

H3: Practice base support environment is positively associated with perceived training quality.

2.5 Dual Mentor Guidance Competence and Practice Base Support Environment

The relationship between mentoring and the practice environment follows from the contextual nature of professional learning. Mentoring is not simply an interpersonal exchange between an individual mentor and a student; its educational value depends on how mentoring is organised, supported, and connected to the wider learning environment (Nuis et al., 2023). The systematic review by Nuis et al. (2023) shows that mentoring programmes vary in purpose, characteristics, and implementation, indicating that mentoring quality cannot be separated from the arrangements through which mentoring is delivered. Workplace-learning research reaches a related conclusion from the environmental side. Billett (2001, 2004) demonstrates that workplace learning depends on the interaction between learner agency and affordances created by organisational participation practices, including access to activities, guidance, and support. Workplace pedagogy similarly depends on intentional guidance and sequenced access to workplace activities, while the organisation of participation determines how learning opportunities are distributed (Billett, 2002). WIL research further shows that effective learning requires collaboration among students, universities, and workplace partners rather than treating the workplace as an independent site of learning (Ruskin & Bilous, 2020; Curto-Reverte et al., 2025). Within this arrangement, mentors can contribute to the practice environment by connecting students with suitable projects, facilitating resources, coordinating academic and professional expectations, providing feedback, and supporting evaluation. Recent workplace-agency research shows that supervisors and students interact through demonstration, stimulated participation, entrustment, learner engagement, negotiated participation, and increasing independence (Ceelen et al., 2025). Thus, mentor competence can extend beyond direct guidance to the organisation of the conditions through which guidance is enacted. In a dual-mentor system, university and practice-based mentors can contribute complementary knowledge and coordination, helping connect academic requirements with workplace activities and organisational resources (Nuis et al., 2023; Ruskin & Bilous, 2020). The practice environment can therefore be partly shaped by the capacity of mentors to organise and connect the resources, activities, feedback, and institutional arrangements required for professional learning.

H4: Dual mentor guidance competence is positively associated with practice base support environment.

2.6 Practice Base Support Environment as a Mediating Mechanism

The preceding literature indicates that mentor guidance and environmental support are complementary rather than isolated features of professional learning. SCT provides a basis for specifying this connection because individuals and social actors operate within environments that shape the opportunities through which behaviour can be enacted (Bandura, 1986, 2001). In professional degree education, competent mentors may provide knowledge and guidance, but the educational value of that competence depends partly on whether students can access authentic tasks, appropriate resources, feedback, projects, and evaluation arrangements through the practice environment (Billett, 2001, 2002, 2004; Ferns et al., 2025). Mentoring research similarly indicates that effective mentoring involves support, interaction, reflection, developmental guidance, and programme characteristics that shape how students experience and use mentoring (Nuis et al., 2023; Nuis et al., 2024b). WIL research adds that meaningful professional learning depends on coordinated relationships between educational institutions and workplace partners and on learning activities that connect academic and professional contexts (Ruskin & Bilous, 2020; Kligyte et al., 2024; Curto-Reverte et al., 2025). This literature suggests a specific mechanism. Mentor competence can help organise the conditions through which professional learning occurs, while the resulting practice environment determines the extent to which those competencies can be converted into accessible and sustained learning opportunities. Mentors may facilitate project participation, connect students with organisational resources, coordinate academic and workplace requirements, establish feedback routines, and support quality assurance. These arrangements create environmental affordances through which students can engage with authentic professional activities (Billett, 2001, 2004; Ceelen et al., 2025). The practice environment can therefore serve as a linking mechanism between mentor competence and training quality. This argument is consistent with evidence that WIL quality depends on purposeful curriculum design, organisational participation, assessment for learning, and

collaboration between educational and workplace stakeholders (Ferns et al., 2025; Luk & Chan, 2024; Curto-Reverte et al., 2025).

H5: Practice base support environment mediates the positive relationship between dual mentor guidance competence and perceived training quality.

2.7 Theoretical Integration and Conceptual Model

The proposed model integrates the individual, social, and environmental dimensions of SCT within postgraduate professional degree education. SIPA represents the learner's capacity to exercise agency through initiative, goal orientation, collaboration, practical engagement, innovative thinking, and persistence, while DMGC represents the social and instructional guidance provided through the dual-mentor arrangement (Bandura, 2001; Nuis et al., 2023; Ceelen et al., 2025). PBSE represents the organisational environment through which authentic activities, resources, projects, support, feedback, and quality-assurance arrangements become available to students (Billett, 2001, 2004; Ferns et al., 2025; Curto-Reverte et al., 2025). The model therefore specifies three direct relationships with PTQ, a relationship between DMGC and PBSE, and an indirect pathway from DMGC to PTQ through PBSE. This structure reflects SCT's proposition that individual capability and environmental conditions operate through reciprocal and socially situated processes rather than isolated influences (Bandura, 1986, 2001). It also responds to WIL research showing that meaningful professional learning depends on the coordination of student participation, supervision, authentic work activities, organisational support, and university-workplace partnerships (Billett, 2002; Ruskin & Bilous, 2020; Kligyte et al., 2024; Curto-Reverte et al., 2025). The conceptual model consequently provides a theoretically integrated explanation of how student agency, dual mentoring, and practice-base conditions are connected to perceived training quality.

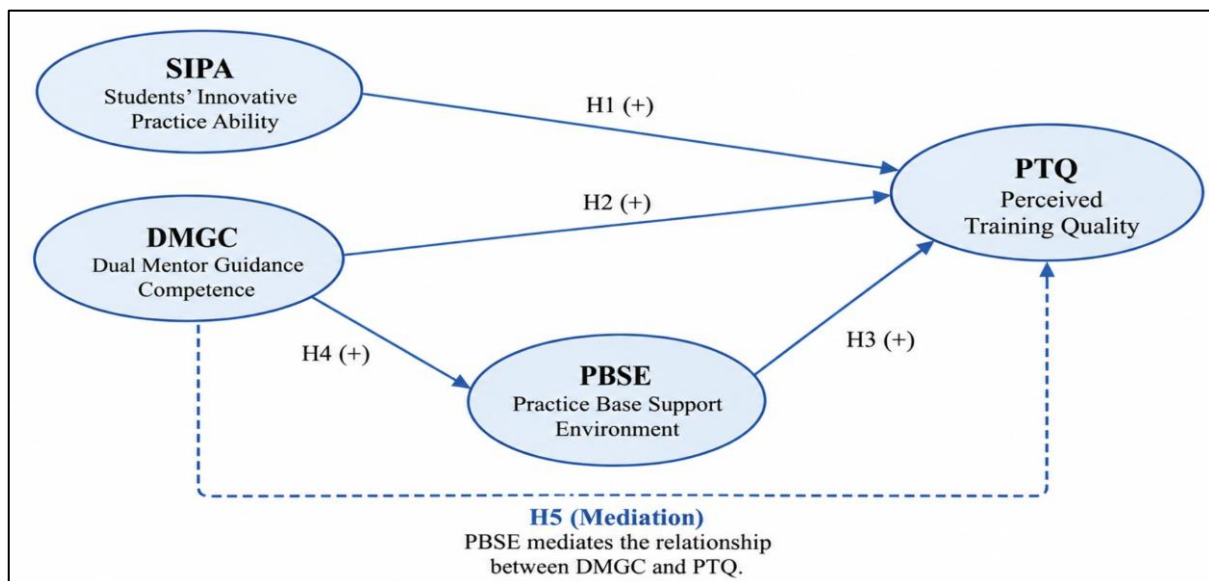


Figure 1. Conceptual model of the study

Source: Authors' work

3 Methods

3.1 Sample and Data Sources

The participants were university-based and industry practice-base mentors involved in postgraduate professional degree education in China. Data were collected from October to November 2024. With assistance from the Jiangsu provincial education authority, targeted distribution through university graduate schools, and contacts at university–enterprise partner organisations, 200 electronic questionnaires were distributed. Responses were retained when the information was complete and no obvious patterned responding was detected, yielding 184 valid questionnaires and a valid response rate of 92%. The sample included mentors from National Double First-Class and ordinary universities. University supervisors accounted for 92.4% of respondents and practice-base supervisors accounted for 7.6%. Professional titles comprised intermediate (9.8%), associate senior (53.8%), and full senior (36.4%), with no respondent classified in the junior category. The professional degree fields comprised engineering (62.5%), agriculture (30.4%), humanities and social sciences (5.4%), and

medicine (1.6%). Mentor-based evaluation provides direct access to professional degree training because the respondents participate in student supervision and observe practice activities, mentor collaboration, resource support, and training outcomes. All respondents completed the same structured questionnaire, and the analytical sample comprised 184 complete cases before measurement and structural analyses were conducted. The study was conducted in accordance with the applicable institutional research-ethics requirements. Participation was voluntary, respondents were informed of the study purpose, and the questionnaire was administered anonymously. No personally identifying information was requested, and responses were used only for research purposes and analyzed in aggregate form.

3.2 Measurement

The study variables were measured using five-point Likert-type items. Item direction was checked for consistency so that higher scores represented more favorable assessments. Four composite indices were constructed from 43 substantive items. SIPA comprised Q6 to Q16, DMGC comprised Q17 to Q27, PBSE comprised Q28 to Q42, and PTQ comprised Q43 to Q48. The questionnaire coding was verified against the original response structure before the composite scores were calculated. The constructs were specified as composites because their indicators cover distinct but related facets of the corresponding conceptual domains. The indicators jointly represent the scope of each construct rather than serving as interchangeable manifestations of a single underlying attribute. This treatment follows the logic of composite measurement described by Schuberth (2021) and is consistent with the confirmatory composite analysis literature (Henseler & Schuberth, 2020; Liu et al., 2022).

Each construct score was calculated as the equal weighted arithmetic mean of its prespecified indicators. Equal weighting was selected because the theoretical framework did not assign differential importance to individual indicators and no external weighting information was available. This procedure provides a transparent and reproducible representation of the four conceptual domains. All 43 indicators were retained in the primary specification, including Q42 in PBSE. The exclusion of Q42 was examined only as a measurement sensitivity analysis. Table 1 summarizes the measurement specification of the four constructs, including their item ranges, number of indicators, substantive content, and treatment in the analysis. The table also shows how the indicators were grouped to represent the conceptual domains of student innovative practice ability, dual mentor guidance competence, practice base support environment, and perceived training quality.

Measurement quality was assessed before structural estimation. The assessment covered indicator loadings, Cronbach's alpha, composite reliability, average variance extracted, and discriminant validity. Fornell and Larcker evidence and the heterotrait monotrait ratio were examined as complementary diagnostics. HTMT values were evaluated against the 0.85 and 0.90 reference points discussed by Henseler et al. (2015). Indicator level collinearity was assessed separately within each formative block using VIF and tolerance values. These diagnostics were used to describe the empirical behavior of the measurement blocks and to inform sensitivity assessment, while indicator retention remained grounded in the prespecified conceptual content.

Table 1. Constructs and measurement specification

Construct	Item range	Core content	Measurement treatment
SIPA	Q6–Q16	Initiative, interest, enthusiasm, collaboration, communication, knowledge, practical skills, learning, innovative thinking, resilience, goal setting	Equal-weighted composite
DMGC	Q17–Q27	Responsibility and ethics, knowledge structure, teaching and practical competence, innovation capability, interaction, instructional design, integration of theory and practice, individualised guidance, methodological innovation	Equal-weighted composite

PBSE	Q28–Q42	Learning materials, conditions, equipment, online resources, institutions, incentives, funding, projects, academic climate, culture, management, quality assurance, training plans, external demand	Equal-weighted composite
PTQ	Q43–Q48	Publication quantity and quality, patents, enterprise contributions, potential for an excellent degree thesis, employer recognition	Equal-weighted composite

Source: Authors' measurement specification based on the study questionnaire.

3.3 Common Method Bias

Because the study used a single questionnaire and a common respondent source, common method bias (CMB) was considered during the research design and analysis. Procedural safeguards included anonymous participation, consistent item direction, and separation of the substantive measurement domains. Statistical diagnostics were then used as supplementary evidence, consistent with the view that method-related variance can arise through multiple mechanisms and should not be assessed with a single post hoc criterion (Podsakoff et al., 2012; Podsakoff et al., 2024). Harman's single-factor procedure was conducted using all 43 substantive indicators in an unrotated principal-component analysis. The analysis recorded the variance explained by the first component and the number of components with eigenvalues greater than one. A full-collinearity VIF assessment was also conducted using the four construct scores. These diagnostics provide complementary information about the possibility of dominant common variance and construct-level collinearity, while neither procedure was treated as a definitive test of CMB.

3.4 Analytical Strategy

The analysis proceeded from data validation and measurement assessment to descriptive statistics, correlation analysis, structural estimation, mediation testing, robustness and sensitivity analysis, and predictive assessment. The analytical sample comprised 184 complete observations. Descriptive statistics included the mean, standard deviation, minimum, maximum, skewness, and kurtosis of the four construct scores. Pearson correlations were calculated for all construct pairs. Structural collinearity was assessed using VIF and tolerance values for the predictors of each endogenous construct. Explanatory power was evaluated using R^2 and adjusted R^2 , and Cohen's f^2 was used to assess the incremental contribution of individual predictors (Cohen, 1988). The structural model was specified as follows.

$$PBSE_i = \alpha_1 + \beta_1 DMGC_i + \beta_2 SIPA_i + \varepsilon_{1i} \quad (1)$$

$$PTQ_i = \alpha_2 + \beta_3 SIPA_i + \beta_4 DMGC_i + \beta_5 PBSE_i + \varepsilon_{2i} \quad (2)$$

Bootstrap inference provided the primary basis for structural path inference. A nonparametric case-bootstrap procedure with 5,000 replications generated bootstrap standard errors and 95% percentile confidence intervals. HC3 heteroskedasticity-consistent standard errors were estimated as a robustness procedure, following the finite-sample considerations of MacKinnon and White (1985) and the subsequent evaluation of heteroskedasticity-consistent estimators by Long and Ervin (2000).

3.5 Mediation Analysis

The mediation model examined whether PBSE carries part of the association between DMGC and PTQ while SIPA remains an exogenous predictor in the model. The mediator equation was specified as:

$$PBSE_i = a_0 + a_1 DMGC_i + a_2 SIPA_i + \varepsilon_{1i} \quad (3)$$

The outcome equation was specified as:

$$PTQ_i = b_0 + c' DMGC_i + b PBSE_i + d SIPA_i + \varepsilon_{2i} \quad (4)$$

The total-effect equation was specified as:

$$PTQ_i = c_0 + c DMGC_i + d SIPA_i + \varepsilon_{3i} \quad (5)$$

The indirect effect was calculated as a_1b , where a_1 represents the association between DMGC and PBSE and b represents the association between PBSE and PTQ. The direct effect is c' , representing the DMGC and PTQ association after PBSE is included. The total effect c represents the corresponding DMGC and PTQ association when PBSE is excluded while SIPA remains in the model. The decomposition was verified using $c = c' + a_1b$. The direct, indirect, and total effects were estimated from the same 5,000 case-bootstrap replications. The indirect effect was evaluated using its 95% bootstrap percentile confidence interval, following the logic of bootstrap mediation inference described by Hayes (2017) and Alfons et al. (2022).

3.6 Robustness, Sensitivity, Explanatory, and Predictive Assessment

Several complementary analyses were conducted to assess the stability of the structural and mediation results. HC3 inference was examined alongside the primary bootstrap estimates. Q42 was excluded from the PBSE composite, and the structural and mediation models were re-estimated to assess measurement sensitivity. Influence diagnostics were examined using Cook's distance, leverage, and externally studentised residuals. A combined influence criterion identified observations for a separate sensitivity analysis. These exclusions were applied only to the sensitivity specification. The indirect effect was reproduced under the primary, Q42-exclusion, and influence-exclusion specifications using 5,000 bootstrap replications for each specification. The robustness assessment considered the direction, magnitude, and bootstrap confidence interval of the indirect effect across the specifications. Explanatory performance was assessed using R^2 , adjusted R^2 , and f^2 . Predictive performance was assessed through repeated 10-fold cross-validation with 50 repetitions. Predictions for each held-out fold were compared with a training-sample mean benchmark. Predictive performance was summarized using root mean squared error, mean absolute error, and cross-validated predictive Q^2 . The latter was treated as an out-of-sample predictive measure because it was calculated from held-out observations, rather than as a traditional blindfolding-based Stone–Geisser statistic (Shmueli et al., 2019).

4 Results

The collected data were assessed using Python (version 3.9.6). The analytical dataset was first examined for data completeness and integrity, after which descriptive statistics and construct-level correlations were assessed before proceeding to the measurement and structural analyses.

4.1 Descriptive Statistics and Correlation Analysis

Table 2 presents the descriptive statistics and Pearson correlations for the four core constructs. DMGC recorded the highest mean score ($M = 4.051$, $SD = 0.674$), followed by PBSE ($M = 3.664$, $SD = 0.813$), SIPA ($M = 3.508$, $SD = 0.821$), and PTQ ($M = 3.495$, $SD = 0.950$). Skewness ranged from -0.829 to -0.271 , while kurtosis ranged from -0.369 to 1.098 . Pearson correlations were positive and statistically significant across all six construct pairs, with coefficients ranging from 0.603 to 0.667 and $p < 0.001$. SIPA had its strongest bivariate association with PTQ ($r = 0.667$), while its association with PBSE was the smallest among the six construct correlations ($r = 0.603$). DMGC was positively correlated with PBSE ($r = 0.627$) and PTQ ($r = 0.653$), and PBSE was positively correlated with PTQ ($r = 0.635$).

Table 2. Descriptive statistics and Pearson correlations

Variable	M	SD	Skewness	Kurtosis	1	2	3	4
1. SIPA	3.508	0.821	-0.276	-0.215	1			
2. DMGC	4.051	0.674	-0.829	1.098	0.616***	1		
3. PBSE	3.664	0.813	-0.371	-0.285	0.603***	0.627***	1	
4. PTQ	3.495	0.950	-0.271	-0.369	0.667***	0.653***	0.635***	1

Note. * $p < .05$; ** $p < .01$; *** $p < .001$. Source: Authors' calculations based on the survey data.

4.2 Measurement Diagnostics and Common Method Bias Assessment

Table 3 presents the measurement diagnostics for the four constructs. Cronbach's alpha ranged from 0.922 to 0.963 , composite reliability ranged from 0.934 to 0.967 , and average variance extracted ranged from 0.566 to 0.737 . Indicator loadings ranged from 0.509 to 0.905 . Q18, Q27, and Q42 were the three indicators with loadings below 0.708 , although each remained above 0.40 . All 43 indicators were retained in the primary specification because the composite constructs were designed to capture

distinct but related dimensions of their respective conceptual domains. Discriminant validity was supported by both the Fornell–Larcker criterion and the heterotrait–monotrait ratio. The square root of AVE for each construct exceeded its correlations with the other constructs, while HTMT values ranged from 0.629 to 0.712 and remained below both the 0.85 and 0.90 reference values. The detailed Fornell–Larcker and HTMT results are reported in Supplementary Table S3, with the corresponding construct-level correlation and HTMT patterns presented visually in Supplementary Figure S3.

Table 3. Measurement diagnostics for the four constructs

Construct	Cronbach's α	Composite reliability	AVE	Minimum loading	Maximum loading
SIPA	0.957	0.963	0.703	0.770	0.879
DMGC	0.921	0.934	0.565	0.636	0.828
PBSE	0.963	0.967	0.665	0.508	0.883
PTQ	0.927	0.943	0.737	0.830	0.905

Note. AVE = average variance extracted. All 43 substantive indicators were retained in the primary specification. Source: Authors' calculations based on the survey data.

Common method bias was examined using Harman's single-factor assessment and full-collinearity VIF. The first unrotated component accounted for 48.11% of the total variance, and five components had eigenvalues greater than one. Full-collinearity VIF values for the four construct scores ranged from 2.030 to 2.340, with the maximum value below the 3.3 reference point. The complete results are reported in Supplementary Table S1. Indicator-level diagnostics were subsequently examined within each measurement block. Indicator VIF values ranged from 1.541 to 5.144, with the highest value observed for Q41 in PBSE (VIF = 5.144). Fifteen of the 43 indicators had VIF values of at least 3.3, while one exceeded 5.0. The indicator-level means, standard deviations, skewness, kurtosis, VIF, and tolerance values are reported in Supplementary Table S2.

4.3 Structural Paths and Hypothesis Tests

The structural model explained 46.9% of the variance in PBSE and 57.3% of the variance in PTQ. Table 4 reports the bootstrap estimates for the four direct hypotheses. SIPA was positively associated with PTQ ($B = 0.394$, $\beta = 0.340$, bootstrap SE = 0.103, 95% CI [0.185, 0.591]), supporting H1. DMGC was positively associated with PTQ ($B = 0.404$, $\beta = 0.287$, bootstrap SE = 0.107, 95% CI [0.183, 0.606]), supporting H2. PBSE was positively associated with PTQ ($B = 0.292$, $\beta = 0.250$, bootstrap SE = 0.093, 95% CI [0.133, 0.497]), supporting H3. DMGC was positively associated with PBSE ($B = 0.497$, $\beta = 0.412$, bootstrap SE = 0.098, 95% CI [0.283, 0.672]), supporting H4. The corresponding f^2 values were 0.147 for SIPA, 0.100 for DMGC, and 0.078 for PBSE in predicting PTQ, and 0.199 for DMGC and 0.143 for SIPA in predicting PBSE. Structural VIF values ranged from 1.611 to 1.931 across the predictor terms, indicating low structural collinearity. The complete structural VIF and effect-size diagnostics are reported in Supplementary Table S4, while Supplementary Figure S1 provides a visual profile of the structural VIF values.

Table 4. Direct structural path estimates and hypothesis tests (N = 184)

Hypothesis	Path	B	β	Bootstrap SE	95% CI	f^2	Conclusion
H1	SIPA to PTQ	0.394	0.340	0.103	[0.185, 0.591]	0.147	Supported
H2	DMGC to PTQ	0.404	0.287	0.107	[0.183, 0.606]	0.100	Supported
H3	PBSE to PTQ	0.292	0.250	0.093	[0.133, 0.497]	0.078	Supported
H4	DMGC to PBSE	0.497	0.412	0.098	[0.283, 0.672]	0.199	Supported

Note. B = unstandardized coefficient; β = standardized coefficient; SE = bootstrap standard error; CI = 95% bootstrap percentile confidence interval. Confidence intervals are reported for B. Source: Authors' calculations based on 5,000 bootstrap replications.

The mediation analysis examined whether PBSE carries part of the association between DMGC and PTQ. Table 5 reports the direct, indirect, and total effects of DMGC on PTQ based on 5,000 nonparametric case-bootstrap replications. The association between DMGC and PBSE was positive ($B = 0.497$, $\beta = 0.412$), as was the association between PBSE and PTQ ($B = 0.292$, $\beta = 0.250$). The

resulting indirect effect was positive ($B = 0.145$, $\beta = 0.103$), with a bootstrap SE of 0.058 and a 95% percentile confidence interval of [0.054, 0.279]. Because the confidence interval excludes zero, H5 is supported.

Table 5. Direct, indirect, and total effects of DMGC on PTQ

Effect	Path	B	β	Bootstrap SE	95% CI
Direct effect	DMGC to PTQ	0.404	0.287	0.107	[0.183, 0.606]
Indirect effect	DMGC through PBSE to PTQ	0.145	0.103	0.058	[0.054, 0.279]
Total effect	DMGC to PTQ	0.549	0.390	0.109	[0.330, 0.757]

Note. The indirect effect was estimated using 5,000 nonparametric case-bootstrap replications. The proportion mediated was 26.4%. Source: Authors' calculations based on the survey data.

The total association between DMGC and PTQ was $B = 0.549$ ($\beta = 0.390$, bootstrap SE = 0.109, 95% CI [0.330, 0.757]). After PBSE was included, the direct association remained positive at $B = 0.404$ ($\beta = 0.287$, bootstrap SE = 0.107, 95% CI [0.183, 0.606]). Thus, the total association comprised a direct component of 0.404 and an indirect component of 0.145. The indirect effect represented 26.4% of the total association. Figure 2 presents the final structural model, showing the hypothesised relationships among SIPA, DMGC, PBSE, and PTQ, together with the estimated standardised path coefficients, explanatory power for the endogenous constructs, and the indirect pathway through PBSE. The pattern indicates that PBSE accounts for part of the association between DMGC and PTQ while a positive direct association remains.

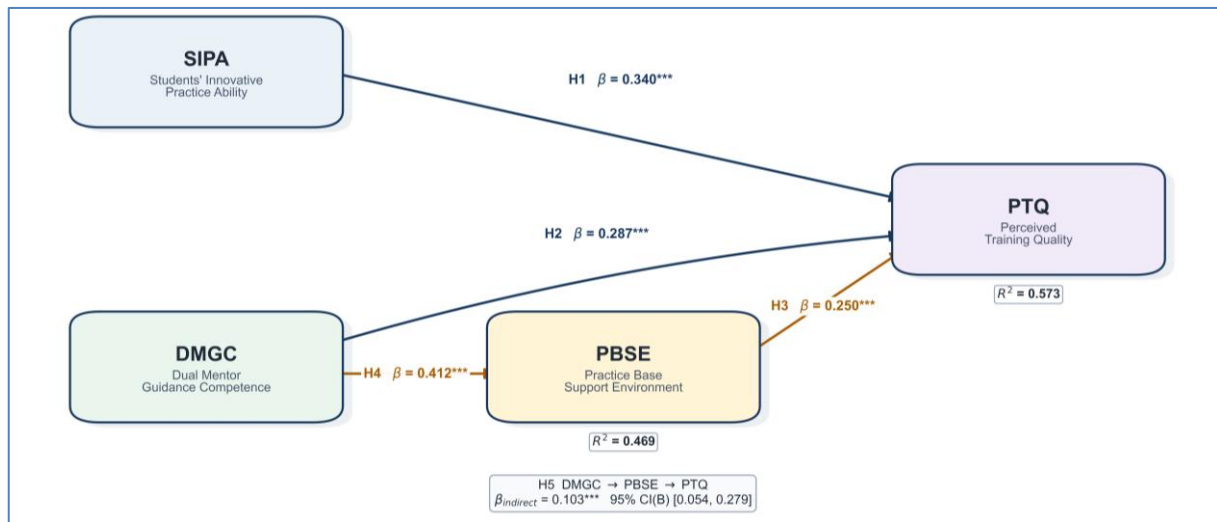


Figure 2. Structural model

Source: Authors' calculations based on 5,000 bootstrap replications.

4.4 Robustness, Sensitivity, Explanatory Power, and Predictive Assessment

The structural findings remained consistent when heteroskedasticity-consistent HC3 inference was applied. The resulting confidence intervals for the primary structural paths remained positive, supporting the stability of the direct-path estimates. The full HC3 results are reported in Supplementary Table S5. The measurement sensitivity analysis excluding Q42 produced an indirect effect of $B = 0.133$ with a 95% bootstrap confidence interval of [0.046, 0.263], compared with $B = 0.145$ and [0.054, 0.279] in the primary specification. The total effect remained $B = 0.549$, while the direct association was $B = 0.416$. The indirect effect therefore retained its positive direction and bootstrap support under the alternative measurement specification.

Influence diagnostics identified seven observations meeting the combined influence criterion. Excluding these observations produced a sensitivity sample of 177 cases. The indirect effect remained positive at $B = 0.151$, with a bootstrap SE of 0.057 and a 95% confidence interval of [0.061, 0.283]. The direct association was $B = 0.332$. The complete robustness and sensitivity results are reported in Supplementary Table S5, while the corresponding influence diagnostics are shown in Supplementary Figure S2. The structural equations explained 46.9% of the variance in PBSE and 57.3% of the variance in PTQ. Repeated 10-fold cross-validation with 50 repetitions produced

predictive Q^2 values of 0.452 for PBSE and 0.552 for PTQ. For PBSE, RMSE was 0.604 compared with a benchmark of 0.816, while MAE was 0.437 compared with 0.656. For PTQ, RMSE was 0.638 compared with 0.953, while MAE was 0.493 compared with 0.790. The positive predictive Q^2 values indicate that the structural equations retained predictive information when evaluated on held-out observations. The complete explanatory and predictive assessment is reported in Supplementary Table S6.

5 Discussion and Research Implications

The findings suggest that professional degree training quality is better understood as the product of interacting learner, mentoring, and organisational conditions rather than as the outcome of any single component. The positive association of SIPA with PTQ indicates that students remain active participants in converting practice opportunities into learning outcomes. This extends a largely environment-centred view of practice education by highlighting the role of learner agency in determining how effectively students engage with tasks, feedback, knowledge, and problem-solving opportunities. Workplace-learning research similarly suggests that learning opportunities do not automatically translate into development; their value depends partly on how learners participate in and make use of those opportunities (Stabel et al., 2022; Nymberg & Jakobsson, 2022). The finding is therefore consistent with a view of professional learning in which organisational provision and student engagement operate as complementary conditions.

Further, the results indicate that dual-mentor guidance has a broader role than direct interaction with students. Its association with PBSE suggests that mentor competence is connected with the conditions through which practice-based learning is organised and supported. This is important because dual mentoring involves more than transferring knowledge or providing individual advice. Effective mentoring requires coordination of academic expectations, practical tasks, feedback, resources, and student development across different learning settings. Prior research similarly emphasises the importance of mentoring quality, interaction, role clarity, and institutional support in shaping students' learning experiences (Nuis et al., 2024a; Nuis et al., 2024b). The mediation finding adds to this literature by suggesting that the practice base provides an organisational pathway through which mentoring resources can be translated into training opportunities. In this sense, the practice environment does not replace the contribution of mentors. It provides the conditions under which that contribution can be extended and sustained.

This interpretation also helps explain why professional degree education requires closer integration between universities and practice organisations. A capable mentor may provide knowledge, feedback, and guidance, but these contributions have greater educational value when students can access meaningful projects, appropriate resources, institutional support, and opportunities to apply what they learn. WIL research similarly stresses continuity between curriculum objectives, workplace activities, mentoring, reflection, and partnership arrangements (Ferns et al., 2025; Curto-Reverte et al., 2025). The findings therefore position the practice base as an important organisational interface connecting mentoring and student development rather than simply as a location for workplace experience. Because the evidence comes from a cross-sectional design, this interpretation concerns the structural relationships observed in the data rather than a fixed causal sequence.

5.1 Theoretical Contributions

This study makes four theoretical contributions. First, it advances an ecological explanation of professional competence development by bringing learner agency, mentoring, and practice conditions into the same analytical framework. These elements are often discussed separately, which provides limited insight into how they operate alongside one another. The findings suggest that professional training quality is associated with the interaction of individual capability, instructional support, and organisational conditions. SIPA showed the strongest independent association with PTQ, while DMGC and PBSE also contributed positively. This extends workplace-learning perspectives that emphasise the interdependence of individual participation and environmental affordances (Stabel et al., 2022; Kligyte et al., 2024). The contribution therefore lies not in treating these factors as competing explanations, but in specifying their distinct and connected roles within professional degree education. Second, the study develops the embedded dual-mentor mechanism by moving beyond the treatment of mentor competence as an isolated individual attribute. DMGC was positively associated with PBSE, and the mediation analysis showed that part of its association with PTQ operates through the practice-base environment. The result suggests that mentor competence acquires additional educational value when it is supported by project arrangements, resources, feedback processes,

incentives, and quality-assurance structures. Mentoring therefore involves more than the transfer of knowledge or individual guidance. Its effectiveness also depends on the institutional setting in which mentoring is enacted (Nuis et al., 2024a; Nuis et al., 2024b). This perspective shifts the theoretical focus from what mentors possess to how mentor resources become embedded within the organisational conditions of professional learning.

Third, the study extends the conceptualisation of professional degree training quality beyond conventional academic outcomes. PTQ was operationalised as a formative composite incorporating publication quantity and quality, patent applications, technical contributions to enterprises, potential for an excellent degree thesis, and employer recognition. These dimensions reflect the academic, technical, organisational, and career-oriented purposes of professional degree education. A formative specification is appropriate because the indicators jointly define the scope of the construct rather than represent interchangeable manifestations of an underlying trait (Henseler & Schubert, 2020; Schubert, 2021; Liu et al., 2022). The study therefore provides a broader conceptual basis for evaluating training quality in programmes where academic achievement and workplace contribution are expected to develop together. Fourth, the study extends a social cognitive perspective to professional practice learning by specifying how learner agency and environmental affordances operate within a dual-mentor setting. SIPA and PBSE each showed independent associations with PTQ, while DMGC was also associated with the practice environment. This pattern suggests that students do not simply respond to a predetermined training environment. They actively engage with available opportunities, while mentors help structure and guide those opportunities within institutional settings. The practice base consequently provides an important contextual interface between mentoring and student development. This interpretation extends social cognitive reasoning from the individual learner–environment relationship to a more organisationally embedded setting in which mentors participate in shaping the conditions through which learning opportunities become educational outcomes.

5.2 Practical Implications

The findings have direct implications for the development of postgraduate professional degree education in China. Improvement should focus not only on individual mentor capability but also on the conditions that allow students and mentors to engage effectively in practice-based learning. WIL research similarly emphasises structured learning arrangements, mentoring, reflection, and cooperation between universities and practice organisations (Curto-Reverte et al., 2025). For education providers, this means moving beyond training mentors in isolation towards an organisational system in which university-based and practice-base mentors can coordinate expectations, tasks, feedback, and assessment. Clear role descriptions and shared responsibility arrangements can help distinguish responsibilities for task design, process guidance, technical requirements, academic standards, and outcome evaluation. Recognising joint mentoring in workload and performance systems may also encourage more substantive participation from practice-base mentors. Practice bases should complement investment in facilities with structures that organise learning around authentic work. The findings indicate that PBSE is positively associated with PTQ, suggesting that equipment and physical space alone are insufficient. Practice bases can strengthen learning by maintaining meaningful projects, providing access to relevant resources, creating opportunities for feedback and reflection, and documenting students' progress and outcomes. Such arrangements can help connect workplace participation with educational objectives and support the continuity between curriculum, practice, mentoring, and assessment emphasised in WIL research (Ferns et al., 2025; Curto-Reverte et al., 2025). At the student level, the positive association between SIPA and PTQ also points to the importance of active participation. Practice-goal agreements, reflective records, problem-solving activities, and capability portfolios could help students take greater responsibility for identifying problems, applying knowledge, responding to feedback, and documenting their development.

5.3 Policy Implications

The findings suggest that quality governance in professional degree education should place greater emphasis on coordination and implementation, rather than treating the presence of mentors, practice bases, facilities, and other inputs as sufficient evidence of educational quality. Formal provision does not necessarily indicate that these resources are functioning as an integrated learning system. Evaluation mechanisms could therefore consider the quality of joint mentoring, students' access to authentic practice opportunities, opportunities for independent task participation, collaboration between universities and practice organisations, and the extent to which feedback and assessment are integrated across settings. Such indicators would provide a closer representation of how

professional degree education operates in practice. Policy attention should also extend beyond mentor training alone. The findings indicate that mentor competence is associated with the practice-base environment as well as with training quality, suggesting that institutional conditions are relevant to how mentoring resources are translated into educational experiences. Accreditation and programme evaluation could therefore encourage shared governance arrangements between university and practice-base mentors, clearer responsibilities for learning and assessment, sustainable project provision, and mechanisms for reviewing and improving practice-based training. This approach would shift quality governance from verifying whether required components are present towards examining whether those components work together to support students' professional development.

5.4 Conclusion

Using survey data from 184 university-based and practice-base mentors, predominantly from Jiangsu Province, this study developed and tested a three-pillar student–dual-mentor–practice-base model of professional degree training quality. The findings show that student capability, dual-mentor guidance, and the practice-base environment are all positively associated with PTQ, while their roles are structurally different. The final model explained 57.3% of the variance in PTQ, with SIPA, DMGC, and PBSE each showing a significant positive association. The mediation analysis further showed that part of the association between DMGC and PTQ operates through PBSE, indicating that mentoring is connected to training quality both directly and through the organisational conditions in which mentoring is enacted. The findings therefore move beyond a simple argument that students, mentors, and practice bases all matter. They suggest that professional degree training is shaped by the interaction between learner agency, mentoring support, and the organisational conditions that make practice-based learning possible. The findings also provide a more nuanced understanding of the dual-mentor system. Mentor competence is not only an individual resource that is transferred directly to students. It is also connected with the practice environment through which students access projects, resources, feedback, and other learning opportunities. At the same time, the significant direct association between DMGC and PTQ indicates that the contribution of mentoring cannot be reduced entirely to environmental conditions. The study therefore conceptualises the practice base as an important organisational interface linking mentoring and student development. For professional degree education, strengthening this interface requires more than appointing additional mentors. It requires coordinated responsibilities, meaningful practice opportunities, institutional support, and mechanisms through which students can actively engage with and learn from practice. These findings provide an empirical basis for viewing the dual-mentor system as an integrated educational arrangement rather than a staffing configuration.

5.5 Limitations and Future Research

Several limitations provide directions for future research. First, the cross-sectional design does not establish temporal ordering or causal direction. The observed relationships should therefore be interpreted as structural associations rather than confirmation of a causal sequence. Reciprocal relationships between DMGC and PBSE are also possible because effective mentors may strengthen the practice environment, while well-developed practice bases may simultaneously facilitate effective mentoring. Longitudinal or cross-lagged designs could examine these relationships more rigorously. Second, the study relies on a single questionnaire source, which creates a potential risk of common method variance. Although procedural safeguards and statistical diagnostics were applied, method-related variance cannot be ruled out completely. Future research should combine student assessments, mentor evaluations, employer assessments, and objective outcome records, preferably with temporal separation between measurements.

Third, the sample is geographically and institutionally concentrated. Most respondents were from Jiangsu Province, while practice-base mentors and some professional fields were less represented. The findings should therefore be interpreted within the characteristics of the present sample rather than assumed to generalise uniformly across Chinese professional degree education. Future studies could include institutions from different regions and increase representation across mentor roles and professional fields. Fourth, PTQ is based on mentor assessments rather than directly matched objective outcomes. Future research could examine whether perceived training quality corresponds with students' actual publications, patents, enterprise project contributions, thesis outcomes, or employment-related indicators. Finally, substantial collinearity was observed among several formative indicators. The robustness analyses showed that the principal structural and mediation findings remained stable under alternative measurement and influence specifications, but high indicator overlap limits interpretation of the marginal contribution of individual items. Future research could

refine the measurement domains through expert-based validation, alternative weighting procedures, or higher-order formative specifications. The present study also does not explicitly model the possible clustering of respondents within universities or practice bases. Multi-level designs incorporating students, mentors, practice bases, and universities would provide a stronger basis for examining how individual and organisational conditions jointly shape professional degree training quality.

Declarations

Ethical approval: This study was reviewed and approved by Jiangsu University and was conducted in accordance with the ethical principles of the Declaration of Helsinki and the relevant institutional ethical guidelines and regulations of Jiangsu University.

Informed consent: Participation was voluntary, and all participants were informed about the purpose of the study, the anonymity and confidentiality of their responses, and the use of the data for academic research. Informed consent was obtained from all participants before completing the questionnaire.

Data availability: The anonymized data, codebook, and analysis code supporting the findings of this study are available from the corresponding author upon reasonable request.

Author contributions: Zhengsong Zhou contributed to conceptualization, investigation, data collection, and writing of the original draft. Mingxing Li contributed to conceptualization, methodology, and supervision. Xiaomeng Chi contributed to investigation, data curation, and literature review. Muhammad Amir contributed to methodology, formal analysis, validation, interpretation of the findings, and review and editing of the manuscript. Yamin Hu contributed to investigation, data curation, and manuscript review. Jie Gao contributed to supervision, project administration, and review and editing. All authors reviewed and approved the final manuscript.

Competing interests: The authors declare no competing interests.

Funding: This study was supported by the National Foreign Expert Project (Project Numbers: Y20240100 and Y20240101).

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