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Original Article

Implementing Progressive Project-Based Learning (PPBL) in Experimental Teaching of Human Anatomy and Physiology: An Empirical Study in Chinese Pharmaceutical Higher Education

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ABSTRACT

Background: This study diagnosed critical student-side bottlenecks in experimental teaching of Human Anatomy and Physiology for pharmacy students, including content overload and insufficient post-class support, and explored student perceptions regarding a Progressive Project-Based Learning (PPBL) reform to guide systematic course restructuring. **Materials and Methods:** Using convenience sampling, a structured survey was administered to 328 undergraduate and postgraduate students. The instrument evaluated course cognition, pedagogical modalities, assessment fairness, and self-rated objective attainment in accordance with the Association for Evaluation in Education (AEE) Guidelines. Quantitative analysis was performed via SPSS 24.0 using independent *t*-tests, one-way ANOVA, and Chi-square ($\chi 2$) tests. **Results:** While respondents highly acknowledged the course's foundational significance (3.91±0.82), only 41.6% felt the current curriculum reflected modern scientific frontiers. Primary bottlenecks centered on overloaded instructional content (51.2%) and a notable gap in post-class review guidance (45.7%). While 58.5% explicitly favored on-site clinical practice, standard textbook-skimming preview engagement was remarkably low (18.6%). Notably, 93.9% of students endorsed the transition toward the PPBL framework. Chi-square analysis revealed that self-perceived learning attainment was significantly associated with overall course satisfaction ($\chi^2 = 67.73$, $p<0.001$), emerging as the strongest correlate, whereas content congestion was inversely associated with positive course appraisal ($\chi^2=4.05$, $p=0.044$). **Conclusion:** Pharmaceutical undergraduates experience significant cognitive overload and a theory-practice disconnect, but exhibit a robust demand for incremental, scaffolded pedagogy. This study advocates the immediate institutionalization of a three-tier modular project framework ("Basic-Comprehensive-Innovative") underpinned by an optimized lifecycle formative assessment model to maximize students' intellectual gains.

Keywords: Formative assessment, Human Anatomy and Physiology Experiment, Pedagogical Reform, Pharmaceutical Education, Progressive Project-Based Learning.

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INTRODUCTION

"Human Anatomy and Physiology Experiment" represents a foundational cornerstone bridging basic medical sciences and advanced pharmaceutical applications in higher education.[1,2] Utilizing macroscopic specimens, digital histopathological sections, and live animal models, this lab-intensive curriculum systemically investigates physical morphology and functional homeostasis.[3,4] Through rigorous training, pharmaceutical undergraduates are expected to transition from static structural memorization to dynamic physiological reasoning, thereby establishing the vital competencies required for downstream courses such as Pharmacology, Biopharmaceutics, and Toxicology.

However, traditional laboratory pedagogy within pharmaceutical curricula increasingly faces severe frictions.[5,6] Amid modern curricular optimization, physical contact hours have been drastically compressed, yet the granular volume of anatomical nomenclature and abstract functional mechanisms remains immensely vast.[7-9] Under the Lecture-Based Learning (LBL) paradigm, students predominantly act as passive

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operators-mechanically following "cookbook" protocols to verify pre-established results.[10,11] This configuration produces severe cognitive overload, pre-class preview inertia, and a distinct theory-practice disconnect, failing to cultivate the critical thinking and scientific inquiry mandated by the New Medicine initiative.

To address these educational bottlenecks, Progressive Project-Based Learning (PPBL) has emerged as a strategic evolution of the classical PBL paradigm, providing step-by-step guidance that helps students transition from mastering basic lab techniques to designing independent experiments.[12-17] Although PBL has been widely used in the field of pharmaceutical education, empirical data on progressive project designs remain limited. Research by Zhan *et al.* at Anhui Medical University on integrated PBL combined with traditional lecturing showed that the experimental group significantly outperformed the control group in clinical skills and internal/external medicine, with over 80% of students reporting improvements in self-directed learning.[18] Lin *et al.* integrated PBL with multidisciplinary teams and flipped classrooms, finding that the experimental group achieved significantly higher scores in theoretical and skill assessments, alongside marked improvements in motivation, clinical reasoning, and classroom satisfaction.[19] However, these studies primarily focus on clinical medicine theory or skills. PPBL research specifically tailored for Human Anatomy and Physiology Experiment courses in pharmacy-related majors has yet to be conducted.

Previous studies indicated that pharmacy students frequently struggle with the abstract and complex nature of this course, highlighting an urgent demand for a more structured, progressive instructional system.[20-22] Furthermore, most current evaluations of teaching effectiveness are conducted from the perspective of instructors or institutions, with scant systematic analysis from the students' perspective regarding the internal correlations between learning engagement, process perception, assessment satisfaction, and learning outcomes. As the primary participants and beneficiaries of pedagogical reform, students' learning experiences, perceived difficulties, and reform demands are crucial for optimizing instructional design.[23] Given that students are the primary agents and direct beneficiaries of curricular innovations, a quantitative needs analysis from their perspective is paramount. Therefore, this study utilizes empirical data from 328 pharmacy students to assess the limitations of this course teaching and to provide guidance and suggestions for optimizing the PPBL framework.

MATERIALS AND METHODS

Participants and Sampling

This study employed a convenience sampling approach to recruit undergraduate and postgraduate students from a pharmaceutical university. Inclusion criteria targeted undergraduate and postgraduate students who had either completed or were currently enrolled in the Human Anatomy and Physiology Experiment course. Freshmen were rigorously excluded due to their incomplete exposure to the comprehensive curricular timeline. Responses with a total completion duration of less than 60 sec or those displaying clear logical inconsistencies were automatically purged. The final cleaned sample comprised 328 valid respondents (90.9% effective rate, Figure 1), consisting of 125 sophomores (38.1%), 140 juniors (42.7%), 22 seniors (6.7%), 29 Master's candidates (8.8%), and 12 Doctoral students (3.7%), with a balanced gender distribution of 149 males (45.4%) and 179 females (54.6%).

Course Design

The Human Anatomy and Physiology Experiment course was systematically restructured by integrating PPBL. This involved delineating specific instructional stages and designing progressive content across three distinct modules (Table 1). To improve the students' innovative practical abilities, the design adopts a modular three-tier "Basic experimental project → Comprehensive experimental project → Innovative experimental project" framework, leading to a seamless pedagogical pipeline from knowledge acquisition to innovative output. The Basic experimental project is tailored for novices and focuses on the mastery of fundamental experimental principles and core operational techniques. The "Comprehensive experimental project" requires students to synthesize disparate knowledge points, facilitating a cognitive leap from fragmented information to a systematic understanding of physiological systems. The Innovative experimental project is oriented toward cutting-edge scientific inquiries, which mandate the autonomous design of original experimental protocols. This course design effectively shifts the student's role from a passive operator to an active problem-solver.

Research and Data Analysis Methods

We developed the *Survey on Teaching Effectiveness of the Human Anatomy and Physiology Experiment Course*, which was based on a comprehensive literature review and preliminary group interviews of students (n=10). The process of this survey adhered to the AEE Survey Guidelines (Association for Evaluation in Education).[24] The process followed a multi-stage refinement: (1) Dimension Definition: Four pre-defined dimensions, including instructional content, pedagogical methods, assessment and evaluation, and learning outcomes, were established. (2) Expert Consultation: Six senior pharmaceutical education experts, comprising two course directors, two teaching supervisors, and two higher education researchers, conducted two rounds of content validity reviews via structured interviews. Based on their feedback, three ambiguous items were deleted, and two redundant items were merged (see Supplementary Material: Interview Outline). (3) Pilot Testing: A pilot study was conducted with 20 non-sample students to

identify cognitive biases in item interpretation. Phrasing was subsequently adjusted to ensure clarity.

The final instrument consisted of 28 closed-ended items and 2 open-ended items. The closed-ended portion was partitioned into: (i) Course Perception and Importance (3 items); (ii) Instructional Content and Curricular System (8 items); (iii) Pedagogical Modalities and Faculty Evaluation (9 items); and (iv) Assessment Methods and Self-rated Learning Outcomes (8 items). The open-ended section elicited qualitative feedback for curricular enhancement.

Reliability Analysis

The overall instrument demonstrated high internal consistency with a Cronbach's α of 0.912 (Table 2). The Cronbach's α coefficients for individual dimensions were 0.657 (Course Perception and Importance), 0.916 (Instructional Content and Curricular System), 0.611 (Pedagogical Modalities and Faculty Evaluation), and 0.864 (Assessment Methods and Learning Outcomes). All coefficients exceeded the threshold of 0.6, indicating acceptable reliability and robust internal consistency.

Structural Validity

The Kaiser-Meyer-Olkin (KMO) measure was 0.93, and Bartlett's Test of Sphericity reached significance ($p<0.001$), confirming suitability for factor analysis (Table 3). Exploratory Factor Analysis (EFA) extracted three factors, accounting for 68.7% of the total cumulative variance. Confirmatory Factor Analysis (CFA) yielded a less than satisfactory model fit: $\chi^2/df=4.06$, CFI=0.774, RMSEA=0.097, and SRMR=0.123. (CFI: Comparative Fit Index; RMSEA: Root Mean Square Error of Approximation; SRMR: Standardized Root Mean Square Residual.) The values fall below the conventional acceptance thresholds, indicating that the current factorial structure requires substantial refinement; hence, the following results should be interpreted with caution, and future studies are needed to revise the item allocation.

Data Collection

The survey was administered online via the Wenjuanxing platform using an anonymous and self-administered format. The landing page of the survey featured an Informed Consent Form, which explicitly outlined the research objectives, anonymity guarantees, data confidentiality protocols, the voluntary participation principle, and the right to withdraw at any stage. To mitigate potential bias, class counselors disseminated the survey link through official student communication channels (QQ and WeChat groups), emphasizing that the data would be used solely for aggregated academic research and would have no bearing on students' course grades.

The data collection period spanned 25 days (May 6 to June 19, 2024), during which two follow-up reminders were issued. To ensure data integrity, the platform was configured to restrict responses to one submission per device. A total of 361 responses were retrieved. Applying the pre-defined exclusionary criteria, 33 invalid questionnaires from freshmen were purged; no responses were excluded due to logical errors or insufficient completion time. This resulted in 328 valid samples, yielding an effective response rate of 90.9%.

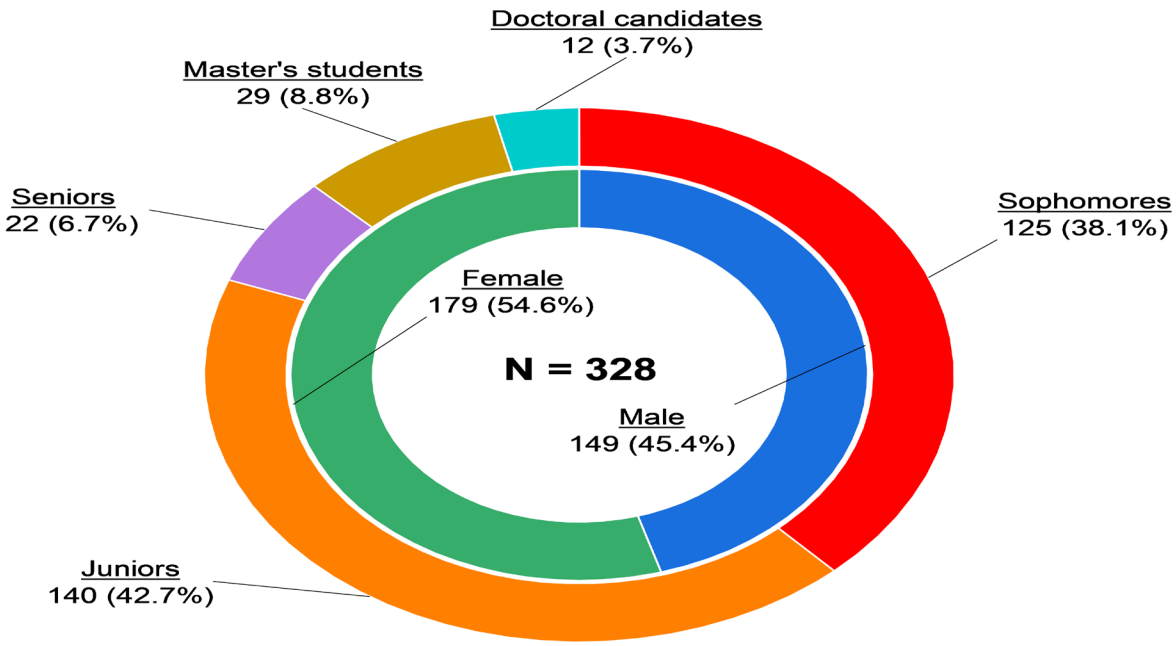


Figure 1: Demographic characteristics of the research subjects (*n*=328).

Table 1: The optimized three-tier curricular framework of PPBL with pharmacy-specific integration.

Items	Basic Experimental Project	Comprehensive Experimental Project	Innovative Experimental Project
Class hours	**14 hr**	**28 hr**	**6 hr**
Learning objectives	Master the basic experimental principles and fundamental experimental operation techniques; Cultivate an initial innovative awareness and ability to apply interdisciplinary knowledge.	Be capable of attempting to solve complex problems and integrating theory with practice; Possess the initial ability to discover, analyze, and solve problems.	Under the norms of professional ethics, apply professional basic knowledge and core abilities to the coordinated resolution and expansion innovation of complex problems, and possess scientific research thinking and innovation capabilities.
Core laboratory projects	Spinal cord reflex; Osmotic fragility of red blood cells; Physiological functions of insulin; Blood-brain barrier verification; Toad mesenteric microcirculation observation.	Influence of chemical substances on isolated toad hearts; Innervation of toad heart activity; Organization of excitatory observation; Rabbit neurohumoral regulation of blood pressure; Regulation of breathing exercises.	Design experimental items to detect the release of acetylcholine at the neuromuscular junction; Design a test project to explore the effects of stimulating the vagus nerve on inflammation; Design a project to explore the influences the body's metabolic changes of humoral factors.
Pedagogical modality	Digital video scaffolding + Traditional detailed on-site demonstration.	Sandwich Grouping Teaching Method + 3D-body spatial visualization.	Human-computer interactive virtual simulation + Quasi-scientific inquiry teams.

Table 2: Results of questionnaire reliability analysis.

Dimension	Items	Cronbach's α
Total Scale	28	0.912
Course Perception and Importance	3	0.657
Instructional Content and Curricular System	8	0.916
Pedagogical Modalities and Faculty Evaluation	9	0.611
Assessment Methods and Learning Outcomes	8	0.864

Statistical Analysis

Data cleaning and analysis were performed using SPSS version 24.0. Initially, descriptive statistics were employed to summarize demographic characteristics and scores across items and dimensions. Categorical variables are presented as frequencies and percentages (n,%), while continuous variables are reported as mean±standard deviation (M±SD).

Comparative analyses were conducted as follows: independent samples *t*-tests were utilized to evaluate gender-based differences, while one-way analysis of variance (ANOVA) was used for inter-grade comparisons. In cases of homogeneity of variance, the Least Significant Difference (LSD) method was applied for *post hoc* pairwise comparisons. Furthermore, Chi-square tests were executed to analyze the distribution of key categorical variables across different satisfaction groups. The statistical significance floor was uniformly set at two-tailed (α=0.05).

RESULTS

Quantitative Evaluation of Curricular Content and Systemic Bottlenecks

Students' assessments of the current instructional content and curricular system are detailed in Figure 2. Regarding teaching content, while most of the respondents acknowledged that the course was "topic-focused" (66.5%) and "aligned with professional characteristics" (62.1%), a notable gap was identified in its currency. Only 41.6% felt the curriculum "reflects the latest advancements in the field", with 58.4% identifying this as a critical area for improvement. In terms of systematicity, students generally affirmed the "logical flow" (59.8%), "comprehensiveness" (64.5%), and "conciseness" (57.9%) of the course.

Analysis of challenges students faced during class (multiple-choice) revealed that the primary challenge was "excessive and overly detailed content", making information retention difficult (51.2%). This was followed by a "lack of effective post-class review guidance" (45.7%) and "monotonous instructional delivery with insufficient course design" (35.2%). Additionally, students cited "textbook-based lecturing lacking engagement" (30.2%) and "inadequate pre-class preparation support" (28.5%) as significant hurdles.

Remarkably, when presented with the proposed scaffolded three-tier project architecture ("Basic → Comprehensive → Innovative"), the student body voiced an overwhelming endorsement, yielding a cumulative approval rate of 93.9% (41.5% "highly reasonable"; 52.4% "reasonable"). Regarding optimization priorities within this new framework, 35.5% of students demanded tighter synchronization with concurrent theoretical lectures, 29.1% requested direct integration with clinical/practical applications, and 26.6% advocated for interdisciplinary convergence, such as the blending of Pharmacy and Artificial Intelligence (AI).

Evaluation of Pedagogical Modalities

Students' assessments of instructional methods and faculty performance are summarized in Table 4. A significant disparity was observed in learning engagement outside the classroom. Regarding pre-class preparation, only 18.6% of students "frequently" engaged in previewing, while 58.5% "never" or only "occasionally" did so, with "skimming textbooks" (73.8%) remaining the predominant method. After-class consolidation followed a similar pattern: 26.3% of respondents reported no follow-up study, while 37.1% utilized video resources for review. The most formidable challenge identified was the "vast and intricate nature of the knowledge system" (55.1%).

In terms of instructional efficacy, Field Practice was endorsed by 58.5% of students-far outpacing detailed demonstrations (25.8%). Reactions to collaborative learning were polarized: 45.2% believed it played a Substantial role, whereas 19.9% dismissed it as Mere formality. Conversely, attitudes toward classroom questioning were broadly positive (72.2%). Faculty evaluations remained high, with over 70% of students praising instructors for their ability to stimulate interest and participation (70.4%) and overall teaching excellence (74.2%).

Regarding the preferred modalities within the PPBL framework, students showed a clear preference for a blended approach. Traditional faculty-led lecturing remained the top choice (52.6%), followed by a growing interest in Teaching Assistant (TA)-assisted instruction by postgraduates (37.4%) and AI-augmented learning (31.9%). Other preferences included flipped classrooms (21.6%) and academic seminars/lectures (16.6%).

Evaluation of Assessment and Grading Modalities

Students' feedback on the current assessment framework is studied (Figure 3). Regarding perceived difficulty, only 28.8% of respondents categorized the assessment as "simple", while the vast majority (71.2%) rated it as "average" or "not simple". The framework received favorable scores for its structural integrity: 55.6% of students affirmed the "richness of assessment indicators", 63.7% viewed the metrics as "objective", and 70.4% regarded the overall system as "fair and equitable". Despite this general satisfaction with fairness, qualitative feedback from the open-ended section highlighted a critical area for reform. Numerous students expressed concerns that "The proportion of final exam scores is too high". They advocated for a strategic recalibration of the grading system, specifically recommending an increased weighting for formative assessments, such as experiment reports and consistent classroom performance.

Learning Outcomes and Overall Satisfaction

Students' self-assessment of learning objective attainment is detailed in Table 5. For Objective 1 (Foundational Knowledge), 65.7% of respondents scored themselves above 70, with 33.0% exceeding 80. For Objective 2 (Scientific Reasoning and Technical Skills), these figures rose to 67.9% and 36.3%, respectively. Notably, for Objective 3 (Reflective Inquiry, Innovation, and Ethics), 72.9% scored above 70, and 41.1% exceeded 80. This pattern suggests that self-perceived attainment of higher-order objectives may have exceeded that of foundational knowledge.

The overall course evaluation was positive: 84.0% of students assigned a score above 70, while 57.6% rated it above 80, placing the average satisfaction within the "Good" range. Regarding competency enhancement (multiple-choice), students primarily reported improvements in "manual dexterity and animal experimentation skills" (74.2%) and "breadth of knowledge and practical application" (68.4%). Conversely, the primary barriers to achieving expected outcomes included the "abstract and

Table 3: Results of the validity test of the Questionnaire structure.

Validity type	Index	Results	Requirements
Construct Validity	KMO[a]	0.93	>0.70
	Bartlett's Test of Sphericity	<0.001	<0.05
	Cumulative Variance Explained Rate	68.70%	≥60%
	Factor Loading	>0.50	≥0.40
Confirmatory Factor Analysis (CFA)	χ^2/df	4.06	<3.00
	CFI[b]	0.774	≥0.90
	RMSEA[c]	0.097	<0.08
	SRMR[d]	0.123	<0.08

[a]KMO: Kaiser-Meyer-Olkin; [b]CFI: Comparative Fit Index; [c]RMSEA: Root Mean Square Error of Approximation; [d]SRMR: Standardized Root Mean Square Residual.

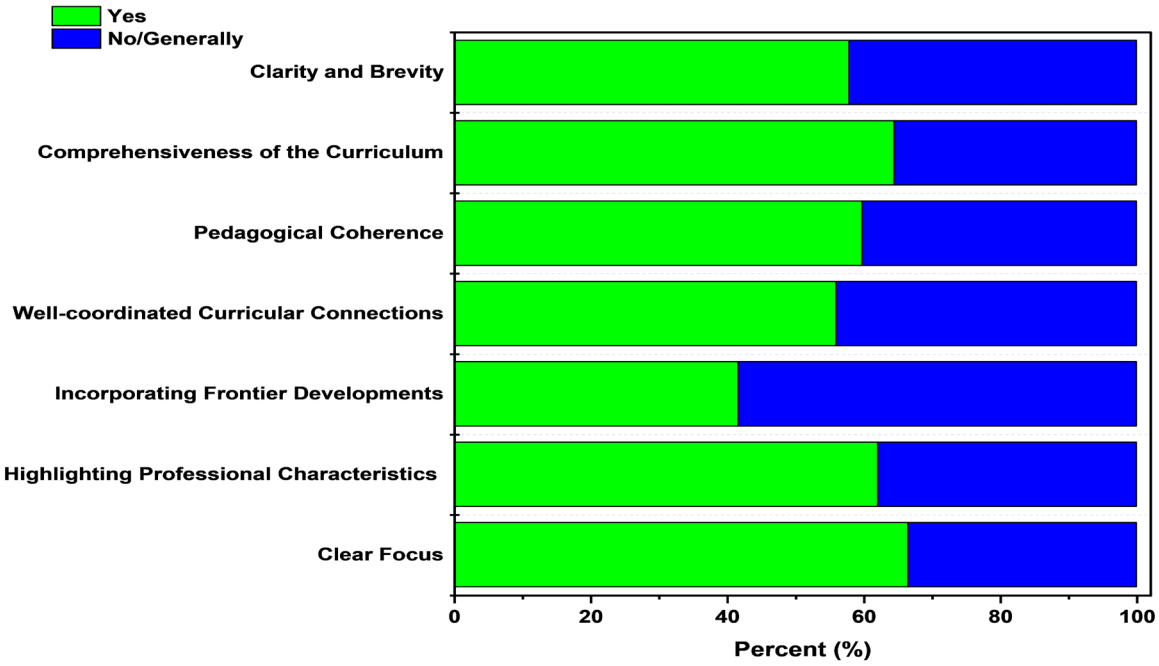


Figure 2: Evaluation of the curriculum system content.

Table 4: Descriptive proportions of pedagogical modalities and faculty appraisals (*n*=328).

Index Dimension	Category	Percent (%)
Pre-class Preview Frequency	Frequently	18.6
	Never/Occasionally	58.5
Post-class Review Mechanisms	Complete Absence of Follow-up Study	26.3
	Digital Video Resource Consumption	37.1
Primary Cognitive Barrier	Vast and Intricate Nomenclature/Knowledge Network	55.1
Most Effective Delivery Modality	On-site Clinical/Field Practice	58.5
Collaborative Group Dynamics	Substantial/High-utility Role	45.2
	Mere formality	19.9

cumbersome nature of the content" (52.1%), followed by a lack of "effective learning strategies" (45.2%) and "disciplined study habits" (44.9%). Additionally, 41.8% of students cited "limited contact hours and a rapid instructional pace" as significant constraints.

As illustrated in Table 6, students' intrinsic interest (3.87±0.85) and cognition of importance (3.91±0.82) of the course were above average, while perceived difficulty (3.28±0.94) leaned toward the challenging end of the spectrum. The converted overall evaluation score was 3.68±0.96 (approximately 80 on a 100-point scale), consistent with the earlier finding that 84.0% of students scored the course above 70. Significantly, the 93.9% approval rating for the PPBL framework underscores robust student support for the transition toward a progressive, project-based curriculum.

Comparative Analysis of Demographic Differences Across Dimensions

To investigate the influence of demographic characteristics on course perception, instructional satisfaction, and learning outcomes, independent samples *t*-tests and one-way ANOVA were conducted to assess gender-based and grade-based differences, respectively. For dimensions showing homogeneity of variance, the Least Significant Difference (LSD) method was utilized for *post hoc* pairwise comparisons. Dimension scores are presented as M±SD (Table 7).

The results revealed statistically significant inter-grade differences in assessment evaluation (F=3.00, p=0.019) and overall course satisfaction (F=3.18, p=0.014). *post hoc* comparisons indicated a progressive upward trend in assessment scores associated with higher grade levels: seniors (2.65±0.36) scored significantly higher than both sophomores (2.34±0.51) and juniors (2.50±0.47), while juniors significantly outperformed sophomores (p<0.05). A mirrored trend was observed in overall course satisfaction, where senior scores (4.00±0.76) significantly exceeded those of sophomores (3.39±1.22) and juniors (3.79±0.99), with juniors scoring significantly higher than sophomores (p<0.05). Although differences in course cognition (p=0.095), evaluation of teaching content (p=0.109), and self-assessment of learning outcomes (p=0.068) did not reach statistical significance, they consistently exhibited a gradual ascent across grade levels. Notably, gender had no significant influence across any dimensions (p>0.05).

These findings suggested that senior students harbor a more positive appraisal of the assessment framework and overall curriculum. This elevation in satisfaction may be ascribed to their subsequent exposure to advanced courses such as Pharmacology and Toxicology, which likely elucidated the foundational utility of Human Anatomy and Physiology Experiment in the broader pharmaceutical context. Furthermore, while the rise in self-rated learning outcomes was not statistically significant, the numerical progression-from sophomores (2.96) to juniors (3.26) and culminating in seniors (3.47)-suggests a steady accumulation of "perceived gains" throughout the academic trajectory. The absence of gender-based variance implies that future pedagogical reforms do not require gender-specific differentiation.

Analysis of Factors Influencing Overall Course Satisfaction

To identify the critical determinants of student satisfaction, respondents were categorized into a High Satisfaction group (scores > 80, n=194, 59%) and a Low Satisfaction group (scores<80, n=134, 41%). Chi-square tests were performed to compare the distribution of key variables between these two cohorts (Table 8). The results indicated that the perception of "content congestion" was significantly lower in the high satisfaction group (43.2%) compared to the low satisfaction group (55.2%) (χ^2 = 4.05, p=0.044), identifying content overload as a primary deterrent to student satisfaction. Furthermore, self-rated learning attainment emerged as the core predictor of satisfaction: 47.4% of the high satisfaction group reported high attainment (scores ≥ 80), a stark contrast to only 4.5% in the low satisfaction group (χ^2 = 67.73, p<0.001).

Table 5: Student self-assessment of multi-tier learning objective attainment (n=328).

Curricular Target Dimension	Perceived Score	
	≥70 (%)	≥80 (%)
Objective 1: Foundational Knowledge	65.7	33.0
Objective 2: Scientific Reasoning and Technical Skills	67.9	36.3
Objective 3: Reflective Inquiry, Innovation, and Ethics	72.9	41.1

Table 6: Statistics on students' cognition and satisfaction with the course (n=328).

Items	Scoring method	Results
Course Interest (Q4, Levels 1-5)	Mean±SD	3.87±0.85
Course Importance (Q5, Levels 1-5)	Mean±SD	3.91±0.82
Course difficulty (Q6, Levels 1-5)	Mean±SD	3.28±0.94
Overall course evaluation score (Q28, converted grades 1-5)	Mean±SD	3.68±0.96
Evaluation of PPBL (Q30)	Highly Reasonable	136 (41.5%)
	Fairly Reasonable	172 (52.4%)
	Unreasonable	20 (6.1%)

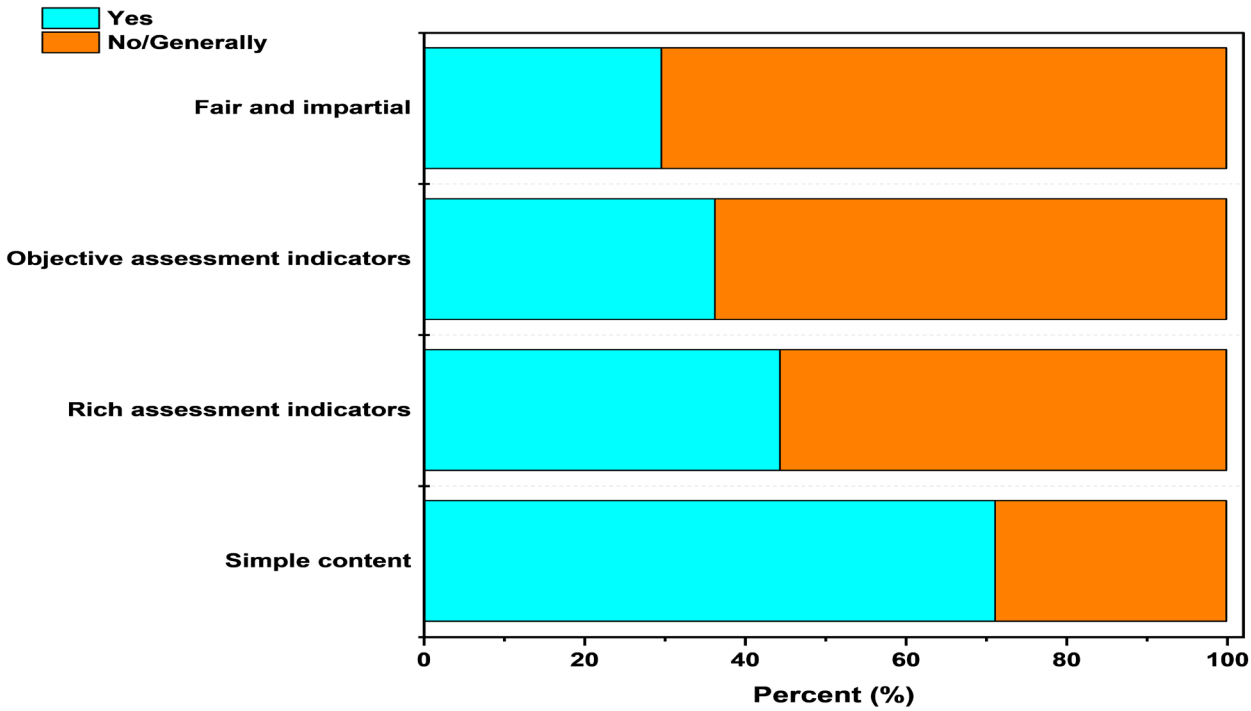


Figure 3: Evaluation of the assessment system (n=328).

Table 7: Comparison of the differences in scores of different grades and genders in each dimension.

Dimension	Grade (M±SD)					*F*	*p*	Posterior Comparisons	Gender (M±SD)		*t*	*p*
	Sophomores (*n*=125)	Juniors (*n*=140)	Seniors (*n*=22)	Master's Students (*n*=29)	Doctoral candidates (*n*=12)				Male (*n*=149)	Female (*n*=179)		
Course cognition	2.85±0.74	2.95±0.73	3.18±0.80	2.72±0.71	3.21±0.75	1.99	0.0952	Sophomores< Seniors< Master's	2.92±0.82	2.91±0.68	0.08	0.936
Evaluation of teaching content	2.44±0.57	2.59±0.44	2.62±0.50	2.43±0.62	2.62±0.48	1.91	0.1086	Sophomores < Juniors	2.49±0.57	2.54±0.48	-0.94	0.348
Evaluation of the assessment	2.34±0.51	2.50±0.47	2.65±0.36	2.52±0.60	2.50±0.44	3.00	0.0186	Sophomores < Juniors	2.46±0.52	2.45±0.49	0.23	0.816
Self-assessment of learning outcomes	2.96±1.08	3.26±0.95	3.47±0.8	3.07±0.81	3.06±1.05	2.21	0.0680	Sophomores < Juniors	3.23±1.11	3.07±0.90	1.44	0.152
Overall course satisfaction	3.39±1.22	3.79±0.99	4.00±0.76	3.52±0.83	3.75±0.97	3.18	0.0139	Sophomores < Juniors < Seniors	3.65±1.18	3.61±1.00	0.30	0.767

Table 8: Comparison of the distribution of key variables among different satisfaction groups.

Items	Sort	High Satisfaction (*n*=194)	Low satisfaction (*n*=134)	χ^2	*p*
Complex and diverse content	Yes	84 (43.2%)	74 (55.2%)	4.05	0.044
	No	110 (56.8%)	60 (44.8%)		
Lack of review guidance after class	Yes	87 (44.8%)	58 (43.3%)	0.027	0.868
	No	107 (55.2%)	76 (56.7%)		
Recognition of PPBL	Yes	187 (96.4%)	121 (90.3%)	4.13	0.042
	No	7(3.6%)	13 (9.7%)		
Self-assessment of learning outcomes	High (score ≥80)	92 (47.4%)	6 (4.5%)	67.73	<0.001
	Low (score <80)	102 (52.6%)	128 (95.5%)		
Field practice preference	Yes	126 (64.9%)	71 (53.0%)	4.24	0.039
	No	68 (35.1%)	63 (47.0%)		

Regarding the PPBL framework, the approval rate was significantly higher among the high satisfaction cohort (96.4%) than the low satisfaction cohort (90.3%) (χ^2=4.13, p=0.04). This suggests that while the progressive project system enjoys broad consensus, this endorsement is positively and significantly correlated with overall course appraisal. Conversely, the "lack of post-class review guidance" showed no significant inter-group difference (p>0.05), indicating it is a common concern rather than a pivotal variable distinguishing satisfaction levels. Finally, a significant difference was observed in "Field practice preference" (p=0.039), with the high satisfaction group showing a stronger inclination toward practical sessions (64.9%). This implies that even satisfied students harbor a robust expectation for increased hands-on opportunities to augment their learning.

DISCUSSION

Optimizing the Progressive Curriculum to Address Content Overload and Competency Gaps

Our empirical results identify "vast, granular, and congested knowledge systems" as the foremost obstacle for 55.1% of pharmaceutical undergraduates. Interestingly, the self-rated attainment of higher-order objectives (Objective 3: 72.9%) paradoxically surpassed that of foundational knowledge (Objective 1: 65.7%), indicating that while students possess a strong self-perception of their innovative thinking, their mastery of systematic fundamental knowledge remains relatively fragile. This discrepancy highlights a critical structural flaw in traditional medical laboratory organization within engineering institutions, leading to a state where students "learn extensively but remember fragmentarily and struggle to apply".

To bridge this theory-practice gap, the curriculum would benefit from systematic restructuring and iterative refinement into a three-tier modular framework of "Novice Exploration → Intermediate Inquiry → Advanced Challenge". The Basic Stage (14 hr) must prioritize single-variable verification experiments (such as spinal cord reflexes, erythrocyte osmotic fragility) to eliminate cognitive friction and solidify basic operational skills. The Comprehensive Stage (28 hr) should introduce integrated multi-variable experiments, specifically the neuro-humoral regulation of rabbit blood pressure. This requires students to horizontally synthesize physiology (baroreceptor reflexes) and pharmacology (receptor agonists/antagonists), facilitating a cognitive leap from fragmented data to systemic comprehension. The Innovative Stage (6 hr) must break traditional medical boundaries by infusing New Medicine and engineering elements. For instance, exploring the vagus nerve's impact on inflammatory responses mandates that students autonomously formulate hypotheses, utilize multi-channel signal acquisition systems, and establish neuro-immune interactions.

Given that the perception of "content congestion" significantly eroded student satisfaction (χ^2=4.05, p=0.044), stripping away redundant morphological lecturing and integrating AI-driven digital models must be prioritized as a core strategic reform objective.

It should be noted that the upward trend in satisfaction among senior students may be subject to alternative interpretations. While we attribute this to students' growing appreciation of the course's foundational value through subsequent advanced coursework, another equally plausible explanation is learned adaptation.[25] Students gradually become accustomed to the course's assessment format and teaching style over time. These two interpretations have different implications for curriculum reform: the former supports strengthening the course's foundational positioning, while the latter suggests a need for enhanced adaptive support for junior students. The cross-sectional design of this study does not allow us to determine the relative contribution of these two mechanisms. Future research employing longitudinal designs could track the same cohort across multiple time points to clarify the driving factors behind this observed trend, and qualitative interviews could further illuminate how senior students perceive the course's value.

Adopting On-site Practice via Sandwich Modality to Overcome Engagement Deficits

Our data reveals a stark contrast in student behavior: while only 18.6% regularly engage in pre-class preparation, 58.5% identify on-site practice as the most effective learning modality. This pronounced preference exposes a fundamental flaw in the prevailing lecture-driven paradigm, where the students' aspiration to transition from passive recipients to active practitioners remains unfulfilled. Chi-square analysis further confirms that a preference for on-site practice is significantly associated with overall satisfaction (p=0.039), underscoring that the availability of hands-on opportunities is a decisive determinant of student appraisal.

To resolve pre-class inertia and post-class guidance voids (cited by 45.7% of respondents), we propose an integrated, practice-centered instructional pipeline spanning the "Pre-class scaffolding → In-class sandwich flipping → Post-class digital extension" continuum.

Pre-class (Scaffolding Independence): To support the 28.5% of students reporting a lack of initial guidance, teachers should deploy 3D-body anatomical software and brief procedural

Table 9: The Operationalized Lifecycle Formative Assessment Matrix.

Evaluation Type	Specific Assessment Indicator	Measurement Tool and Criteria
Formative Evaluation (Process-oriented)	Attendance and Lab Professional Ethics	Attendance logs, laboratory safety compliance, and standard operating protocol adherence.
	Pre-class Online Video Mastery and Quizzes	Automated platform metrics (viewing duration, micro-quiz accuracy)
	Virtual Simulation and Human-Computer Interaction	Virtual platform logs capturing trial-and-error dissection performance and correction pathways
	In-class Sandwich Peer Tutoring and Presentation	Rubrics assessing communication clarity, model demonstration logic, and peer-to-peer evaluation.
	In vivo Animal Hand-on Operation Proficiency	Real-time instructor checklists monitoring surgical skill dexterity, tissue isolation precision, and signal stability.
	Intra-group Contribution and Collaboration	Anonymous peer-review scales mitigating the "free-rider" effect in project teams.
Summative Evaluation (Outcome-oriented)	Comprehensive Cloud Experimental Reports	Evaluation of scientific reasoning, data visualization, and depth of discussion regarding biological mechanisms.
	Terminal Practical Blind-Draw Operational Exam	Randomly drawn surgical or anatomical tasks evaluated on a rigorous itemized rubric under strict time constraints.

videos coupled with online formative micro-quizzes. Providing structured "key-question lists" can effectively dismantle the ambiguity that breeds preview inertia.

In-class (The Sandwich Modality): The laboratory session must be activated through the German Sandwich teaching method combined with screen-broadcasting technology. Instead of watching a crowded teacher demonstration, simple and discrete anatomical modules are assigned to student sub-groups. Through cross-group rotation and peer-tutoring, each student takes turns serving as a peer instructor to explain structures using physical models. This format directly leverages interactive inquiry, which was highly endorsed by 72.2% of our respondents.

Post-class (Consolidating Perceived Gains): Addressing the deficit in post-class support, we advocate for the deployment of intelligent cloud-based bio-signal analysis systems. Experimental waveforms can be automatically uploaded to generate paperless cloud reports, enabling instructors to provide tailored, data-driven feedback and dynamic error tracking.

Notably, 52.6% of students who had experienced PPBL still preferred lecture-based instruction, yet 93.9% simultaneously endorsed the PPBL framework. These findings are not contradictory-the former reflects a learning style preference, while the latter signals support for systemic reform. More importantly, this does not invalidate PPBL, and it clarifies its implementation logic. The three-tier "Basic→Comprehensive→I nnovative" framework follows a gradual release model: students receive intensive instructor support at the basic stage, building competence before progressively transitioning to independent inquiry. Thus, students' lecture preference should be interpreted not as resistance to reform, but as a demand for structured guidance in the early learning phases-precisely what the PPBL framework is designed to provide.

Establishing a Lifecycle Scientific Assessment Mechanism to Address Formative Evaluation Demands

The survey findings present a compelling contrast: while only 28.8% of students considered the assessment content "simple", qualitative feedback revealed widespread criticism of the excessive weighting of the final examination. Given that 70.4% of respondents affirmed the fairness of the system, this data uncovers a nuanced demand-students do not contest the objectivity of the evaluation, but rather the "high-stakes" design where a single exam determines the outcome. Chi-square analysis reinforces this, showing that self-rated learning attainment is the most potent predictor of satisfaction (χ^2=67.73, p<0.001). This statistically validates the core pedagogical philosophy that perceived student gains drive satisfaction. Consequently, the PPBL model necessitates a lifecycle assessment framework. The specific evaluation system is detailed in Table 9.

By implementing this comprehensive "Experimental Instructional Portfolio", the grading mechanism transitions from an anxiety-inducing hurdle into a scientific diagnostic tool.[26] This matrix ensures that student effort, collaborative agility, and higher-order critical thinking are dynamically quantified, successfully driving long-term retention and satisfying the rigorous talent-cultivation standards of modern pharmaceutical higher education.

LIMITATIONS

Despite the insights gained, several limitations of this study warrant acknowledgement. First, the cross-sectional design restricted our ability to establish definitive causal relationships between variables, offering only correlational evidence. Future research should employ quasi-experimental designs-such as incorporating control groups and pre-test/post-test comparisons-to rigorously validate the interventional efficacy and underlying mechanisms of the PPBL model. Second, the data relied on student self-reports. Although measures were taken to ensure anonymity and decouple the survey from academic performance, the results may still be subject to social desirability bias. To address this, future investigations will aim to triangulate data from multiple sources, including objective performance scores from experiments and faculty evaluations. By establishing a tripartite evaluation framework-integrating self-assessment, peer/faculty review, and objective performance metrics-we can achieve a more comprehensive and objective appraisal of pedagogical reforms.

CONCLUSION

From a student-centric evaluative perspective, this study executed a systematic needs analysis of the Human Anatomy and Physiology Experiment course within higher pharmaceutical education. Our quantitative findings demonstrate that students face profound cognitive frictions, specifically rooted in structural content congestion (51.2%), a lack of standardized pre-through-post class support structures, and an inequitable high-stakes final examination weight. Proportional comparisons via Chi-Square testing confirmed that while content overload severely damages course satisfaction, high self-rated learning attainment operates as the single most robust predictor of positive course evaluation, proving that cultivating a distinct sense of student gain is more fundamental than the mere rearranging of textbooks.

The overwhelming 93.9% student approval rate for the proposed "Basic-Comprehensive-Innovative" modular project architecture delivers a powerful empirical mandate for a thorough pedagogical overhaul. The significant upward satisfaction trend observed among seniors further reinforces the course's vital "pioneering value" when retrospectively mirrored against advanced pharmacology sub-disciplines. In summary, this study maps a transferable optimization pathway for physiology and medical

laboratories, successfully harmonizing digital visualization, virtual trial-and-error simulation, and sandwich-driven active engagement to cultivate medical and pharmaceutical talents.

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ABBREVIATIONS

AI: Artificial Intelligence; **ANOVA:** Analysis of Variance; **CFA:** Confirmatory Factor Analysis; **CFI:** Comparative Fit Index; **EFA:** Exploratory Factor Analysis; **KMO:** Kaiser-Meyer-Olkin; **LBL:** Lecture-Based Learning; **LSD:** Least Significant Difference; **PPBL:** Progressive Project-Based Learning; **RMSEA:** Root Mean Square Error of Approximation; **SRMR:** Standardized Root Mean Square Residual; **TA:** Teaching Assistant.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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AUTHORS CONTRIBUTION

J.C.: Conceptualization, Methodology, Data Curation, Funding Acquisition, Writing - Original Draft, Writing - Review and Editing. **B.L.:** Data Curation, Writing - Original Draft. **J.F.:** Formal Analysis, Writing - Original Draft. **T.L.:** Investigation, Writing - Original Draft. **J.T.:** Supervision, Writing - Original Draft, Writing - Review and Editing. **P.W.:** Supervision, Writing - Original Draft, Writing - Review and Editing. All authors approved the final manuscript.

ETHICAL APPROVAL

Students voluntarily participate in the survey and research. The studies involving human participants were reviewed and approved by the Ethics Committee of China Pharmaceutical University (2024042610). The participants provided their written informed consent to participate in this study.

DATA AVAILABILITY STATEMENT

The data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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