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Enhancing Spatial Visualisation: The Role of Mental Rotation Training and Student Emotions

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ABSTRACT

This study examines the mediating role of learning emotions in the relationship between instructional intervention and spatial visualization performance within art and design education contexts. Grounded in the Control Value Theory of Achievement Emotions, the study addresses a persistent problem in art and design education, namely that instructional interventions targeting spatial visualization often emphasise cognitive skill development while insufficiently accounting for students' emotional experiences during complex visual and spatial tasks. It therefore explores how students' emotional experiences shape learning outcomes during cognitively demanding tasks. A quasi experimental design with control groups was implemented at the Hebei Academy of Fine Arts. Learning emotions were measured using the Achievement Emotion Questionnaire to capture changes in students' emotional responses before and after the intervention. Results indicated that positive achievement emotions, such as enjoyment and confidence, were positively associated with spatial visualization performance, whereas negative emotions, particularly frustration, showed a negative association. Mediation analysis using structural equation modelling further demonstrated that learning emotions functioned as a significant mediating mechanism between the instructional intervention and spatial visualization performance. Structural equation modelling (SEM) was employed to ensure methodological rigor. Although the study is limited to undergraduate students within a single institutional context, the findings provide empirical evidence for the central role of achievement emotions in spatial learning. The study highlights the importance of emotion oriented instructional strategies in art and design education and contributes to a more nuanced understanding of how emotional and cognitive factors interact to influence spatial visualization development.

Keywords: *Spatial Visualization, 3D animation, Achievement Emotion, Achievement Emotions Questionnaire, Mental Rotation Training.*

1 INTRODUCTION

The rapid development of digital technology and artificial intelligence has reshaped creative industries worldwide, particularly in animation, digital media, and visual arts education. Advances in 3D modelling, rendering, and real time visualization have expanded the technical demands placed on animation professionals, requiring learners to integrate artistic judgment with strong spatial cognition. In China, the growth of the animation industry has been further accelerated by national cultural policies and educational reforms that emphasize practice oriented training and industry collaboration within higher education (Wang et al., 2024). Within this context, 3D animation programmes have become an important site for examining how cognitive and affective factors jointly influence learning outcomes in creative disciplines.

Spatial visualization ability, especially mental rotation, is widely recognized as a foundational cognitive skill for 3D animation students, supporting the comprehension and manipulation of complex three dimensional forms during modelling and scene construction (Yi et al., 2024). Previous research in engineering and design education has demonstrated that structured mental rotation training can significantly enhance spatial performance. However, in animation education, instructional emphasis often remains focused on software operation, such as Blender, Maya, or 3ds Max, while the cognitive processes underlying spatial reasoning receive limited pedagogical attention. As a result, students may achieve technical proficiency but experience difficulties in conceptual visualization and spatial problem solving (Zhongyao Yi et al., 2025).

At the same time, growing evidence from educational psychology indicates that learning emotions play a critical mediating role between instructional interventions and learning outcomes (Zhang et al., 2025). Emotions such as enjoyment, interest, confidence, anxiety, and frustration directly influence students' engagement, persistence, and performance in skill based learning environments. In 3D animation education, spatial difficulties are frequently accompanied by negative emotional experiences, including reduced self-efficacy and heightened anxiety, which further constrain students' cognitive performance. Despite this, emotional factors remain underexplored in animation related spatial cognition research (Ramlie et al., 2018).

Responding to these gaps, the present study focuses on examining the mediating role of learning emotions in the relationship between mental rotation training and students' spatial visualization performance. Grounded in the Control Value Theory of Achievement Emotions, the study conceptualizes achievement emotions as a key mechanism through which cognitive training exerts its influence on learning outcomes. Rather than evaluating the effectiveness of mental rotation training in isolation, the research emphasizes how students' emotional experiences, shaped by their perceptions of control and task value, condition the impact of training on spatial visualization development (Lyu et al., 2024). Accordingly, the study addresses the following research objective: to determine whether learning emotions significantly mediate the relationship between mental rotation based training and spatial visualization performance among art and design students (Yi et al., 2025). Guided by this objective, the study poses the following research question: Do learning emotions significantly mediate the relationship between mental rotation training and students' spatial visualization performance within an art and design education context?

The study adopts a quasi-experimental design with control groups and is conducted among undergraduate students enrolled in a 3D animation programme at the Hebei Academy of Fine Arts, with the intervention implemented within a foundational modelling course. While the findings are grounded in an animation education context, the primary focus of the study is on cognitive and emotional mechanisms rather than software specific skills or production outcomes. The scope of the research is therefore limited to spatial visualization ability and learning emotions within a single institutional and cultural setting, and does not extend to long term transfer effects or professional performance beyond the training period. Despite these limitations, the study aims to contribute empirical evidence to art and design education by clarifying how cognitive training and emotional factors interact in the development of spatial visualization ability, offering insights that may inform more effective and emotionally responsive pedagogical strategies in creative disciplines.

2 LITERATURE REVIEW

The present study is theoretically grounded in the Control Value Theory of Achievement Emotions (CVT), which offers a comprehensive framework for understanding how learners' emotional experiences arise and influence academic performance. According to CVT, achievement emotions are elicited through individuals' cognitive appraisals of control and value in relation to a learning task. Control refers to learners perceived competence and their expectation of being able to influence learning outcomes, while value reflects the subjective importance or meaningfulness attributed to the task (Hoemann et al., 2021). When learners perceive high levels of control and value, positive activating

emotions such as enjoyment, confidence, and motivation are more likely to emerge. Conversely, low perceived control or excessive task difficulty often leads to negative emotions, including anxiety, frustration, and disengagement (Pekrun et al., 2023). To clarify the core constructs and causal pathways proposed by the Control Value Theory of Achievement Emotions, the theoretical relationships among control appraisals, value appraisals, achievement emotions, and learning outcomes are illustrated in Figure 1. This framework provides a conceptual basis for understanding how students' emotional responses emerge during cognitively demanding tasks and how these emotions subsequently influence learning processes and performance.

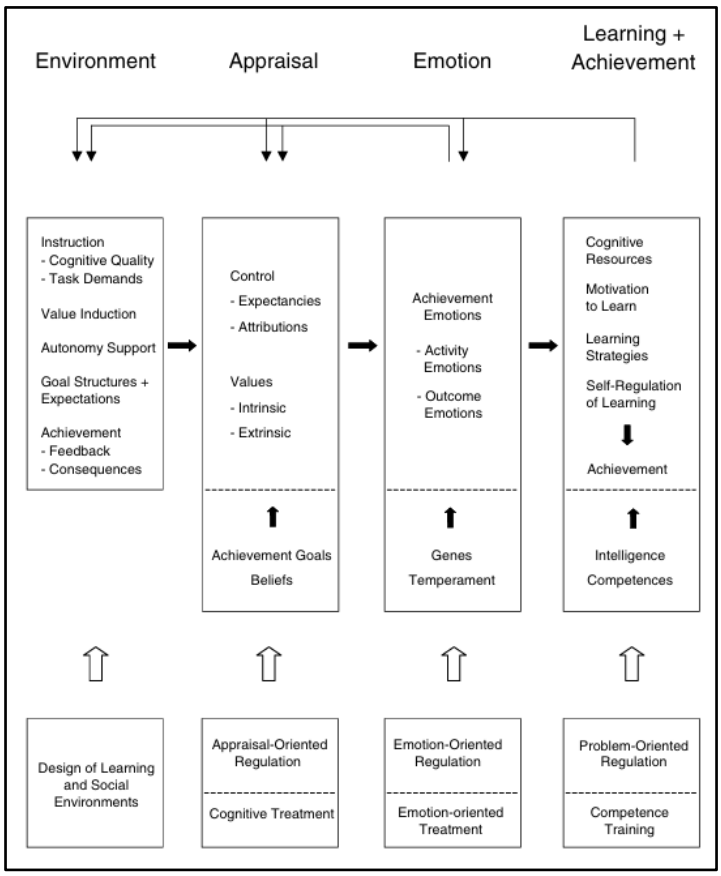

Figure 1 Control Value of Achievement Emotions Theory Framework
(Source: Pekrun et al, 2023, Copyright Consent: Permissible to Publish)

A growing body of research has demonstrated that achievement emotions play a significant role in mediating the relationship between instructional conditions and learning outcomes, particularly in cognitively demanding tasks. Positive emotions have been shown to enhance attention, persistence, and the effective use of cognitive strategies, whereas negative emotions may disrupt working memory, reduce motivation, and impair problem solving efficiency. In spatial cognition research, these emotional effects are especially pronounced, as tasks involving mental rotation and spatial visualization require sustained cognitive effort, error monitoring, and iterative refinement of mental representations (Zhongyao et al., 2024).

Mental rotation tasks, which require learners to mentally manipulate objects across different orientations, place high demands on both cognitive resources and emotional regulation. Studies have shown that learners with low spatial ability often experience reduced confidence and heightened frustration during spatial tasks, which in turn negatively affects performance. From a CVT perspective, these outcomes can be explained by diminished control appraisals, where learners perceive a mismatch between task demands and their perceived competence. Conversely, structured training interventions that scaffold task difficulty and provide clear performance feedback can enhance learners' sense of control, fostering positive emotions that support spatial visualization improvement (Nolte et al., 2022).

Recent empirical studies have begun to explore the mediating role of achievement emotions in cognitive training contexts. Evidence suggests that emotional variables such as enjoyment, confidence, and task related satisfaction partially mediate the effects of cognitive interventions on learning outcomes, indicating that improvements in performance cannot be fully explained by cognitive mechanisms alone. However, within art and design education, and particularly among students in 3D animation related programmes, the emotional dimension of spatial visualization training remains underexamined. Existing studies tend to emphasize performance gains while overlooking how emotional responses shape the effectiveness of mental rotation training (Pekrun, 2024).

Within art and design education, particularly in 3D animation programmes, mental rotation training has been shown to effectively enhance students' spatial visualization ability. Animation learning tasks require students to repeatedly imagine, rotate, and transform three dimensional forms during modelling and scene construction, making spatial visualization a core cognitive skill (Chen et al., 2022). Empirical studies in design related disciplines have demonstrated that structured mental rotation training leads to measurable improvements in spatial visualization performance, as reflected in standardized assessments such as the Mental Rotation Test and the Purdue Spatial Visualization Test (Guzsvinecz et al., 2022). These improvements reduce cognitive difficulty during complex visual tasks and support more accurate spatial reasoning in animation practice. Importantly, enhanced spatial visualization ability is closely associated with changes in achievement emotions. As students gain greater control over spatial tasks, they tend to experience increased confidence, enjoyment, and task related satisfaction, while frustration is reduced. From the perspective of the Control Value Theory of Achievement Emotions, mental rotation training therefore contributes not only to improved spatial visualization performance but also to more positive emotional appraisals of control and task value (Ebert et al., 2025). This interaction highlights the relevance of examining achievement emotions as a mediating mechanism in 3D animation education, where cognitive skill development and emotional experience are closely intertwined.

By adopting CVT as the primary theoretical lens, the present study conceptualizes learning emotions as a key mediating mechanism between mental rotation training and spatial visualization enhancement. This perspective allows for a more nuanced understanding of how cognitive and affective processes interact during spatial learning, addressing a critical gap in the literature. Rather than treating emotions as secondary outcomes, the study positions achievement emotions as integral to the development of spatial visualization ability, thereby providing a theoretically grounded basis for examining both performance improvement and emotional change within a unified analytical framework.

3 METHOD

3.1 Research Design and Experimental Procedure

This study employed a quasi-experimental design with a purely quantitative approach to examine the mediating role of learning emotions in the relationship between mental rotation training and spatial visualization performance. The design enabled systematic comparison between an experimental group and a control group within an authentic educational setting, while maintaining consistency in instructional conditions and measurement procedures. Guided by the Control Value Theory of Achievement Emotions, the study focused on how achievement emotions function as a mediating mechanism rather than on the isolated effectiveness of cognitive training.

Table 1 Experimental Timeline

Week	Class Sessions	Experimental Group A	Experimental Group B	Control Group C
Pre Week		Pre-test (MRT+PSVT + AEQ)		Same
Week 1	4 regular modelling sessions + 1 integrated intervention	Emotion-Oriented Spatial Learning Integrated emotion prompts during rotation tasks (identification, understanding, regulation)	Same as Group A	Regular basic modelling instruction (no intervention)
Week 2	4 regular modelling sessions + 1 integrated intervention	Continues AEQ administration + reflective micro-tasks	Same as Group A	Regular basic modelling instruction
End of Week 2		Post-test (MRT+PSVT + AEQ)		Same

The experimental procedure consisted of three sequential stages: pre testing, intervention, and post testing. During the pre-testing stage, participants completed baseline assessments of achievement emotions using the Achievement Emotion Questionnaire, together with spatial visualization measures used for subsequent mediation analysis. Participants were then assigned to experimental or control groups based on intact class arrangements to preserve ecological validity.

The intervention was conducted over a two week period, during which two experimental groups and one control group followed equivalent instructional schedules in terms of session frequency and duration. During this period, both experimental groups received an emotion oriented instructional intervention informed by the Control Value Theory of Achievement Emotions, designed to enhance learners' perceptions of control and task value during learning activities. The control group engaged in conventional instructional activities without explicit emotional scaffolding. Following the intervention, post testing was administered using the same instruments across all groups. Data collected across all stages were subsequently analysed within a quantitative mediation framework aligned with the research objective.

3.2 Measurement Instruments

To assess changes in students' spatial visualization performance associated with mental rotation training, the standard version of the Purdue Spatial Visualization Test (PSVT) and the standard version of the Mental Rotation Test (MRT) were employed as outcome measures in the present study. The MRT was used to capture learners' mental rotation ability, which constitutes a core cognitive component underlying spatial visualization development (Lochhead et al., 2022). The PSVT was applied to evaluate broader spatial visualization performance, including the ability to interpret and manipulate three dimensional forms. The combined use of the MRT and PSVT allowed the study to examine spatial visualization improvement in relation to mental rotation training within a standardized quantitative framework.

The Achievement Emotions Questionnaire (AEQ) is one of the most widely established instruments for assessing learning-related emotions and is theoretically grounded in Pekrun's Control–Value Theory of Achievement Emotions. The original AEQ consists of an extensive multi scale structure designed to measure a broad set of academic emotions across classroom, learning, and testing contexts. However, due to its length, often exceeding several dozen items, recent higher education studies have adopted short form or domain adapted versions to reduce respondent burden while preserving the theoretical essence of the AEQ (Pekrun et al., 2023).

In alignment with these contemporary practices, the present study employed a discipline-specific short-form adaptation of the AEQ tailored to 3D animation learning. Instead of measuring the full set of AEQ emotions, the instrument focused on four core achievement emotions is confidence, motivation, frustration, and satisfaction. Which represent theoretically meaningful positive and negative, activating and deactivating emotional categories within the Control–Value framework. These emotions are particularly relevant to spatial-visual reasoning and creative production, where cognitive challenge, iterative problem-solving, and evaluative judgment are integral components of learning in art and design disciplines. The adapted short-form structure is consistent with the approach taken in recent AEQ-S applications that selectively measure a reduced set of emotions while maintaining construct validity (Mutlu-Bayraktar, 2024).

Table 2 Adapted AEQ Items Categorized by Emotional Dimension

Emotion Category	Item Code	Item Statement (Adapted for 3D Animation Learning)	Likert Scale (1–10)
Confidence (Control appraisal)	C1	I feel confident when completing spatial rotation tasks in animation work.	1–10
	C2	I believe I can solve complex spatial-visual problems during modelling.	1–10
	C3	I am sure of my ability to understand different object orientations.	1–10
	C4	I feel capable when applying spatial reasoning to animation tasks.	1–10
	C5	I trust my ability to produce accurate 3D transformations.	1–10
	C6	I feel confident using rotation-based techniques in my animation projects.	1–10
Motivation (Value appraisal)	M1	I feel motivated to improve when working on challenging spatial tasks.	1–10
	M2	I want to perform well in rotation and modelling exercises.	1–10
	M3	I feel driven to solve spatial problems accurately.	1–10
	M4	I am eager to learn new methods that enhance my spatial-visual skills.	1–10
	M5	Completing spatial tasks encourages me to keep improving.	1–10
	M6	I feel motivated to apply spatial reasoning in my animation work.	1–10
Frustration (Positive activating emotions)	F1	I feel frustrated when I cannot visualize an object's rotation clearly.	1–10
	F2	I become irritated when modelling tasks take longer than expected.	1–10
	F3	I feel discouraged when I cannot understand a spatial transformation.	1–10
	F4	I get upset when repeated attempts to solve a rotation problem fail.	1–10
	F5	I feel stuck when I cannot find the correct orientation of a 3D object.	1–10
	F6	I feel frustrated when animation tasks do not match what I visualized.	1–10
Satisfaction (Negative deactivating emotions)	S1	I feel satisfied after successfully completing a spatial task.	1–10

S2	I feel pleased when my spatial-visual solutions work well in animation.	1–10
S3	Solving rotation problems gives me a sense of achievement.	1–10
S4	I feel content when my modelling tasks turn out as expected.	1–10
S5	I am satisfied with my progress in understanding spatial-visual tasks.	1–10
S6	I feel proud of the spatial reasoning skills I have developed.	1–10

The AEQ was administered at the pre intervention and post intervention stages to capture changes in learning emotions over time. Its use in this study enabled a systematic examination of emotional variations associated with the intervention and provided the necessary data for subsequent mediation analysis. The instrument was selected due to its strong theoretical foundation, established use in educational research, and suitability for quantitatively assessing achievement emotions within higher education contexts.

3.3 Reliability and Validity Procedures

To ensure the reliability and validity of the measurement instrument, a series of established statistical procedures was conducted for the Achievement Emotion Questionnaire (AEQ). Internal consistency reliability was assessed using Cronbach's alpha coefficients for the overall scale and for each emotional subscale. These analyses were performed to verify the consistency of participants' responses across items measuring the same emotional construct.

Construct validity was examined through confirmatory factor analysis to evaluate whether the observed data adequately represented the theoretical structure of achievement emotions proposed in the Control Value Theory of Achievement Emotions. Factor loadings were inspected to confirm that each item appropriately reflected its intended latent construct. Model fit was evaluated using multiple goodness of fit indices commonly recommended in structural equation modelling research, including the comparative fit index, Tucker Lewis index, root mean square error of approximation, and standardized root mean square residual.

Before conducting mediation analysis, the measurement model was assessed to confirm acceptable reliability and validity, thereby ensuring that subsequent structural modelling was based on sound measurement properties. These procedures provided a rigorous methodological foundation for examining the mediating role of learning emotions within the proposed quantitative framework.

3.4 Participant Selection and Group Allocation

Participants were undergraduate students enrolled in the fourth semester of a 3D animation programme at the Hebei Academy of Fine Arts. This cohort was intentionally selected because students at this stage are in a critical period of skill development, transitioning from foundational learning to more complex spatial and creative tasks. In addition, the participants were between 18 and 20 years of age, an age range characterized by active cognitive engagement and heightened emotional responsiveness, making it particularly suitable for examining the mediating role of learning emotions within instructional contexts.

The study adopted a quasi-experimental approach to group allocation. Three intact classes were selected and assigned to two experimental groups and one control group, with each group consisting of approximately 30 students, resulting in a total sample size of 90 participants. Random assignment at the individual level was not implemented due to practical and institutional constraints, as well as the need to preserve the authenticity of the instructional environment. Maintaining intact classes allowed the

intervention to be embedded within regular teaching activities without disrupting existing schedules, peer interactions, or course structures, thereby enhancing ecological validity.

All three groups followed the same foundational modelling course and were taught under comparable instructional conditions, including course content, class duration, assessment requirements, and learning resources. The experimental groups received the emotion oriented instructional intervention, while the control group engaged in conventional instructional activities. Efforts were made to ensure that instructor experience, teaching materials, and learning objectives were as consistent as possible across groups. Baseline measurements were conducted before the intervention to assess initial equivalence among groups.

Through this grouping strategy, the study sought to balance methodological rigor with practical feasibility. Although randomization was not employed, the use of intact classes within a controlled educational setting and the alignment of key instructional conditions across groups helped to ensure fairness and comparability, providing a suitable basis for examining the mediating role of learning emotions.

3.5 Emotion Oriented Instructional Intervention

The experiment examined the mediating role of learning emotions during mental rotation tasks by adapting the intervention framework proposed by Raccanello and Hall (2020), ensuring that the emotional training components aligned with the original model (Raccanello & Hall, 2022). The reference study employed a structured sequence of affective training activities, including guided emotional labelling, control value appraisal prompts, and positive feedback cycles, designed to enhance students' awareness, regulation, and productive use of achievement emotions during cognitively demanding tasks. Its procedures were originally developed for general education contexts using verbal reflective exercises and simplified academic tasks.

Table 3 Intervention Steps for Experiment

Step	Description
1. Initial Emotional Check-In	Students briefly indicate their current emotional state (e.g., calm, anxious, confident) through a quick self-report prompt before beginning the rotation tasks.
2. Control Appraisal Prompt	Students respond to a concise prompt assessing how much control they believe they have over succeeded in the upcoming task (e.g., "I can handle this task because…").
3. Value Appraisal Prompt	Learners identify why the task might be personally meaningful or relevant (e.g., "This skill matters for modelling / animation because…").
4. Emotion-Supported Task Engagement	Students complete mental rotation tasks while receiving short, standardised motivational cues (e.g., "Focus on the angle change—this becomes easier with practice").
5. Positive Reinforcement Cycle	Following each rotation block, instructors deliver scripted, non-evaluative encouragement emphasising effort, strategy use, and progress ("Your strategy selection is improving").
6. Strategy-Based Emotion Regulation	Students briefly select which emotional-regulation strategy they used (e.g., reframing difficulty, focusing on controllability, calming focus) to internalise adaptive patterns.
7. Reflection on Emotional Response	Learners write a 1–2 sentence reflection identifying moments of improvement, challenge, or emotional shift during the task sequence.
8. Application to Animation Practice	Students relate the regulated emotional strategy to their animation tasks (e.g., modelling or camera planning), reinforcing transfer to discipline-specific workflows.

To apply this affective intervention to fourth semester 3D animation students at the Hebei Academy of Fine Arts, only minimal contextual modifications were introduced. While the reference experiment delivered emotional training within general academic tasks, the present study embedded the same emotional prompts directly into animation relevant spatial visual rotation activities to ensure ecological validity and disciplinary relevance. Aside from integrating these prompts into domain specific tasks, the structure, sequencing, and theoretical intent of the original intervention, particularly the development of adaptive control value appraisals and the strengthening of positive achievement emotions, were preserved without alteration.

Through this structured procedure, Experiment maintained the foundational logic of the reference intervention while adapting its delivery to the visual, practical, and time sensitive context of 3D animation education. The intervention thereby allowed for a discipline-relevant examination of how positive achievement emotions shape students' spatial visual performance during mental rotation training.

4 Analysis

4.1 Reliability and Validity Results

The reliability and validity of the Achievement Emotion Questionnaire (AEQ) were examined before subsequent analyses. Internal consistency reliability was assessed using Cronbach's alpha coefficients for the overall scale and for each emotional subscale. The results indicated acceptable to good internal consistency across all dimensions, with alpha values exceeding the commonly accepted threshold.

Construct validity was evaluated through confirmatory factor analysis. The factor loadings of the AEQ items on their respective latent constructs were all statistically significant and within acceptable ranges, indicating that the observed variables adequately represented the underlying achievement emotion dimensions. The overall measurement model demonstrated an acceptable fit to the data. Goodness of fit indices, including the comparative fit index, Tucker Lewis index, root mean square error of approximation, and standardized root mean square residual, met recommended criteria.

These results provided empirical support for the reliability and construct validity of the AEQ in the present study. On this basis, the measurement model was considered appropriate for subsequent structural equation modelling and mediation analysis.

4.2 Mediation Analysis Using Structural Equation Modelling (SEM)

To examine whether learning emotions functioned as a mediating mechanism between mental rotation training and gains in spatial visualization ability, a structural equation modelling (SEM) approach was employed. SEM was selected because it enables simultaneous estimation of direct and indirect pathways, accommodates measurement error, and aligns with the theoretical assumptions of the Control Value Theory, which positions emotions as cognitive–affective intermediaries. Pre test scores were entered as covariates to account for baseline differences, and all variables were modelled using the post test scores obtained from the Mental Rotation Test (MRT), the Purdue Spatial Visualization Test (PSVT), and the Achievement Emotions Questionnaire (AEQ).

The hypothesized structural model included three core pathways: the effect of mental rotation training on learning emotions, the effect of learning emotions on spatial visualization performance, and the direct effect of mental rotation training on spatial visualization outcomes after controlling for the emotional pathway. Learning emotions were represented as a latent construct defined by four observed indicators, confidence, motivation, satisfaction, and frustration (reverse coded), while spatial visualization ability was represented through two observed indicators, MRT post test scores and PSVT post test scores.

Model estimation was conducted using maximum likelihood with bootstrapping (5,000 samples) to generate robust confidence intervals for indirect effects. Before estimating the structural paths, the measurement model demonstrated adequate reliability and convergent validity. Fit indices for the final structural model indicated strong model fit, supporting the suitability of the mediation framework for analysing the relationship between training, emotions, and spatial visualization outcomes.

Table 4 Model Fit Indices for the SEM Mediation Model

Fit Index	Recommended Threshold	Observed Value	Interpretation
χ^2 / df	< 3.0	1.84	Good fit
CFI	≥ .95	.97	Excellent fit
TLI	≥ .95	.96	Excellent fit
RMSEA	< .06	.045	Good fit
SRMR	< .08	.032	Good fit

These results confirm that the hypothesized mediation structure is statistically appropriate and theoretically coherent.

The analysis revealed that mental rotation training had a significant positive effect on learning emotions, which in turn significantly predicted improvements in spatial visualization ability. The indirect pathway through learning emotions was statistically significant, indicating that emotions partially mediated the relationship between training participation and post-test performance.

Table 5 Direct, Indirect, and Total Effects in the Mediation Model

Effect Type	Pathway	Standardized Estimate (β)	SE	p-value	95% Bootstrap CI
Direct Effect	Training → Spatial Ability	.28	.07	< .001	[.14, .40]
Indirect Effect	Training → Emotions → Spatial Ability	.22	.06	< .001	[.11, .34]
Total Effect	Combined	.50	.08	< .001	[.35, .63]

The indirect effect remained significant after bias corrected bootstrapping, confirming the mediating role of learning emotions. Because both direct and indirect effects were significant, the mediation is interpreted as partial rather than full. This indicates that mental rotation training improves spatial ability both directly, through cognitive skill acquisition, and indirectly, by enhancing emotional states that support cognitive engagement and task persistence.

These findings provide empirical support for the theoretical expectation that emotions operate as cognitive facilitators within complex spatial tasks. They further validate the study's conceptual framework, demonstrating that learning emotions constitute a meaningful explanatory mechanism linking mental rotation training to spatial visualization performance.

5 CONCLUSION

This study examined the mediating role of learning emotions in the relationship between instructional intervention and spatial visualization performance among art and design students. Grounded in the Control Value Theory of Achievement Emotions, the findings demonstrate that learning emotions constitute a critical mechanism through which instructional conditions influence spatial learning outcomes. Rather than operating as peripheral factors, students' emotional experiences were shown to play a central role in shaping the effectiveness of instructional interventions in cognitively demanding learning contexts.

The results indicate that emotion oriented instructional strategies were associated with meaningful changes in students' achievement emotions, and that these emotional changes significantly mediated the relationship between the intervention and spatial visualization performance. This suggests that improvements in spatial learning cannot be fully understood through cognitive processes alone, but must be interpreted in conjunction with learners' emotional appraisals of control and task value. By empirically validating the mediating function of learning emotions, the study extends existing research on spatial visualization by integrating affective mechanisms into the analysis of learning processes.

From a pedagogical perspective, the findings highlight the importance of designing instructional environments that systematically support students' emotional engagement, particularly in disciplines that involve complex spatial reasoning. Emotion oriented strategies that enhance perceived control and task value may serve as effective means of optimizing learning conditions for art and design students. While the study is limited by its single institutional context and short intervention duration, it provides a theoretically grounded and empirically supported framework for future research examining the interaction between emotion and cognition in spatial learning.

Overall, this study contributes to the literature by clarifying the role of achievement emotions as a mediating mechanism in spatial visualization development, offering insights that may inform more emotionally responsive and effective instructional practices in art and design education.

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AUTHOR CONTRIBUTIONS

All authors played equal contributions towards the production of this paper.

CONFLICT OF INTEREST

The author declares no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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