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A Study on the Mechanism of Learning Experience and Sense of Accomplishment in Influencing Satisfaction with Road and Bridge Engineering Courses

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Abstract: To explore the role of learning experiences, sense of accomplishment, and satisfaction in road and bridge engineering courses for optimizing teaching quality evaluation, this study collected data through questionnaires, extracted key influencing factors using principal component analysis, and constructed a comprehensive evaluation model via ridge regression. Findings reveal that student learning engagement is the primary determinant of learning experience; instructor teaching commitment indirectly influences student engagement through empowerment; sense of accomplishment primarily stems from process-oriented experiences such as skill development and problem-solving; while satisfaction is directly driven by teacher-student relationships and instructional content quality. The model further indicates that learning experience and sense of accomplishment mutually reinforce each other to jointly influence satisfaction, with learning experience exerting a more significant direct impact.

Keywords: Learning experience; Sense of accomplishment; Satisfaction; Road and Bridge Engineering; Evaluation model; Influence mechanism

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1. Introduction

In the era of globalization and the knowledge economy, the intrinsic development of higher education is crucial to national competitiveness. In 2018, China's Ministry of Education proposed the principles of "prioritizing undergraduate education" and "returning to four fundamentals," establishing the core status of talent cultivation and undergraduate teaching. This shift propelled China's higher education from scale expansion toward quality enhancement. Against this backdrop, the teaching evaluation system urgently requires reform, with student learning experiences and satisfaction emerging as key indicators of quality. Therefore, establishing a systematic and quantifiable mechanism for evaluating and improving teaching quality has become a critical task in current higher education reform.

Learning experience, sense of learning achievement, and course satisfaction represent key dimensions in contemporary educational quality assessment. Learning experience, rooted in constructivism, has evolved in the digital context into a comprehensive concept encompassing cognitive, affective, behavioral, and social interactions [1–3], forming the foundation of learning. Building upon this foundation, the sense of learning achievement specifically denotes students' substantive growth in knowledge, skills, competencies, and value formation [4], serving as the core motivator for sustained learning engagement. Learning satisfaction serves as the ultimate comprehensive assessment, reflecting the alignment between students' expectations and actual perceptions of course instruction and services. Its evaluation framework is continually refined through methodologies such as service quality models and structural equation modeling [5–7]. These three elements are interrelated, collectively mapping the complete pathway from the learning process and intrinsic gains to the final evaluation.

Current research on learning experiences, perceived gains, and satisfaction remains limited in several respects: on one hand, these dimensions are often examined in isolation, failing to integrate the intrinsic logic of the "experience-gain-evaluation" educational quality loop; on the other hand, methodological approaches frequently rely on single-dimensional holistic measurements, making it difficult to unravel the underlying multidimensional drivers. To address this, this study constructs a unified framework. It employs principal component analysis to objectively extract core factors from subjective evaluation data, establishing a more explanatory and diagnostic evaluation model. This approach advances related research through theoretical integration and methodological innovation.

2. Survey and analysis of student learning experience, sense of achievement, and satisfaction

2.1. The process of teaching reform

This study is based on the ongoing teaching reform practices in the Road and Bridge Engineering program at a local university. Since 2019, the program has progressively advanced teaching innovation: first introducing the OBE (outcome-based education) concept to reconstruct the curriculum system, forming a teaching closed-loop of "backward design and forward implementation." Subsequently, it established a blended learning model integrating online and offline instruction, innovating the "OBE+BOPPPS" course-based ideological and political education design, which gained recognition from over 80% of students. The program then comprehensively implemented the BOPPPS model and separated teaching from assessment, conducting systematic surveys on learning experiences, sense of fulfillment, and satisfaction in 2023. In 2024, it initiated the development of AI course clusters to advance the transition toward a data-driven teaching paradigm.

2.2. Survey design and data collection

This study's questionnaire was designed with reference to relevant domestic and international research, reviewed and revised by eight faculty members to ensure validity and appropriateness. The 30-item questionnaire comprises four sections: basic information (gender, age, student leadership role), factors influencing learning experience (16 items), sense of learning achievement (6 items), and course satisfaction (5 items), all scored using a 5-point Likert scale. The survey was administered to third-year students majoring in Road and Bridge Engineering from the 2020 and 2021 cohorts in December 2023 and December 2024, respectively. Using cluster sampling, 170 questionnaires were distributed, with 153 valid responses collected.

2.3. Validity and reliability testing

The questionnaire underwent reliability and validity testing using SPSS 26.0 software. Cronbach's alpha coefficients were employed for measurement, yielding an overall scale reliability of 0.976. The coefficients for each subscale (learning experience, sense of accomplishment, and satisfaction) ranged from 0.932 to 0.960, indicating high internal consistency of the questionnaire. Validity was assessed using KMO values and Bartlett's sphericity test. The overall KMO value was 0.940, with all subscales exceeding 0.84. Bartlett's tests yielded significance levels consistently below $P < 0.01$, confirming the questionnaire's sound construct validity and suitability for factor analysis.

2.4. Principal component analysis

2.4.1. Student learning experience

This study employed principal component analysis to identify key factors influencing learning experiences. Principal components were extracted from the correlation matrix and rotated using the maximum variance method, yielding two principal component factors from 16 influencing factors. Among these, three items—including "Pre-class reflection encourages me to prepare for courses in a timely manner"—exhibited factor loadings exceeding 0.5 on both dimensions and were subsequently removed. Detailed results of the principal component analysis and item loadings are presented in Tables 1 and 2.

Table 1. Principal component analysis results

Item	Component	Initial eigenvalue			Extracted loadings sum of squares		
		Total	Percentage of variance	Cumulative %	Total	Percentage of variance	Cumulative %
Learning experience	1	10.184	63.651	63.651	10.184	63.651	63.651
	2	1.721	10.755	74.406	1.721	10.755	74.406

According to the results of principal component analysis (**Table 1)**, the two extracted principal components collectively account for 74.406% of the variance, indicating minimal information loss—a level fully acceptable in social science research [8]. The first principal component contributes 63.651% of the variance, primarily driven by items reflecting student learning engagement (e.g., participating in group discussions, actively sharing perspectives). The second principal component accounts for 10.755% of the variance, primarily associated with teacher instructional engagement (e.g., clear teaching methods, timely summaries). Together, these two principal components encompass the key factors influencing the learning experience, effectively replacing the original 13 indicators.

The original 13 indicators of learning experience influencing factors are replaced by two principal components: student learning engagement (X_1) and teacher instructional engagement (X_2). Using standardized scoring metrics, principal component factor scores can be calculated. The principal component expression for learning experience influencing factors is shown in **Equation (1)**.

$$X_i = \sum_{j=1}^{13} \alpha_j T_j \quad (1)$$

In the formula, α_j represents the weight corresponding to each item, obtained by dividing the initial factor loading by the square root of the principal component eigenvalue [9]; T_j denotes the standardized indicator for each item of the respective experiential dimension. The calculated principal component weights for each learning experience influencing factor are presented in **Table 2**.

Table 2. Principal component loadings and weights for each item

Item	Symbol	Heading	Load value		Weight	
			1	2	1	2
Factors influencing the learning experience	T_1	Participate in group cooperative learning and peer discussions	0.862	0.267	0.253	0.307
	T_2	Proactively share your perspectives and ideas	0.853	0.272	0.252	0.299
	T_3	Ask valuable questions and engage in discussions	0.839	0.242	0.243	0.309
	T_4	Take initiative in learning based on resources provided by the instructor	0.826	0.262	0.244	0.291
	T_5	Demonstrate interest in the course and willingness to invest additional time and effort	0.752	0.469	0.272	0.138
	T_6	Maintain a clear learning plan	0.739	0.231	0.217	0.261
	T_7	Adapt well to the pace of classroom instruction	0.659	0.440	0.245	0.104
	T_8	Possess a solid understanding of course objectives	0.620	0.446	0.237	0.080
	T_9	Present content in an accessible and engaging manner	0.218	0.893	0.243	-0.378
	T_{10}	Provide timely summaries of each lesson's content	0.248	0.892	0.249	-0.361
	T_{11}	Employ diverse teaching methods as appropriate	0.286	0.858	0.251	-0.322
	T_{12}	Offer prompt assistance when needed	0.358	0.835	0.262	-0.272
	T_{13}	Provide abundant learning resources	0.353	0.821	0.258	-0.266

Based on the results of principal component analysis, a principal component coefficient model for student learning experiences was constructed using the variance contribution rates corresponding to the two principal components as weights, as shown in **Equations (2) to (4)**.

$$Y_1=0.637X_1+0.108X_2 \tag{2}$$

$$X_1=0.253T_1+0.252T_2+0.243T_3+0.244T_4+0.272T_5+0.217T_6+0.245T_7+0.237T_8+0.243T_9+0.249T_{10}+0.251T_{11}+0.262T_{12}+0.258T_{13} \tag{3}$$

$$X_2=0.307T_1+0.299T_2+0.309T_3+0.291T_4+0.138T_5+0.261T_6+0.104T_7+0.080T_8-0.378T_9-0.361T_{10}-0.322T_{11}-0.272T_{12}-0.266T_{13} \tag{4}$$

The weight analysis of the Student Experience Index (Y_1) reveals that student learning engagement (0.637) significantly outweighs teacher instructional engagement (0.108), indicating that the learning experience is primarily driven by students' pre-class preparation, in-class participation, and intrinsic motivation. Teachers' instructional engagement has a limited direct impact, primarily exerting influence indirectly by stimulating and supporting student engagement. Therefore, teaching must shift toward a "student-centered" approach, moving from focusing on "how to teach" to designing tasks, providing resources, and offering feedback to foster active, deep learning among students.

In summary, this model reveals that the key to generating meaningful learning experiences lies in unleashing students' agency. Teachers should transition from being "lecturers" to "facilitators" to foster students' deep engagement in learning.

2.4.2. Sense of achievement and satisfaction in learning

Through principal component analysis (using correlation matrix extraction and maximum variance rotation), one principal component factor was extracted for both perceived satisfaction and overall satisfaction. The analysis results and item loadings are presented in **Tables 3** and **4**, respectively.

Table 3. Principal component analysis results

Item	Component	Initial eigenvalue			Extracted loadings sum of squares		
		Total	Percentage of variance	Cumulative %	Total	Percentage of variance	Cumulative %
Sense of achievement	1	4.684	78.060	78.060	4.684	78.060	78.060
Satisfaction	1	3.973	79.469	79.469	3.973	79.469	79.469

As shown in **Table 3**, the cumulative variance contribution rates of the principal components for sense of fulfillment and satisfaction are 78.060% and 79.469%, respectively. This indicates that the extracted factors adequately represent the original indicators with minimal information loss. The principal component weights for the factors influencing learning experience, calculated using **Equation (1)**, are presented in **Table 4.**

Table 4. Principal component loadings and weights for each item

Item	Symbol	Heading	Load value		Weight	
			1	2	1	2
Sense of achievement	H_1	Solve practical problems	0.862	0.267	0.253	0.307
	H_2	Identify and address shortcomings	0.853	0.272	0.252	0.299
	H_3	Achieve expected learning objectives	0.839	0.242	0.243	0.309
	H_4	Master key and challenging content	0.826	0.262	0.244	0.291
	H_5	Acquire effective learning methods	0.752	0.469	0.272	0.138
	H_6	Support career development	0.739	0.231	0.217	0.261
Satisfaction	M_1	Teacher-Student Relationships	0.659	0.440	0.245	0.104
	M_2	Teaching Practices	0.620	0.446	0.237	0.080
	M_3	Assessment and Evaluation	0.218	0.893	0.243	-0.378
	M_4	Teaching Process	0.248	0.892	0.249	-0.361
	M_5	Teaching Models	0.353	0.821	0.258	-0.266

Based on the results of principal component analysis, using the variance contribution rate corresponding to each principal component as the weight, the principal component coefficient models for students' sense of learning achievement (Y_2) and satisfaction (Y) are given by **Equations (5) and (6)**, respectively.

$$Y_2=0.425H_1+0.419H_2+0.416H_3+0.413H_4+0.412H_5+0.363H_6 \quad (5)$$

$$Y=0.470M_1+0.461M_2+0.446M_3+0.442M_4+0.415M_5 \quad (6)$$

Among these, Y_2 represents the student sense of fulfillment indicator; Y represents the student satisfaction indicator.

Students' sense of fulfillment is driven by a gradient: immediate feedback from solving practical problems and self-correction yields higher perceived gains than the distant prospect of career development. This disparity is widened by students' preference for instant self-efficacy and the current lack of real-world integration in career guidance. Similarly, student satisfaction is dominated by "human" factors—teacher-student interactions and instructional quality—which provide immediate emotional and cognitive gratification. While assessment processes directly impact perceptions of fairness, teaching model innovations have a limited short-term effect due to student path dependency, technological constraints, and the time required for such changes to manifest.

2.5. Statistical analysis

2.5.1. Student learning experience

A statistical analysis was conducted on 13 student learning experience indicators. The results of the mean and standard deviation analysis are shown in **Figure 1**.

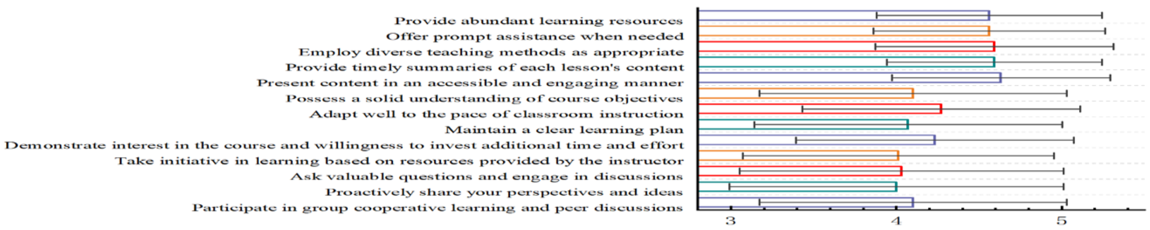

Figure 1. Statistical analysis results for mean and standard deviation of learning experiences

Survey results indicate that road and bridge engineering students rated all aspects of their course learning experience above 4.0 on average, reflecting an overall positive outlook. Specifically, scores for teaching performance metrics—such as lecture delivery and class summaries—ranged between 4.56 and 4.63. Notably, 93.47% of respondents rated "clear and accessible lecture delivery" positively, demonstrating strong student recognition of instructors' teaching abilities, resource support, and classroom management. Regarding learning engagement, students demonstrated strong collaborative awareness (group work and idea sharing averaged above 4.0) and self-directed learning abilities (resource utilization and course interest averaged 4.01 and 4.23, respectively), alongside effective learning planning skills. Standard deviations for each item ranged between 0.65 and 1.01, reflecting high evaluation consistency. Overall, the course achieved significant outcomes in both teaching practice and student development dimensions, fostering a virtuous cycle of mutual growth between teaching and learning.

2.5.2. Sense of achievement and satisfaction in learning

An independent samples *t*-test was conducted to analyze the impact of students' basic information on their sense of fulfillment and satisfaction ratings. Results indicate no significant differences ($P > 0.05$) across gender, age, or student leadership roles in either evaluation. The mean and standard deviation statistics for sense of fulfillment and satisfaction ratings are presented in **Figures 2** and **3**.

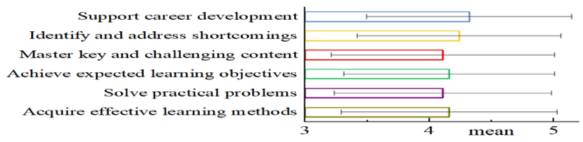

Figure 2. Statistical analysis of student achievement

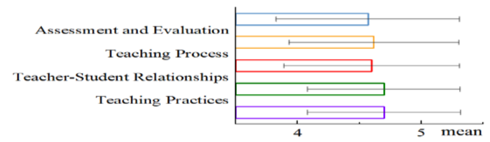

Figure 3. Statistical analysis of student satisfaction

Statistical analysis indicates that over 70% of students achieved positive outcomes in their coursework, including mastering learning methods, enhancing problem-solving abilities, accomplishing learning objectives, understanding key concepts and difficulties, and improving weaknesses. Moreover, the majority of students acknowledged the course's contribution to their career development. However, 13.07–24.84% of students reported moderate satisfaction, while a small minority gained limited benefits. The mean satisfaction score ranged from 4.11 to 4.32 with a standard deviation of 0.81–0.90, indicating a generally high overall level. Evaluations were particularly concentrated on the "course aids career development" dimension, whereas the standard deviation for "mastery of key and difficult content" was slightly higher, reflecting persistent challenges for some students in synthesizing knowledge. Statistical analysis of student satisfaction indicates that nearly 70% of students expressed "high satisfaction" with the teaching model, with mean satisfaction scores ranging between 4.60 and 4.70 across all indicators, reflecting an overall positive evaluation. The slightly larger standard deviation for teaching model satisfaction suggests that while most students endorse this approach, a few individuals may struggle to adapt.

Based on findings from semi-structured interviews, students who report lower levels of satisfaction and struggle to adapt to teaching methods commonly exhibit academic deficiencies and a lack of interest in coursework. This suggests that future teaching reforms should place greater emphasis on addressing individual student differences, with a focus on advancing personalized instruction.

3. Satisfaction evaluation model construction

Due to the presence of multicollinearity in traditional linear regression (VIF = 7.128 > 5), ridge regression was employed in this study to enhance model robustness. This method effectively mitigates the interference of multicollinearity on parameter estimation by introducing a penalty term, ultimately yielding the regression equation shown in **Equation (7)**.

$$Y=0.003+0.705\cdot Y_1+0.103\cdot Y_2 \tag{7}$$

Among these, λ = 0.18 serves as the ridge parameter, which constrains the magnitude of regression coefficients to mitigate multicollinearity issues.

Based on the results of the ridge regression analysis, the model exhibits an overall good fit, with an R^2 of 0.607 and an adjusted R^2 of 0.602. This indicates that student learning experiences and sense of learning achievement can explain approximately 60.2% of the variance in course satisfaction. The regression coefficients reveal that learning experience (Y_1) exerts the most significant influence on course satisfaction (β = 0.705, $P < 0.001$), with a standardized coefficient of 0.587, confirming its status as the primary predictor variable. Although learning sense of accomplishment (Y_2) had a smaller effect (β = 0.103, $P < 0.05$), it remained statistically significant, indicating it also contributed explanatory power within the model. After controlling for multicollinearity, student course satisfaction is primarily directly influenced by learning experience, particularly classroom interaction and teaching methods. In contrast, while the effect of learning acquisition is weaker, it remains important as it relates to students' learning outcomes and self-efficacy. Educators should enhance students' sense of acquisition by improving learning feedback and goal guidance, thereby indirectly increasing course satisfaction [10].

Teaching practices should concurrently optimize learning experiences and fulfillment to drive course satisfaction. Instructional design should foster immersion through high-interaction methods—such as project-based learning and collaborative groups—supported by timely feedback and emotional engagement. Simultaneously, courses must feature coherent frameworks and clear objectives that align theory with practical application. By bridging the gap between instructional goals and perceived competency, this dual approach ensures that positive student experiences translate into a tangible sense of achievement.

4. Conclusion

This study identifies student engagement as the primary driver of learning experiences, reinforcing student-centered principles. Faculty engagement acts indirectly by empowering active learning, marking a shift from lecturers to "designers and facilitators." Findings reveal that a sense of fulfillment stems from immediate self-improvement and practical problem-solving rather than long-term career goals. Furthermore, student satisfaction is rooted in interpersonal factors—such as teacher-student relationships—rather than instructional model innovation. Consequently, high-quality education must balance positive experiences with tangible gains. Educators should prioritize supportive, interactive environments while enhancing objective clarity, content practicality, and feedback-driven assessments. Future reforms should integrate strengthened pedagogical interaction with systematic activity design to bridge the gap between student satisfaction and effective learning outcomes.

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Disclosure statement

The authors declare no conflict of interest.

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