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RESEARCH ARTICLE

From course experience to innovation capability: A dual mediation analysis of student engagement and learning motivation in modular teaching

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ABSTRACT

This study examines how learning experiences shape the development of students' creative competencies through the dual mediating roles of academic engagement and motivational factors. Focusing on students from the Department of Art and Design at a vocational and technical college in China, the study adopts purposive sampling to gather 287 valid responses. A structured questionnaire was designed encompassing four latent constructs: instructional quality, participation, drive to learn, and creative capacity. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to evaluate the model and test mediation effects. Results reveal no significant direct influence of instructional experiences on students' creative outcomes. However, indirect effects were observed via full mediation by academic engagement and partial mediation by motivation. The model explains 56.8% of the variance in the outcome variable (R^2 = 0.568) and achieves a strong model fit (GoF = 0.657). These findings emphasize the interplay between instructional design and internal psychological mechanisms, offering insights for pedagogical strategies and theory-building in creative education domains.

Keywords: instructional quality; academic engagement; learning motivation; creative capacity; structural equation modeling; design education; vocational learning; psychological mediation

1. Introduction

In response to the transformative shifts brought about by the knowledge economy and the digital age, cultivating students' innovative capabilities has become a central objective in the reform of higher education—particularly within the fields of art and design. Amid the global wave of innovation-driven economies and educational transformation, art and design education has moved beyond traditional technical training to emphasize core competencies such as creative thinking, interdisciplinary integration, and self-directed learning [1][2][3][4]. International organizations such as UNESCO have also underscored that arts education plays a critical role in fostering innovation and preparing individuals for future labor market adaptability[5][6][7][8].

Extensive literature and policy analyses further suggest that arts education contributes significantly to the development of creative thinking and cross-disciplinary competencies, warranting its integration into

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both educational and workforce training policies (Wade-Leeuwen & McLachlan, 2019[9]; Davies et al., 2018[10]). As the higher education landscape undergoes rapid transformation, particularly under the profound impact of digital technologies on creative industries, "innovation capability" is increasingly recognized as a key developmental indicator for universities worldwide.

In Europe, for example, highlight that enhancing knowledge-sharing practices and fostering an innovation-oriented culture can improve team performance and learning outcomes[11]. Similarly, regions such as Asia[12] and the Middle East[13] have responded to the need for innovation competencies through curriculum design and institutional reform[14]. Moreover, national governments and higher education institutions in countries including the United States, China, Australia, the United Kingdom, Taiwan, Spain, Canada, Turkey, South Korea, and Israel have increasingly emphasized the strategic importance of creativity and innovation in university education, both in policy frameworks and instructional practice[15].

Innovation competence is now regarded as a core literacy that higher education must prioritize. It is also a key competitive advantage for students entering the workforce, signifying their potential to generate novel and valuable outcomes[16][17]. Building on this perspective, the present study defines innovation competence as follows: Innovation competence refers to an individual's ability to generate novel ideas, engage in creative problem-solving, and apply original thinking in specific domains, often involving a combination of cognitive flexibility, motivation, and goal-directed action[18][19].

Extending to the context of education in China, vocational education is undergoing a phase of structural reform under the impetus of national policies. Within this framework, art and design education—an interdisciplinary field that merges creativity with practical skills—has increasingly become a focal point in the transformation of vocational education. The *Vocational Education Law (Revised 2022)* explicitly grants vocational education equal status to general education, promoting an educational philosophy centered on "moral and technical cultivation, integration of industry and education, and synergy between learning and innovation," while emphasizing innovation and entrepreneurship education as well as competency-based curriculum structures[20].

Furthermore, at the *National Vocational Education Conference* held in April 2021, China officially proposed strategies such as the integration of "positions, curricula, competitions, and certifications" (*gang-ke-sai-zheng rongtong*) and the implementation of modular curriculum design. These strategies aim to enhance curriculum flexibility, student engagement, and interdisciplinary integration[21][22]. Such student-centered curriculum models are considered particularly well-suited for disciplines like art and design, which value both creativity and application, and are aligned with the dual expectations of "pedagogical innovation" and "talent competitiveness" in vocational education[23].

However, at the practical level, the development of innovation competencies among current university students continues to face numerous challenges. Although students in art and design disciplines often possess creative potential and foundational technical skills, their capacity for innovation is frequently constrained by traditional pedagogical approaches, limited resources, and insufficient curriculum integration[24][25][26]. In reality, the innovation process in the fields of art and design requires the convergence of creativity, materials, and design thinking, supported by a flexible, diverse, and integrative teaching and learning environment [27][28][29]. Current curricula still tend to emphasize skill output and technical training, often lacking a systematic innovation-oriented framework[30][31]. As have pointed out, how modularized instruction can be employed to meet the demands of cultivating innovation capacity has emerged as a central issue in contemporary reforms of art and design education[32][33].

Relevant literature also highlights that modularized instruction, as a structured curriculum design model, can enhance students' creativity and practice-oriented competencies through thematic units and flexible pacing. This approach is particularly well-suited for courses in fashion design and digital creation [34][35]. Moreover, modular curricula that incorporate STEAM elements have been shown to effectively promote students' innovative thinking and design capabilities[36][37][38]. However, some studies caution that when modular structures become overly rigid, they may suppress students' creative thinking and limit their freedom of participation, thereby constraining creative expression. If modular instruction lacks flexibility and integrative capacity, it may inadvertently hinder the development of student creativity, underscoring the need to balance structure with openness in curriculum design[39][40]. Overall, determining the appropriate balance between structure and flexibility remains a critical design challenge in modularized teaching.

In light of these considerations, modularized instruction has garnered increasing attention in recent years within the field of art and design education. As a structured curriculum design strategy, modular teaching deconstructs learning content into focused thematic units, emphasizing flexible pacing and student autonomy in course selection. Existing research indicates that modularized instruction enhances students' creativity and practice-oriented competencies (Ismail, 2024; Cristina & João, 2024), while also strengthening learning motivation and engagement, thereby contributing to the development of innovative capacities[41][42]. The clear structure and flexible design of such instructional models foster greater student involvement and agency[43] and support the cultivation of creative problem-solving skills[44]. Moreover, the personalized choices and learning pathways enabled by modular instruction promote creative thinking orientations and professional practice competencies among students[45][46]. Overall, striking a balance between "structure" and "openness" is regarded as a critical strategy in fostering innovative instructional design.

While modularized instruction has been shown to facilitate innovation competencies, existing studies primarily focus on its direct impact on teaching structure and curriculum design, with limited attention to the psychological and behavioral mechanisms demonstrated by students during the learning process. In particular, the mediating roles of "learning motivation" and "student engagement" remain underexplored and lack systematic empirical validation. Furthermore, most studies have concentrated on STEM fields, with comparatively little focus on the innovation processes within the context of art and design education. Therefore, this study adopts a dual mediation model to examine how students' curricular experiences are transformed into innovation competencies through psychological processes, aiming to address this dual gap in theory and practice.

Furthermore, within the learning process of modular teaching, students' psychological engagement and behavioral participation are regarded as key factors that may influence the development of their innovation capabilities. Research has indicated that modular curricula, by emphasizing thematic focus and offering choices in learning paths, can enhance students' intrinsic motivation and sense of involvement [47][48], thereby strengthening their creative thinking and commitment to the creative process[49][50]. When students engage proactively and adopt self-directed learning behaviors, they are more likely to demonstrate actual innovative performance.

Accordingly, *learning motivation* and *student engagement* may serve as critical psychological mediators in the relationship between modular teaching and innovation capabilities—yet this mediating mechanism has not been sufficiently validated through empirical studies.

Therefore, this study aims to construct and validate a dual mediation model—"Students' Course Experience → Learning Motivation/Engagement → Innovation Competence"—to address theoretical gaps and deepen the practical application of instructional strategies.

Based on the aforementioned theoretical framework and literature review, the following research hypotheses are proposed:

H1: Learning motivation mediates the relationship between students' course experience and their innovation competence.

H2: Student engagement mediates the relationship between students' course experience and their innovation competence.

By employing structural equation modeling (SEM), this study seeks to elucidate the psychological mechanisms through which course experience influences innovation competence. In doing so, it complements existing research in art and design education, particularly in areas where prior studies have inadequately addressed underlying psychological processes, and extends the application of mediation theory within the context of pedagogical innovation.

Accordingly, this study seeks to construct and interpret a dual mediation model—"Students' Course Experience → Learning Motivation / Engagement → Innovation Competence"—to address the lack of inquiry into psychological processes in the current literature on art and design education. This model also aims to enhance both the depth and precision of instructional strategy applications.

It is anticipated that the proposed dual mediation model will offer a clearer depiction of the mechanisms through which course experiences influence students' innovation competence. In particular, it aims to address existing theoretical gaps in modular teaching literature concerning the processes of learning motivation and student engagement.

Furthermore, by integrating Partial Least Squares Structural Equation Modeling (PLS-SEM) with mediation analysis, this study proposes a concrete and practicable validation framework. This framework is expected to serve as a valuable reference for future curriculum design and pedagogical innovation, while also contributing to the expansion of perspectives and methodological foundations in innovation education research.

2. Materials and methods

2.1. Research design

This study adopted a purposive sampling approach, targeting first- to third-year students enrolled in the Department of Art and Design at Shanghai Industrial and Commercial Polytechnic. The aim was to investigate the impact of modular instruction on university students' innovation competence and to further examine the mediating roles of student engagement and learning motivation within this relationship.

To ensure contextual alignment between the sample and the instructional setting, the research team coordinated with faculty members in advance and administered the survey during designated class sessions.

Descriptive statistical analysis was first conducted to summarize the characteristics of the sample and the distribution of variables. Subsequently, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to construct and validate the proposed theoretical model. This analysis assessed the reliability and validity of latent constructs and examined the structural path relationships among variables. Mediation analysis was also performed to test the proposed hypotheses.

2.2. Participants

The participants of this study were first- to third-year students from the Department of Art and Design at Shanghai Industrial and Commercial Polytechnic, aged between 18 and 22. A total of 320 questionnaires

were distributed. After data cleaning—excluding incomplete responses, duplicate entries, and logically inconsistent answers, as well as removing statistical outliers—287 valid questionnaires were retained, yielding a valid response rate of 89.7%. Among the respondents, 115 were male (40.1%) and 172 were female (59.9%). The grade distribution was as follows: 78 first-year students (27.2%), 107 second-year students (37.3%), and 102 third-year students (35.5%). The sample demonstrated a relatively balanced distribution across gender and academic year, providing a reasonable degree of representativeness for empirical testing of the proposed theoretical model.

2.3. Instruments

A structured questionnaire was employed as the primary data collection instrument. It comprised four major constructs: student course experience, student engagement, learning motivation, and innovation competence. All items were measured using a five-point Likert scale (1 = strongly disagree, 5 = strongly agree), where higher scores indicate stronger perceptions or behaviors related to each construct. The scales used are as follows:

1. Student Course Experience Questionnaire (SCEQ)

Based on standardized version of the Student Course Experience Questionnaire, this scale includes 28 items across five subscales: *Good Teaching Scale (GTS), Clear Goals and Standards Scale (CGS), Appropriate Assessment Scale (AAS), Appropriate Workload Scale (AWS),* and *Generic Skills Scale (GSS)*[51]. Six reverse-scored items were recoded prior to analysis. Total scores range from 28 to 140, with higher scores reflecting more positive student perceptions of teaching quality and course design.

2. Innovation Competence Barometer (ICB)

This 22-item short version of the Innovation Competence Barometer, developed assesses five key dimensions: *Creative Problem Solving, Systems Thinking, Goal Orientation, Teamwork,* and *Networking*[52]. Scores range from 22 to 110, with higher scores indicating stronger abilities in creative thinking, problem-solving, and collaborative integration.

3. Student Engagement Survey (SES)

Developed this 24-item instrument measures students' engagement in learning across emotional, behavioral, and cognitive domains[53]. It comprises four subscales: *Emotional Engagement, Physical Engagement, Cognitive Engagement (In-Class),* and *Cognitive Engagement (Out-of-Class)*. The total score ranges from 24 to 120, where higher scores represent greater levels of emotional involvement and proactive learning behaviors.

4. MUSIC Model of Academic Motivation Inventory (Short Form)

This 22-item scale, originally proposed and further refined evaluates four motivational constructs: *Empowerment, Usefulness, Success Expectancy,* and *Caring*[54][55]. The total score ranges from 22 to 110, with higher scores indicating a greater sense of autonomy, perceived course value, confidence in success, and perceived instructor support—reflecting stronger intrinsic motivation and learning drive.

2.4. Statistical analysis

A multi-stage statistical analysis procedure was adopted to validate the research model. Initially, SPSS 23.0 was used to conduct descriptive statistics, summarizing the basic characteristics of the sample and examining measures of central tendency and dispersion for each construct.

Subsequent analyses were performed using SmartPLS software to implement Partial Least Squares Structural Equation Modeling (PLS-SEM). This method is suitable for small to medium sample sizes, non-normally distributed data, and the testing of complex models., the PLS-SEM analysis consisted of three major steps[56][57]:

1. Measurement Model Evaluation

This step assessed the reliability and validity of the constructs, including examination of outer loadings, composite reliability (CR), average variance extracted (AVE), and discriminant validity using the Fornell-Larcker criterion and HTMT (Heterotrait-Monotrait) ratio.

2. Structural Model Evaluation

This stage involved testing path coefficients and their significance using bootstrapping with 5,000 resamples. Model quality was further evaluated through indicators such as coefficient of determination (R^2), effect size (f^2), Goodness-of-Fit (GoF) index, and multicollinearity diagnostics.

3. Mediation Analysis

The significance of indirect effects was tested using the bootstrapping method, allowing determination of whether the mediators exerted full or partial mediation within the proposed model.

2.5. Study limitations

Despite the rigorous design and implementation of this study, several limitations should be acknowledged:

1. Limited Sample Scope:

The study focused on students from a single academic discipline (Art and Design) within one geographic region. As such, the external validity of the findings should be interpreted with caution. Future research could expand the scope to include comparative studies across different disciplines and regions.

2. Cross-sectional Design:

The study adopted a cross-sectional research design, which captures only correlational relationships among variables and does not allow for causal inferences. It is recommended that future studies employ longitudinal or experimental designs to strengthen causal interpretations.

3. Self-reported Data and Social Desirability Bias:

Data were collected through self-administered questionnaires, which may be subject to social desirability bias. Future research is encouraged to incorporate interviews, behavioral observations, or learning outcome assessments to triangulate findings.

4. Cultural and Contextual Adaptation of Scales:

Although the scales used in this study were translated and adapted, their underlying constructs may still be influenced by cultural contexts. Further semantic and cultural validation of the instruments is recommended to ensure appropriateness across diverse settings.

5. Unaccounted Potential Confounding Variables:

Factors such as teaching styles, curriculum design, and peer interactions were not included in the model but may influence outcomes. Future studies should consider incorporating these variables to enhance the model's comprehensiveness and explanatory power.

In conclusion, while this study provides preliminary empirical support for the relationship between modular instruction and innovation competence, it also offers theoretical insights and practical recommendations for future educational reform and academic inquiry.

3. Results and discussion

This study employed Partial Least Squares Structural Equation Modeling (PLS-SEM) as the primary statistical technique to construct and validate the proposed theoretical model. PLS-SEM is particularly well-suited for research contexts involving relatively small sample sizes, non-normally distributed data, and complex model structures that include multiple latent variables and mediation pathways. Compared to the traditional covariance-based structural equation modeling (CB-SEM), PLS-SEM is more prediction-oriented and demonstrates greater robustness in handling multicollinearity, outliers, and missing data, as well as being applicable to both reflective and formative measurement models.

According to PLS-SEM is an appropriate method for theory development and model testing, especially in exploratory research phases or when the relationships among variables are not yet well established[58]. Given the conceptual nature of this study's model and the theoretical need to explore mediating mechanisms, PLS-SEM was deemed the most suitable analytic approach for the empirical validation process.

The analytical procedure of this study consisted of three stages:

1. Conducting descriptive statistics to summarize the distribution of key constructs.
2. Evaluating the reliability and validity of the measurement model.
3. Testing the significance of structural paths and mediation effects, while assessing the model's overall explanatory power and goodness of fit.

3.1. Descriptive statistics

To understand the distribution patterns and response tendencies of the latent constructs within the sample, descriptive statistical analyses were first conducted on the primary variables. The results indicated that the mean score for Student Course Experience was 3.75 (SD = 0.48), suggesting that participants generally held moderately positive perceptions of teaching quality and course design. The mean score for Innovation Competence was 4.41 (SD = 0.59), reflecting that students generally perceived themselves as having a strong capacity for innovation.

Additionally, the mean scores for Student Engagement and Learning Motivation were 4.15 (SD = 0.71) and 4.24 (SD = 0.65), respectively, indicating that participants exhibited relatively high levels of engagement and intrinsic motivation throughout the learning process.

Overall, all four constructs demonstrated above-average levels, providing a solid empirical foundation for the subsequent structural model validation. Detailed statistics are presented in **Table 1**.

Table 1. Descriptive statistics of key constructs (N = 287).

Construct	Minimum	Maximum	Mean	Std. Deviation
Student Course Experience	2.04	4.48	3.75	0.48
Innovation Competence	2.32	5.00	4.41	0.59
Student Engagement	1.71	5.00	4.15	0.71
Academic Motivation	2.95	5.00	4.24	0.65

Note: *All constructs were measured using a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). Higher scores indicate a greater level of perceived agreement or performance on the corresponding construct.*

3.2. Evaluation of the measurement model

This study aims to explore the mechanisms through which modular instruction influences university students' innovation competence, incorporating student engagement and academic motivation as mediating variables to construct a comprehensive research model (see **Figure 1**). The model consists of four primary latent constructs: Student Course Experience, Student Engagement, Academic Motivation, and Innovation Competence.

In this framework, *Student Course Experience* reflects students' subjective perceptions of modular instructional activities, with the assumption that positive evaluations will enhance their engagement and intrinsic motivation, thereby strengthening their innovation performance. Each latent variable is composed of multiple second-order dimensions. For instance, *Student Engagement* includes emotional, behavioral, and cognitive engagement components, while *Academic Motivation* consists of empowerment, usefulness, success expectancy, and caring.

Prior to conducting the measurement model assessment, and to avoid potential multicollinearity effects that may compromise model stability and estimation accuracy, the Variance Inflation Factor (VIF) for each observed indicator was examined in accordance with the guidelines [59]. Indicators with VIF values exceeding 10 were removed to mitigate the influence of high collinearity. After deletion, each construct retained a sufficient number of representative items, and a subsequent reliability and validity analysis was performed to ensure the overall quality of the measurement model.

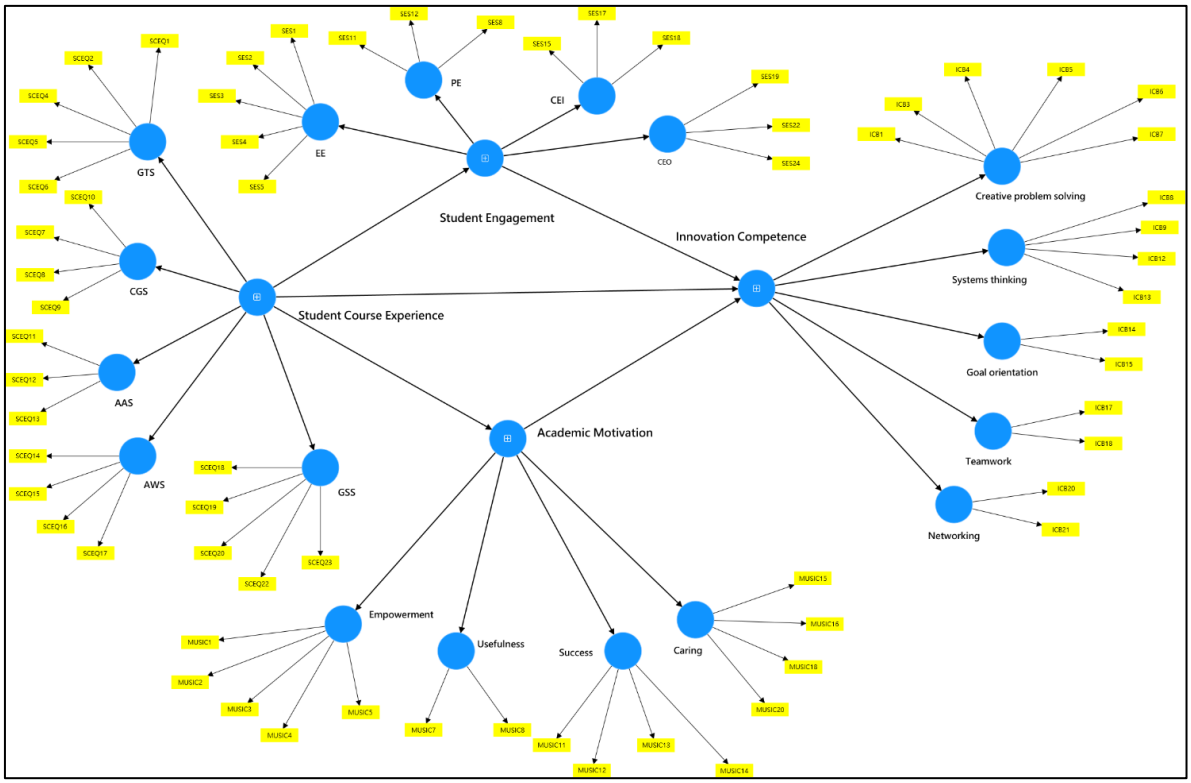

Figure 1. The Effects of template-based teaching on innovation competence: A dual-mediation model.

To ensure that the observed indicators effectively represent the theoretical meaning of each latent construct, this study followed the recommendations[60][61] by examining the standardized factor loadings of

all measurement items. Theoretically, factor loadings should exceed 0.70. Items with loadings between 0.40 and 0.70 were evaluated for retention based on their theoretical relevance and the overall reliability and validity of the measurement model.

3.2.1. Indicator reliability

Based on the results of the PLS-SEM analysis (see **Figure 2**), all observed indicators corresponding to the four higher-order latent constructs—Student Course Experience, Student Engagement, Academic Motivation, and Innovation Competence—achieved statistically significant factor loadings ($p < .001$), indicating strong indicator reliability. The detailed analysis is as follows:

1. Student Course Experience: Factor loadings ranged from 0.645 to 0.952. Although the loading for item SCEQ10 was slightly below the recommended threshold at 0.645, it was retained due to its theoretical importance.
2. Student Engagement: All indicators demonstrated factor loadings between 0.901 and 0.961, reflecting a high degree of internal consistency and strong explanatory power.
3. Academic Motivation: Loadings ranged from 0.905 to 0.955, indicating a stable and coherent structure across measurement items.
4. Innovation Competence: All items exhibited factor loadings between 0.910 and 0.972, well above the recommended threshold, demonstrating exceptional robustness.

Overall, the factor loadings for all observed variables met or exceeded the recommended standards and were statistically significant, providing strong support for the indicator reliability and structural stability of the measurement model in this study.

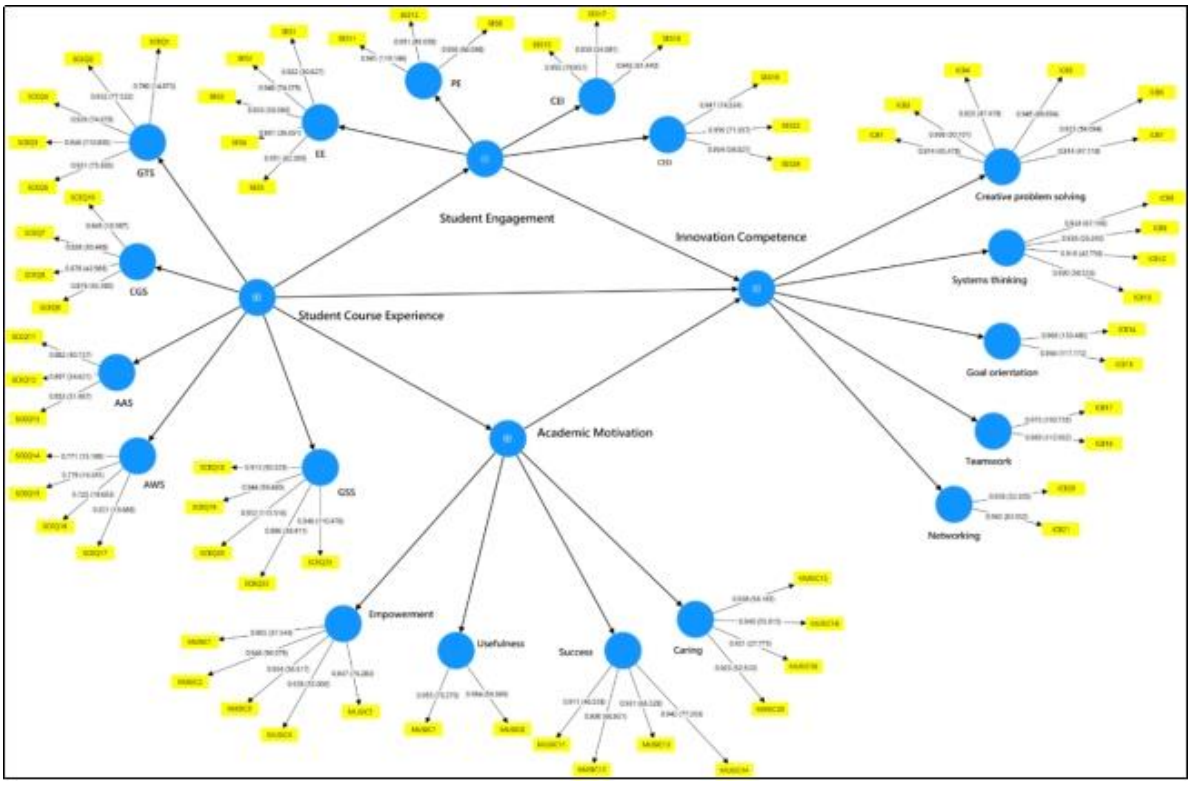

Figure 2. Standardized loadings and t-values for the measurement model.

3.2.2. Internal consistency

This study employed Cronbach's alpha (α) and Composite Reliability (CR) to assess the internal consistency of the latent constructs. According to the guidelines proposed[62], values of both Cronbach's α and CR exceeding 0.70 are indicative of acceptable reliability.

As shown in **Table 1**, all four latent constructs demonstrated very high internal consistency. Specifically:

- *Student Course Experience* exhibited an α of 0.881 and a CR of 0.925;
- *Innovation Competence* showed α = 0.974, CR = 0.977;
- *Academic Motivation* recorded α = 0.979, CR = 0.981; and
- *Student Engagement* reached α = 0.985, CR = 0.986.

These values are well above the recommended thresholds, indicating excellent reliability and strong internal consistency for all measurement constructs in this study.

3.2.3. Convergent validity

To ensure that the latent constructs exhibited adequate convergent validity, this study further examined the Average Variance Extracted (AVE) for each construct. According to the criteria established[63], an AVE value of 0.50 or higher indicates that a construct explains more than half of the variance of its indicators, thus demonstrating sufficient convergent validity.

The results revealed that all four constructs met this standard, with AVE values as follows:

- Student Engagement: 0.835
- Academic Motivation: 0.778
- Innovation Competence: 0.723
- Student Course Experience: 0.526

(See **Table 2** for details.)

Table 2. Reliability and convergent validity assessment of constructs.

	Cronbach's Alpha	CR	AVE
Academic Motivation	0.979	0.981	0.778
Innovation Competence	0.974	0.977	0.723
Student Course Experience	0.881	0.925	0.526
Student Engagement	0.985	0.986	0.835

These results indicate that each construct effectively explains the variance of its corresponding indicators, confirming that the measurement model demonstrates strong convergent validity.

3.2.4. Discriminant validity

To ensure that the latent constructs exhibited adequate discriminant validity, this study applied the criterion proposed. According to this method, discriminant validity is established if the square root of the Average Variance Extracted (AVE) for each construct is greater than its correlations with any other constructs in the model.

As shown in **Table 3**, the square roots of the AVEs for the four higher-order constructs were as follows:

- Academic Motivation: 0.882
- Innovation Competence: 0.850
- Student Course Experience: 0.726

- Student Engagement: 0.914

These diagonal values all exceed the corresponding inter-construct correlation coefficients. For instance, the correlation between *Student Engagement* and *Student Course Experience* was 0.846, which is lower than the square root of Student Engagement's AVE (0.914). Similarly, the correlation between *Academic Motivation* and *Innovation Competence* was 0.745, which is lower than the square roots of their AVEs (0.882 and 0.850, respectively).

Overall, these results meet the Fornell-Larcker criterion, indicating that the latent variables in the model possess strong discriminant validity, thereby supporting the construct validity of the measurement model.

Table 3. Discriminant validity assessment based on the Fornell-Larcker criterion.

	A	B	C	D
A. Academic Motivation	0.882			
B. Innovation Competence	0.745	0.85		
C. Student Course Experience	0.798	0.621	0.726	
D. Student Engagement	0.823	0.732	0.846	0.914

Note: *The diagonal elements in the table represent the square roots of the Average Variance Extracted (AVE) for each construct, while the off-diagonal elements indicate the Pearson correlation coefficients between constructs. According to the criterion proposed by Fornell and Larcker (1981), the square root of the AVE for each construct should exceed the corresponding inter-construct correlations in the same row and column, thereby demonstrating discriminant validity.*

3.3. Evaluation of the structural model

In the structural model evaluation phase of this study, the analysis followed the recommended procedures for PLS-SEM outlined[64]. The evaluation was conducted in a sequential manner to comprehensively assess the explanatory power and stability of the structural model. The following components were examined:

1. Collinearity among latent variables using Variance Inflation Factors (VIF)
2. Structural path coefficients and their significance
3. The model's predictive power, including coefficient of determination (R^2) and predictive relevance (Q^2)
4. The model's overall goodness-of-fit, assessed using the Standardized Root Mean Square Residual (SRMR)

These procedures ensured a robust and thorough evaluation of the model's structural integrity and theoretical validity.

3.3.1. Indicator collinearity diagnosis

To ensure that no severe multicollinearity existed among the observed variables in the structural model, this study followed the guidelines of Hair et al. (2017) by examining the Variance Inflation Factor (VIF) for each indicator. Generally, VIF values exceeding 10 may indicate a high degree of correlation among variables, which could compromise the stability and explanatory power of the model estimates.

The analysis results (**Table 4**) showed that most VIF values were below 5, with only a few items slightly approaching the upper threshold (e.g., *SCEQ5 = 9.484*, *ICB6 = 9.336*, *SES12 = 8.812*, *SES17 = 9.524*). However, none exceeded the critical VIF value of 10, suggesting that the level of multicollinearity remained within acceptable limits.

Moreover, no extremely high collinearity was observed within any of the latent constructs, indicating that multicollinearity did not pose a significant threat to the structural model. Therefore, the model was deemed structurally sound, and subsequent analyses could proceed with confidence.

Table 4.VIF values for collinearity diagnostics of measurement indicators.

student Course Experience Indicator	VIF	Innovation Competence Indicator	VIF	Academic Motivation Indicator	VIF	Student Engagement Indicator	VIF
SCEQ1	2.211	ICB1	4.672	MUSIC1	4.658	SES1	5.931
SCEQ2	6.581	ICB3	5.985	MUSIC2	6.471	SES2	8.371
SCEQ4	7.88	ICB4	6.604	MUSIC3	5.074	SES3	9.065
SCEQ5	9.484	ICB5	7.48	MUSIC4	5.754	SES4	4.245
SCEQ6	5.164	ICB6	9.336	MUSIC5	6.833	SES5	7.097
SCEQ7	1.976	ICB7	5.176	MUSIC7	3.081	SES8	3.796
SCEQ8	3.18	ICB8	4.153	MUSIC8	3.081	SES11	6.108
SCEQ9	2.404	ICB9	4.179	MUSIC11	3.506	SES12	8.812
SCEQ10	3.914	ICB12	3.586	MUSIC12	4.26	SES15	5.278
SCEQ11	2.731	ICB13	3.827	MUSIC13	6.6	SES17	9.524
SCEQ12	4.134	ICB14	4.096	MUSIC14	5.325	SES18	4.183
SCEQ13	1.648	ICB15	4.096	MUSIC15	4.177	SES19	4.431
SCEQ14	3.323	ICB17	8.328	MUSIC16	4.941	SES22	5.735
SCEQ15	3.456	ICB18	6.952	MUSIC18	3.911	SES24	7.09
SCEQ16	3.437	ICB20	3.461	MUSIC20	4.984		
SCEQ17	3.241	ICB21	6.332				
SCEQ18	5.613						
SCEQ19	6.701						
SCEQ20	7.522						
SCEQ22	4.035						
SCEQ23	7.506						

Table 4. (*Continued*)

3.3.2. Path relationship test

As shown in **Table 5**, the results of the structural model analysis revealed that the direct path from Student Course Experience to Innovation Competence was not statistically significant ($\beta = –0.019$, $t = 0.244$, $p > .05$), suggesting that the effect of course experience on innovation competence may be transmitted indirectly through mediating variables.

In contrast, Student Course Experience demonstrated strong and statistically significant positive effects on both Student Engagement ($\beta = 0.846$, $t = 47.461$, $p < .001$) and Academic Motivation ($\beta = 0.798$, $t = 35.498$, $p < .001$).

Further analysis also showed that both Student Engagement ($\beta = 0.314$, $t = 2.047$, $p < .05$) and Academic Motivation ($\beta = 0.470$, $t = 3.758$, $p < .001$) had significant positive effects on Innovation Competence, providing preliminary support for the mediating hypotheses proposed in this study.

3.3.3. Model prediction and explanation power evaluation

To assess the predictive power and explanatory capacity of the structural model for endogenous variables, this study examined the coefficient of determination (R^2) and effect size (f^2) for each relevant construct.

The analysis results indicated that Student Course Experience demonstrated strong explanatory power for both Student Engagement ($R^2 = 0.715$) and Academic Motivation ($R^2 = 0.637$). Collectively, these three constructs accounted for 56.8% of the variance in Innovation Competence ($R^2 = 0.568$), representing a moderate to substantial level of explanatory power, according to the criteria of Hair et al. (2021).

Effect size analysis further revealed that Student Engagement had an f^2 value of 0.026, and Academic Motivation had an f^2 value of 0.075. Based on Cohen's (1988) guidelines, these correspond to small to medium effect sizes, indicating that both mediating constructs made meaningful contributions to the outcome variable.

3.3.4. Model fit test

This study further evaluated the overall model fit using the Goodness of Fit (GoF) index. The GoF value is calculated as the geometric mean of the average variance extracted (AVE) and the coefficient of determination (R^2) across all latent variables[65].

The GoF value for the proposed model was 0.657, which is well above the high-fit threshold value of 0.36 recommended[66]. This result indicates that the structural model demonstrates excellent overall fit and possesses strong predictive capability.

Table 5. Structural model results: Path coefficients, explanatory power, and model fit.

Path Relationship	β	t-value	R^2	f^2	GoF
Student Course Experience → Student Engagement	0.846***	47.461	0.715	2.511	
Student Course Experience → Academic Motivation	0.798***	35.498	0.637	1.755	
Student Engagement → Innovation Competence	0.314*	2.047		0.026	0.657
Academic Motivation → Innovation Competence	0.470***	3.758		0.075	
Student Course Experience → Innovation Competence (Direct Effect)	-0.019	0.244	0.568	0.000	

Note: *$p < .05$, **$p < .001$. GoF = Goodness of Fit Index; R^2 = Coefficient of determination; f^2 = Effect size of predictor on endogenous variable.*

3.4. Evaluation of mediation hypotheses

To further clarify the mechanism through which Student Course Experience influences Innovation Competence, this study conducted a mediation analysis to examine whether Student Engagement and Academic Motivation serve as mediating variables (see **Table 6**).

The analysis revealed that the direct effect of Student Course Experience on Innovation Competence was not significant ($\beta = –0.019$, $t = 0.244$, $p > .05$). However, the indirect effects through Student Engagement ($\beta = 0.265$, $t = 2.048$, $p < .05$) and Academic Motivation ($\beta = 0.375$, $t = 3.728$, $p < .001$) were both statistically significant.

According to Hair et al. (2021), a significant indirect effect accompanied by a non-significant direct effect constitutes evidence of full mediation. To further determine the mediation type, the Variance Accounted For (VAF) was calculated. Results showed that the VAF for the Student Engagement pathway was 84.39%, which meets the criterion for full mediation. Although Academic Motivation also demonstrated a significant indirect effect, its VAF was 49.99%, indicating partial mediation.

In summary, the influence of Student Course Experience on Innovation Competence is not direct, but rather operates through a dual mediation mechanism—fully mediated by Student Engagement and partially mediated by Academic Motivation. This finding highlights that the effectiveness of curriculum design and instructional quality depends largely on students' engagement and motivational activation, which are essential for transforming learning experiences into tangible innovation competencies.

Table 6. Mediating effects of student engagement and academic motivation on the relationship between student course experience and innovation competence.

Pathway	Direct Effect (t)	Indirect Effect (t)	Total Effect (t)	VAF (%)	Mediation Type
Student Course Experience → Innovation Competence	-0.019 (0.244)	–	–	–	Not Significant
Student Course Experience → Student Engagement → Innovation Competence	–	0.265* (2.048)	0.314* (2.047)	84.39%	Full Mediation
Student Course Experience → Academic Motivation → Innovation Competence	–	0.375* (3.728)	0.798* (35.498)	49.99%	Partial Mediation

Note. *$p < .05$. VAF = Variance Accounted For.*

3.5. Discussion

3.5.1. Verifying the psychological process of learning in innovation education

This study examined how *Student Course Experience* influences *Innovation Competence* through two key psychological process variables—*Student Engagement* and *Academic Motivation*—in the context of modular instruction among university students in art and design programs. The results supported the proposed dual mediation model, offering important theoretical contributions to understanding the psychological mechanisms underpinning innovation education.

First, the findings indicated that the effect of *Student Course Experience* on *Innovation Competence* is fully mediated by Student Engagement. This result aligns with previous research suggesting that students' engagement processes play a critical role in shaping learning outcomes[67][68]. From a pedagogical perspective, emphasized that integrating Creative Problem Solving (CPS) strategies into group-based instructional design not only enhances students' active participation and enthusiasm but also cultivates their creative thinking and problem-solving abilities[69]. This underscores that engagement is a pivotal mediating mechanism in transforming curriculum design into tangible learning outcomes.

In addition, using structural equation modeling, confirmed that student engagement fully mediates the relationship between learning readiness and academic achievement[70], which is highly consistent with the findings of the present study. Similarly out that student engagement effectively bridges the psychological process between learning environments and innovation competence, and that this relationship remains stable across diverse educational contexts[71][72] .

Overall, the findings of this study support these perspectives and further suggest that well-structured yet flexible modular curriculum design can stimulate students' willingness to engage, thereby promoting deeper involvement in creative thinking and problem-solving processes (Pastushkova et al., 2019; Rebryna et al., 2024; Zubova, 2021). By validating this psychological mechanism, the study highlights the bridging role of Student Engagement in translating course experience into innovation competence, contributing significantly to both the theoretical construction and empirical validation of psychological variables in innovation education.

Secondly, the study also confirmed that Academic Motivation serves as a significant mediator between *Student Course Experience* and *Innovation Competence*. When students perceive the course positively and demonstrate high levels of interest, their intrinsic motivation is effectively activated, thereby enhancing their innovative performance [73][74][75]. Notably, Goulet-Pelletier et al. (2023) found that students with higher levels of intrinsic motivation tend to self-evaluate their academic creativity more favorably. Similarly, using a design thinking course as context, demonstrated the mediating role of intrinsic motivation between innovation support and innovative behavior, further highlighting the critical impact of motivational processes on innovation outcomes[76].

The findings of this study are also consistent with the core tenets of Self-Determination Theory (SDT), which posits that when the learning environment satisfies students' basic psychological needs—autonomy, competence, and relatedness—it facilitates the internalization of motivation, leading to greater engagement and innovation competence[77].

However, the results also indicate that the mediating effect of academic motivation constitutes only partial mediation (VAF = 49.99%), suggesting that the influence of *Student Course Experience* on *Innovation Competence* is not transmitted solely through motivation. This implies the potential involvement of other psychological mechanisms, such as creative self-efficacy, levels of academic burnout, or perceived teaching styles, which may function as additional mediators or moderators (Hair et al., 2021).

Moreover, differences in types of motivation (e.g., intrinsic vs. extrinsic) may also differentially affect the transformation process, presenting a promising avenue for future research to explore and validate.

In summary, this study highlights the importance for educational designers and future researchers to adopt a multi-dimensional psychological perspective when aiming to effectively promote students' innovative behavior. A comprehensive understanding of learners' engagement and motivational processes is essential.

Future research is encouraged to incorporate additional potential mediating or moderating variables and to employ longitudinal research designs in order to capture the developmental trajectories of motivation and innovation behavior. Such efforts will contribute to a more nuanced and enriched understanding of the psychological processes underlying innovation education.

Although this study confirmed the mediating effects of academic motivation and student engagement, existing literature suggests that these mechanisms may not exhibit stable effects across all educational contexts. For example, found that the mediating role of student engagement between educational resources and learning outcomes may be influenced by factors such as learning habits and the quality of motivation, and its significance may vary depending on the context[78].

Similarly, pointed out that within collegiate or residential learning models, the quality of teacher-student interaction serves as a critical bridge between student engagement and learning outcomes[79]. Without meaningful interaction, even high levels of engagement may fail to translate into positive academic results.

Further research has shown that in innovative learning environments, teacher trust plays a pivotal mediating role between transformational teaching and students' creativity, learning engagement, and task performance, whereas curriculum self-efficacy did not demonstrate a significant mediating effect (Pachler et al., 2019).

These studies suggest that the mediating mechanisms within learning processes may be significantly influenced by specific psychological conditions and instructional environments. While the present study has validated the dual mediating roles of student engagement and academic motivation within modular curricula,

future research should explore how these mechanisms may vary across different educational systems, curriculum design approaches, or cultural contexts. It is also recommended that future studies incorporate additional psychological constructs—such as creative self-efficacy, teacher trust, and learning burnout—into multivariate models, and consider longitudinal designs and qualitative methods to develop a more comprehensive understanding of the psychological processes underlying the development of innovation competence.

3.5.2. Instructional innovation should integrate structural design with psychological guidance

The findings of this study suggest that enhancing students' innovation competence requires more than structural or formal innovation in course design; it also necessitates intentional guidance and support for students' psychological processes. Only when structural innovation is coupled with psychological engagement can innovative behaviors be internalized and consistently manifested. This perspective aligns with recent emphases in higher education on learner-centered and process-oriented instructional approaches [80][81]. Wu and colleagues, in their study on design education, emphasized that psychological investment is a critical prerequisite for innovative performance.

Through empirical research, further found that innovative instruction that stimulates active engagement and reflective thinking enhances both learning motivation and creativity, leading to more sustainable and transferable learning outcomes[82]. Building on this, proposed that interactive, learner-centered instructional design strengthens psychological engagement and deep learning, while fostering critical thinking and lifelong learning capabilities—a view highly consistent with the psychological internalization mechanism revealed in this study[83].

Additionally, the descriptive statistics indicate that participants in this study reported moderate to high levels across all psychological constructs, with Innovation Competence (M = 4.41) and Academic Motivation (M = 4.24) demonstrating the strongest performance. This suggests a generally high level of psychological engagement and creative potential among the sample. Such characteristics may be closely related to China's recent policy efforts promoting modular reforms in art and design education and vocational training, which emphasize the integration of learning and creativity as well as industry-education collaboration (Ministry of Education of the People's Republic of China, 2021). These policy directions have likely provided a supportive institutional environment for the construction and validation of the proposed model.

In conclusion, the dual mediation model of psychological processes proposed and validated in this study not only offers an empirical foundation for understanding the psychological mechanisms of innovation education, but also presents practical implications for higher education pedagogy. Specifically, instructional design should move beyond structural innovation to encompass deep psychological support for learners. By fostering students' engagement and motivational internalization, educators can effectively promote innovative learning processes and outcomes, ultimately shaping autonomous and creative lifelong learners.

3.5.3. Theoretical contributions and future research directions

Overall, this study not only addresses the limitations in existing literature regarding the focus on the direct effects of modular instruction but also provides a systematic validation transformation mechanism of "Course Experience → Psychological Processes → Innovation Competence" within the context of art and design education. The findings offer key contributions to the theoretical advancement of innovation education and provide practical implications for curriculum design.

Specifically, the results suggest that future modular curricula should incorporate greater flexibility and learner choice, while also integrating strategies that foster psychological engagement, thereby enhancing students' intrinsic motivation and sense of involvement, which can be effectively transformed into internal drivers of innovative practice.

Moreover, the study underscores that the development of innovation competence is a multifaceted and progressive process, not solely determined by course structure. Future research should consider incorporating additional psychological process variables, such as creative self-efficacy, learning strategy use, academic burnout, and emotion regulation in learning, to construct more comprehensive mediation and moderation models. In particular, creative self-efficacy and academic burnout have been increasingly recognized in the literature as key factors influencing students' innovation outcomes. Future studies may benefit from integrating these constructs into extended process models to explore how psychological readiness and emotional well-being affect the transformation of course experiences into innovation competence. Such integration would not only enhance the explanatory power of the model but also increase its applicability across diverse learning settings.

In addition, while this study adopted a cross-sectional design due to practical and institutional limitations, we acknowledge that this approach restricts the ability to observe dynamic psychological changes over time. Future research is strongly encouraged to employ longitudinal designs to trace the developmental trajectories of student engagement, motivation, and innovation competence. Such an approach would enhance the interpretability of causal relationships and enrich the theoretical understanding of how modular instruction exerts long-term effects on innovation development.

It is also recommended that future studies adopt longitudinal research designs to capture the temporal dynamics of the learning process or integrate qualitative interviews and action research to gain deeper insight into how students develop innovation competence and experience psychological transformation within modular learning environments.

4. Conclusions and recommendations

4.1. Research conclusions

This study aimed to investigate the mechanisms through which modular instruction influences university students' innovation competence, constructing a comprehensive psychological process model with student engagement and academic motivation as mediating variables. Using PLS-SEM (Partial Least Squares Structural Equation Modeling), the following key conclusions were drawn:

1. Student course experience significantly influences engagement and motivational development.

When students perceive course design, instructional interaction, and task challenges positively, it effectively stimulates their active participation and psychological investment, thereby facilitating deep learning.

2. Student engagement and academic motivation are core predictors of innovation competence.

The study confirmed that students' active involvement and intrinsic drive in the classroom significantly contribute to their creative thinking, systems thinking, and goal-oriented competencies.

3. Psychological processes serve as critical bridges in transforming course experience into innovation competence.

Specifically, *student engagement* demonstrated a full mediation effect, while *academic motivation* showed a partial mediation effect. These results suggest that *course experience* is converted into innovation competence through two parallel psychological pathways—namely, the motivational process and the engagement process.

4. The proposed model exhibits strong explanatory power and statistical fit.

Course experience explained over 63% of the variance in the mediating variables, and the total explained variance for innovation competence was $R^2 = 0.568$. The overall Goodness-of-Fit index (GoF) reached 0.657, indicating that the model demonstrates excellent robustness and predictive validity.

4.2. Practical and theoretical recommendations

Based on the findings of this study, the following practical recommendations are proposed for instructional practice and future academic research:

1. Enhance Course Experience and Instructional Design Quality

Educators should improve course structure and optimize the allocation of learning resources. Emphasis should be placed on designing goal-oriented and challenging learning activities that create meaningful and engaging learning environments.

2. Promote Active Student Participation and Interactive Learning Processes

Instructional strategies such as collaborative learning, task-based learning, and flipped classrooms are recommended to encourage students to engage in critical thinking, creativity, and collaboration. These approaches foster both behavioral participation and psychological involvement.

3. Build a Supportive Environment for Intrinsic Motivation

Incorporating motivational frameworks such as the MUSIC model (Motivation, Usefulness, Success, Interest, Caring) can strengthen students' perceived value, autonomy, and engagement in learning activities, thereby promoting sustained motivation and learning persistence.

4. Expand Research Samples and Contextual Applications

Future studies are encouraged to extend the model to other academic disciplines or cultural contexts to enhance the external validity of the findings. Longitudinal research designs are also recommended to better understand the developmental dynamics of psychological processes and innovation competence over time.

5. Broaden the Model and Explore Deeper Mechanisms

Subsequent research may incorporate creative self-efficacy, digital literacy, and emotion regulation in learning as additional mediating or moderating variables, enabling a more comprehensive understanding of the psychological mechanisms underlying the development of innovation competence.

Author contributions

Conceptualization, J.Y.S. and T.K.C.; methodology, J.Y.S.; software, J.Y.S.; validation, J.Y.S. and T.K.C.; formal analysis, J.Y.S.; investigation, J.Y.S.; resources, T.K.C.; data curation, J.Y.S.; writing—original draft preparation, J.Y.S.; writing—review and editing, T.K.C.; visualization, J.Y.S.; supervision, T.K.C.; project administration, T.K.C.. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interest statement

No conflict of interest was reported by all authors.

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