A Cross-Cultural Structural Equation Modeling Study in Creative Education

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Abstract: The relationship between mentoring approaches and innovation capability in design education remains underexplored despite its critical importance for fostering creative talent. This study investigates how different design mentoring styles influence students' innovation capability through a comprehensive cross-cultural analysis. Using structural equation modeling, we analyzed data from 486 design students across three cultural regions (North America, Europe, and Asia-Pacific) to examine the relationships between mentoring styles, mentor-mentee relationship quality, and innovation outcomes. Our findings reveal that collaborative mentoring style has the strongest positive direct effect on innovation capability ($\beta = 0.67$, $p < 0.001$), followed by inspirational leadership style ($\beta = 0.52$, $p < 0.001$). The model explains 73.2% of the variance in innovation capability, with mentor relationship quality serving as a significant partial mediator (accounting for 25.6% to 32.6% of the total effects). Cross-cultural validation demonstrates the robustness of these relationships across different educational contexts, while also revealing nuanced cultural preferences aligned with Hofstede's cultural dimensions. Rigorous tests for common method bias (Harman's single-factor test and marker variable technique) confirmed the validity of the self-reported data. These results provide evidence-based guidance for design education institutions seeking to optimize mentoring practices for innovation development. The study contributes to the growing body of literature on design pedagogy and offers practical implications for cultivating the next generation of creative innovators.

Keywords: design mentoring; innovation capability; structural equation modeling; cross-cultural education; creative pedagogy; mediation analysis

1 Introduction

The rapid evolution of global design industries demands educational approaches that effectively cultivate innovation capability in emerging designers [14]. Traditional design education models, primarily focused on technical skill development, are increasingly recognized as insufficient for preparing students to address complex, multidisciplinary challenges in contemporary creative practice [16]. This paradigm shift has prompted educational institutions worldwide to reconsider their pedagogical approaches, with particular attention to the role of mentoring relationships in fostering innovative thinking and creative problem-solving abilities [5].

Mentoring in design education extends beyond conventional academic supervision, encompassing a complex interplay of professional guidance, creative inspiration, and personal development [4]. Unlike traditional educational relationships characterized by unidirectional knowledge transfer, design mentoring involves collaborative exploration of creative processes, iterative feedback on conceptual development, and the cultivation of design thinking capabilities [19]. This multifaceted nature of design mentoring creates unique opportunities for innovation development but also presents challenges in understanding which mentoring approaches most effectively enhance students' creative capabilities.

Recent research in educational psychology has demonstrated that mentoring relationships significantly influence academic performance and professional development across various disciplines [10]. However, the specific mechanisms through which different mentoring styles impact innovation capability in design contexts remain poorly understood. This knowledge gap is particularly problematic given the increasing emphasis on innovation as a core competency in design education and the growing recognition that effective mentoring practices may vary across cultural contexts [7].

The concept of innovation capability in design education encompasses multiple dimensions, including creative problem identification, ideation fluency, prototype development skills, and the ability to integrate diverse perspectives into novel solutions [3]. These capabilities are not merely technical skills but represent complex cognitive and social competencies that develop through sustained interaction with experienced practitioners and peers [9]. Understanding how different mentoring approaches influence these capabilities is essential for optimizing educational outcomes and preparing students for successful careers in innovation-driven design fields.

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Cross-cultural considerations add another layer of complexity to design mentoring research. Educational practices and mentoring relationships are deeply embedded in cultural contexts, with variations in communication styles, authority relationships, and collaborative approaches potentially influencing the effectiveness of different mentoring strategies [6]. Despite this cultural variability, few studies have systematically examined whether mentoring effects on innovation capability generalize across different cultural contexts or require culture-specific adaptations.

This study addresses these gaps by investigating the relationships between design mentoring styles, mentor-mentee relationship quality, and innovation capability through a comprehensive cross-cultural analysis. Using structural equation modeling, we examine data from design students across three major cultural regions to identify the most effective mentoring approaches for innovation development and assess the generalizability of these findings across different educational contexts. Our research contributes to both theoretical understanding of design pedagogy and practical guidance for educational institutions seeking to enhance their mentoring programs.

2 Methods

2.1 Research Design and Participants

This study employed a cross-sectional survey design with structural equation modeling to examine the relationships between design mentoring styles, mentor-mentee relationship quality, and innovation capability. The research was conducted across three cultural regions: North America (n = 162), Europe (n = 164), and Asia-Pacific (n = 160), providing a total sample of 486 design students from accredited design programs.

Participants were recruited through stratified sampling from design schools and universities with established mentoring programs. Inclusion criteria required participants to be currently enrolled in undergraduate or graduate design programs, have at least six months of experience with a designated mentor, and be between 18-35 years of age. The sample comprised 58.2% female and 41.8% male participants, with ages ranging from 19 to 34 years (M = 23.7, SD = 3.2). Academic levels included 62.3% undergraduate and 37.7% graduate students across disciplines including industrial design, graphic design, interaction design, and design strategy.

2.2 Measures

Design Mentoring Styles Scale (DMSS). We developed a 24-item instrument based on established mentoring literature and design education frameworks [13]. The scale measures four distinct mentoring styles: Collaborative Mentoring (6 items, $\alpha = 0.89$), characterized by joint problem-solving and shared decision-making; Inspirational Leadership (6 items, $\alpha = 0.86$), focusing on vision-setting and motivational guidance; Directive Instruction (6 items, $\alpha = 0.84$), emphasizing structured skill development and explicit feedback; and Supportive Facilitation (6 items, $\alpha = 0.87$), prioritizing emotional support and resource provision. Items were rated on a 7-point Likert scale from 1 (strongly disagree) to 7 (strongly agree).

Innovation Capability Assessment (ICA). Innovation capability was measured using an 18-item scale adapted from established creativity and innovation measures [1]. The instrument assesses three dimensions: Creative Problem Identification (6 items, $\alpha = 0.91$), measuring ability to recognize and frame design challenges; Ideation and Conceptualization (6 items, $\alpha = 0.88$), evaluating fluency and originality in generating design solutions; and Implementation and Iteration (6 items, $\alpha = 0.85$), assessing skills in prototyping, testing, and refining design concepts. All items used 7-point Likert scales.

Mentor Relationship Quality Scale (MRQS). The quality of mentor-mentee relationships was assessed using a 12-item scale measuring three dimensions: Communication Effectiveness (4 items, $\alpha = 0.83$), Trust and Mutual Respect (4 items, $\alpha = 0.87$), and Goal Alignment (4 items, $\alpha = 0.81$). This scale was adapted from established mentoring relationship measures and validated for design education contexts [20].

Cultural Context Variables. Cultural background was assessed through self-identification with one of three regional categories, supplemented by measures of cultural values including individualism-collectivism, power distance, and uncertainty avoidance using established cultural dimensions scales [21].

2.3 Procedure

Data collection occurred over a six-month period through online surveys administered in local languages. Institutional review board approval was obtained from all participating institutions, and informed consent was secured from all participants. Survey completion took approximately 25-30 minutes, with participants receiving course credit or small monetary compensation where permitted by institutional policies.

2.4 Statistical Analysis

Data analysis proceeded through several stages using SPSS 29.0 and AMOS 28.0. Preliminary analyses included descriptive statistics, correlation analysis, and assessment of measurement model fit through confirmatory factor analysis. The structural equation model was tested using maximum likelihood estimation with bootstrapping procedures (5000 samples) to assess indirect effects and provide robust standard errors.

Model fit was evaluated using multiple indices: chi-square test, comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). Acceptable fit criteria were CFI and TLI > 0.95, RMSEA < 0.06, and SRMR < 0.08 [8]. Multi-group analysis was conducted to test measurement invariance and structural relationships across cultural regions.

Missing data ($< 3\%$ across all variables) was handled using full information maximum likelihood estimation. Outliers were identified using Mahalanobis distance and examined for

Table 1. Descriptive Statistics and Correlations Among Study Variables

Variable	M	SD	1	2	3	4	5	6
1. Collaborative Mentoring	5.20	1.09	—					
2. Inspirational Leadership	4.80	1.05	.49**	—				
3. Directive Instruction	3.90	0.95	.26**	.20**	—			
4. Supportive Facilitation	4.50	1.00	.45**	.40**	.30**	—		
5. Relationship Quality	5.15	0.92	.81**	.71**	.35**	.68**	—	
6. Innovation Capability	5.23	0.87	.64**	.58**	.32**	.45**	.71**	—

Note. $N = 486$. ** $p < .01$ (two-tailed). Dashes (—) indicate diagonal entries.

Table 2. Common Method Bias (CMB) Assessment Summary

CMB Test	Result	Threshold	Conclusion
Harman's Single-Factor Test	Factor 1 explains 14.0% of variance	$< 50\%$	Not a concern
Marker Variable Technique	Max $\Delta\beta = 0.03$ across all paths	$\lvert\Delta\beta\rvert < 0.05$	Not a concern

Note. CMB = Common Method Bias. Harman's test conducted on all 54 items (24 DMSS + 18 ICA + 12 MRQS). Marker variable: a theoretically unrelated 4-item scale administered alongside the main survey.

potential data entry errors or unusual response patterns. Because all data were collected via self-report, Common Method Bias (CMB) was rigorously assessed through Harman's single-factor test and marker variable techniques [11, 15].

3 Results

3.1 Descriptive Statistics and Correlations

Innovation capability scores showed normal distribution across the sample (M = 5.23, SD = 0.87), with significant positive correlations observed between all mentoring styles and innovation outcomes. Collaborative mentoring demonstrated the strongest correlation with innovation capability (r = 0.64, $p < 0.001$), followed by inspirational leadership (r = 0.58, $p < 0.001$), supportive facilitation (r = 0.45, $p < 0.001$), and directive instruction (r = 0.32, $p < 0.001$). Mentor relationship quality showed strong positive associations with both mentoring styles and innovation capability (r = 0.71, $p < 0.001$), suggesting its potential mediating role.

3.2 Common Method Bias (CMB) Assessment

Given the reliance on self-reported data, we rigorously tested for Common Method Bias. Harman's single-factor test, conducted on all 54 items (24 DMSS, 18 ICA, 12 MRQS), revealed that the first unrotated factor accounted for only 14.0% of the total variance, well below the 50% threshold. Furthermore, we employed the marker variable technique using a theoretically unrelated construct. After controlling for the marker variable, all core path coefficients remained stable, with the maximum change in any path coefficient ($\Delta\beta$) being less than 0.03. These results confirm that CMB does not substantially inflate the observed relationships and is not a major concern in this study.

3.3 Measurement Model Assessment

Confirmatory factor analysis supported the proposed factor structure for all measurement instruments. The overall measurement model demonstrated excellent fit: $\chi^2(1247) = 1892.34$, $p < 0.001$; CFI = 0.96; TLI = 0.95; RMSEA = 0.034 (90% CI: 0.031-0.037); SRMR = 0.045. All factor loadings exceeded 0.60, with most surpassing 0.70. Multi-group confirmatory factor analysis across cultural regions supported measurement invariance at the configural, metric, and scalar levels (ΔCFI < 0.01), enabling meaningful comparison of structural relationships across groups [18].

3.4 Structural Equation Model Results

The hypothesized structural model demonstrated excellent fit to the data: $\chi^2(1251) = 1934.67$, $p < 0.001$; CFI = 0.96; TLI = 0.95; RMSEA = 0.035; SRMR = 0.047. The model explained 73.2% of the variance in innovation capability, indicating substantial predictive power.

3.4.1 Direct Effects on Innovation Capability

Collaborative mentoring emerged as the strongest predictor of innovation capability (β = 0.67, SE = 0.08, $p < 0.001$), followed by inspirational leadership (β = 0.52, SE = 0.07, $p < 0.001$). Supportive facilitation showed a moderate positive effect (β = 0.31, SE = 0.06, $p < 0.001$), while directive instruction demonstrated a smaller but significant relationship (β = 0.18, SE = 0.05, $p < 0.01$).

3.4.2 Mediating Role of Relationship Quality

Mentor relationship quality significantly mediated the relationships between all mentoring styles and innovation capability. To quantify the strength of this mediation, we calculated the Proportion of Mediation (Pm = Indirect Effect / Total Effect) for each mentoring style.

Table 3. Model Fit Indices Summary

Model	χ^2	df	CFI	TLI	RMSEA	90% CI	SRMR
Measurement Model	1892.34***	1247	0.96	0.95	0.034	[0.031, 0.037]	0.045
Structural Model	1934.67***	1251	0.96	0.95	0.035	[0.032, 0.038]	0.047
Configural Invariance	1901.23***	1247	0.96	0.95	0.034	[0.031, 0.037]	0.046
Metric Invariance	1918.45***	1263	0.96	0.95	0.033	[0.030, 0.036]	0.048
Scalar Invariance	1935.67***	1279	0.95	0.94	0.034	[0.031, 0.037]	0.050
Acceptable Threshold	—	—	$> .95$	$> .95$	$< .06$	—	$< .08$

Note. CFI = Comparative Fit Index; TLI = Tucker–Lewis Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual. ***$p < .001$.

Table 4. Total Effects Decomposition and Proportion of Mediation (Pm)

Mentoring Style	Direct β	Indirect β	Total β	Pm (%)	95% CI (Indirect)	Mediation Type
Collaborative Mentoring	0.67***	0.23***	0.90	25.6%	[0.17, 0.31]	Partial
Inspirational Leadership	0.52***	0.19***	0.71	26.8%	[0.13, 0.26]	Partial
Supportive Facilitation	0.31***	0.15***	0.46	32.6%	[0.09, 0.22]	Partial
Directive Instruction	0.18**	0.08**	0.26	30.8%	[0.03, 0.14]	Partial

Note. Pm = Indirect Effect / Total Effect. Bootstrapped 95% CIs based on 5,000 resamples. ***$p < .001$; **$p < .01$. All indirect effects exclude zero, confirming significant mediation.

As shown in Table 4, all mentoring styles exhibit partial mediation, as the direct effects remain significant even after accounting for relationship quality. Relationship quality mediates between 25.6% and 32.6% of the total effect, indicating it is an important, though not exclusive, pathway through which mentoring influences innovation capability.

3.5 Cross-Cultural Validation

Multi-group structural equation modeling revealed that the overall pattern of relationships remained consistent across cultural regions, supporting the generalizability of findings. However, notable cultural variations emerged. The effect of collaborative mentoring on innovation capability was strongest in North American contexts ($\beta = 0.72$) compared to European ($\beta = 0.65$) and Asia-Pacific ($\beta = 0.64$) samples. Conversely, the influence of inspirational leadership was most pronounced in Asia-Pacific contexts ($\beta = 0.58$) relative to North American ($\beta = 0.49$) and European ($\beta = 0.51$) samples. The relative importance of different relationship quality dimensions also varied: communication effectiveness was most critical in North America, trust and mutual respect in Europe, and goal alignment in the Asia-Pacific region.

4 Discussion

This study provides the first comprehensive cross-cultural examination of how different design mentoring styles influence innovation capability in creative education contexts. Our findings reveal that collaborative mentoring approaches most effectively foster innovation development, while also demonstrating the critical mediating role of mentor-mentee relationship quality. These results have significant implications for design education theory and practice.

4.1 Theoretical Implications

The strong predictive power of collaborative mentoring aligns with contemporary theories of creative development that emphasize the social construction of innovation [2]. Unlike traditional models of mentoring that position mentors as knowledge transmitters, collaborative approaches engage students as co-creators in the innovation process. This finding supports social constructivist theories of learning and extends them to the specific domain of design innovation [12].

The significant mediating role of relationship quality provides empirical support for relational theories of mentoring effectiveness [17]. By calculating the Proportion of Mediation (Pm), our results demonstrate that relationship quality accounts for approximately 25% to 33% of the total effect of mentoring on innovation. This dual-pathway model suggests that mentoring styles influence innovation capability not only through direct skill development but also by creating conditions for high-quality relationships that facilitate learning and creative risk-taking.

4.2 Cultural Mechanisms in Mentoring Effectiveness

A key contribution of this study is the identification of cultural variations in mentoring effectiveness, which can be interpreted through the lens of Hofstede's cultural dimensions theory. The finding that collaborative mentoring and communication effectiveness are most impactful in North America aligns with the region's high individualism and low power

Table 5. Cross-Cultural Path Coefficients by Region

Mentoring Style → Innovation Capability	North America ($n = 162$)	Europe ($n = 164$)	Asia-Pacific ($n = 160$)	Overall ($N = 486$)
Collaborative Mentoring	0.72***	0.65***	0.64***	0.67***
Inspirational Leadership	0.49***	0.51***	0.58***	0.52***
Supportive Facilitation	0.34***	0.30***	0.28***	0.31***
Directive Instruction	0.20**	0.17**	0.16**	0.18**
Key Relationship Quality Dimension	Communication Effectiveness	Trust & Mutual Respect	Goal Alignment	—

Note. Standardized path coefficients (β) from multi-group SEM. ΔCFI $<$ .01 across all invariance models. ***$p < .001$; **$p < .01$.

distance. In such contexts, students expect egalitarian relationships and value direct, open dialogue as a means of co-creation.

Conversely, the pronounced effectiveness of inspirational leadership and goal alignment in the Asia-Pacific region reflects cultural norms characterized by higher power distance and collectivism. In these contexts, mentors are often viewed as authoritative figures whose primary role is to provide visionary guidance and ensure that the mentee's efforts align with broader collective or institutional goals. European contexts, which often balance individualism with moderate power distance, prioritized trust and mutual respect, suggesting a preference for mentoring relationships built on professional credibility and interpersonal reliability. These insights underscore the necessity of culturally responsive mentoring frameworks rather than a "one-size-fits-all" approach.

4.3 Practical Implications for Design Education

Our findings offer evidence-based guidance for design education institutions seeking to optimize their mentoring programs. The superior effectiveness of collaborative mentoring suggests that programs should prioritize approaches that engage students as partners in the creative process rather than passive recipients of instruction. This may require significant shifts in traditional academic hierarchies and mentor training programs.

The importance of relationship quality as a mediator indicates that institutions should invest in developing mentors' interpersonal skills alongside their technical expertise. Training programs should emphasize communication effectiveness, trust-building, and goal alignment as essential components of successful mentoring relationships [22]. Furthermore, international design programs must train mentors to adapt their styles to the cultural backgrounds of their students, leveraging inspirational leadership for students from high power-distance cultures while emphasizing collaborative co-creation for those from low power-distance backgrounds.

4.4 Limitations and Future Directions

Several limitations should be considered when interpreting these findings. First, the cross-sectional design precludes causal inferences, and longitudinal research is needed to establish the temporal relationships between mentoring experiences and innovation development. Second, while our rigorous CMB tests (Harman's single-factor and marker variable techniques) confirmed the validity of the data, innovation capability is a complex construct. Relying solely on student self-reports may still be susceptible to social desirability bias or overestimation of abilities. Future research should employ triangulation by incorporating objective innovation performance metrics, such as expert blind-ratings of design portfolios or patent applications.

Future research should also examine the optimal timing and sequencing of different mentoring styles throughout students' educational journeys. The role of technology in design mentoring represents another important avenue for future research, as digital tools increasingly mediate mentor-mentee interactions.

5 Conclusion

This study demonstrates that design mentoring styles significantly influence innovation capability development, with collaborative approaches showing particular effectiveness. The partial mediating role of relationship quality highlights the importance of interpersonal dynamics in creative education. Furthermore, the cross-cultural validation not only supports the broad applicability of these findings but also reveals nuanced cultural preferences that align with established cultural dimensions. These results provide evidence-based guidance for design education institutions seeking to cultivate the next generation of creative innovators through culturally responsive and optimized mentoring practices.

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