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Original research article

Evaluating the impact of blended learning in clinical pharmacology among medical and allied health undergraduates: a cross-sectional study

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ABSTRACT

Objective: This study evaluated the effectiveness of a blended learning model in teaching clinical pharmacology to undergraduate healthcare students, including those from medical and allied health disciplines. The study assessed the model's impact on their career development and examined its effects on academic performance, knowledge retention, practical application of pharmacological concepts, career aspirations, and clinical practice readiness.

Methods: A cross-sectional survey was conducted from April 10 to May 20, 2024, in China. Undergraduate healthcare students who completed a clinical pharmacology course via blended learning participated. Data were collected using an online questionnaire through "Questionnaire Star". Out of 513 collected questionnaires, 330 valid responses were analyzed using IBM SPSS Statistics and Python for descriptive statistics, correlation, regression, and cluster analyses.

Results: The blended learning model significantly enhanced student engagement and knowledge acquisition. The Flipped Classroom was the most frequently used method (average frequency 0.75), followed by Face-to-Face Teaching (0.71) and Online MOOC Learning (0.68). Both male and female students reported similar knowledge impact (4.08±0.93 for males, 4.00±0.90 for females). Clinical Medicine students reported the highest satisfaction (4.44±0.66). Regression analysis identified Online MOOC Learning (0.260) and Face-to-Face Teaching (0.201) as significant predictors of knowledge acquisition. Cluster analysis revealed three distinct student groups with varying satisfaction and perceived effectiveness.

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Conclusion: The blended learning model effectively enhances academic performance, knowledge retention, and professional skills among undergraduate medical and allied health students. A balanced integration of online and offline components maximizes learning outcomes. Tailored approaches are needed for different disciplines. Future research should focus on longitudinal studies to assess the long-term impact on career development.

Keywords: blended learning, clinical pharmacology, medical education, career development, undergraduate students

1. Introduction

The rapid advancement of educational technology has transformed teaching methodologies across various disciplines. In medical education, the integration of e- learning components with traditional face- to- face instruction, known as blended learning, offers a promising approach to enhance student engagement and learning outcomes.[1] Clinical pharmacology, a critical subject for medical students, demands an effective teaching strategy to ensure comprehension and application of complex concepts. The necessity for effective pedagogical methods in medical education has never been more pressing, given the complexity and volume of information that students must master.[2]

Blended learning combines online and face- to- face educational methods and is gaining traction in medical education for its potential to enhance learning outcomes and engagement among students. This educational model seeks to harness the best of both worlds: the flexibility and accessibility of online learning, and the interaction and immediacy of traditional classroom settings.[3] By doing so, it aims to address some of the limitations inherent in each approach when used in isolation.[4]

Several studies have demonstrated the potential benefits of blended learning in medical education. For instance, Juhi et al. compared blended learning with traditional methods in teaching clinical examination skills and found significantly higher OSCE scores among students who experienced blended learning. This suggests that blended learning can lead to better academic performance in practical, hands- on skills essential for medical practice.[5]

Specific studies on pharmacology education indicate that blended learning can address the unique challenges faced by medical students in understanding complex pharmacological concepts. Rosenbaum et al. implemented a blended learning course for postgraduate dental students, emphasizing the benefits of flexibility, reinforced learning, and professional application.[6] Similarly, Fang Hui's study on blended learning in clinical pharmacology demonstrated improved exam performance and higher student satisfaction compared to traditional teaching methods.[7] These findings are critical, as they highlight the potential for blended learning to not only enhance understanding but also to improve student satisfaction and engagement, which are crucial for effective learning.

Effective blended learning requires a well- structured approach that balances online and face- to- face interactions. Morton et al. highlighted that structured blended learning modules, particularly in neuropharmacology, can significantly enhance student engagement and satisfaction.[8] This structured approach ensures that students are not overwhelmed by the online components and can integrate their learning effectively. Furthermore, Feng Si-qi proposed using the OBE (Outcome- Based Education) approach combined with Rain Classroom to transform passive learning into active learning, thereby improving student engagement and learning outcomes.[9] This integration of technology and pedagogy appears to be a promising direction for the future of medical education.

This study aims to evaluate the effectiveness of a blended learning model in teaching clinical pharmacology to undergraduate healthcare students and to assess its impact on their career development and professional growth. Specifically, the primary objective is to assess the impact of blended learning on clinical pharmacology outcomes among undergraduate healthcare students, including academic performance, knowledge retention, and practical application of pharmacological concepts. The secondary objective is to evaluate the influence of blended learning on the career development and professional growth of healthcare undergraduates, examining changes in career aspirations, perceived readiness for clinical practice, and overall professional development.

2. Methods

2.1 Study design and setting

This cross- sectional survey study aimed to evaluate the impact of blended learning on clinical pharmacology outcomes and career development among undergraduate healthcare students. The data collection was conducted from April 10 to May 20, 2024, across several provinces in China, including Sichuan, Guizhou, Chongqing, Shaanxi, Yunnan, Guangdong, and Jiangsu. The study was designed to comprehensively assess the effectiveness of blended learning in enhancing students' academic performance and its influence on their career trajectories. A quantitative research design was employed, utilizing an online questionnaire tool to collect data systematically and efficiently.

2.2 Participants and data collection

The target population for this study comprised undergraduate healthcare students who had completed a course in clinical pharmacology through a blended learning model. While the study mainly targeted undergraduate healthcare students, students from pharmacy, public health, and biomedical engineering were included due to their overlap in pharmacological education, enabling a broader evaluation of the blended learning model's effectiveness. Inclusion criteria included students enrolled in medical degree programs and those who had completed the clinical pharmacology course within the past academic year, as well as those who provided informed consent to participate in the survey. Participants were selected from multiple medical schools across several provinces in China to ensure a diverse and representative sample. Exclusion criteria involved students who had not completed the clinical pharmacology course and those with incomplete or inconsistent survey responses.

Responses were valid if completed in over five minutes and if participants correctly answered two embedded logical questions. These criteria were pre-set and communicated at the start to ensure data reliability.

Data collection involved the administration of a structured questionnaire, which was distributed electronically via the "Questionnaire Star" platform, a well-known online questionnaire tool in China. The questionnaire, titled "An Investigation into the Impact of Innovative Blended Teaching Models on Undergraduate Clinical Pharmacology Learning Outcomes and Career Development in Pharmaceutical Majors", was designed based on a thorough literature review and expert consultations to ensure its relevance and comprehensiveness. It included sections on basic demographic information, experiences with blended learning, and career planning and development. Questions were formulated using Likert scales to assess various dimensions of learning outcomes and career development.

A pilot study was initially conducted with 30 participants to refine the questionnaire and enhance its reliability and validity. This preliminary phase was instrumental in improving the survey design and ensuring the quality of the research instrument. The final survey was disseminated broadly, with an emphasis on ensuring voluntary participation and informed consent. Participants were required to provide written informed consent

before proceeding with the survey, which detailed the study's objectives and assured confidentiality.

2.3 Sample size determination

The sample size was calculated using the formula: $z^2 \times p \times (1-p) / d^2$, where 'z' represents the z-score for a 95% confidence level (1.96), 'p' is the estimated proportion of an attribute in the population (set at 0.5 due to lack of prior data), and 'd' is the margin of error (typically set at 0.07). This resulted in an initial target of 196 samples. To ensure data integrity, responses were required to be unique (verified by IP addresses), valid if the completion time exceeded 5 minutes, and correctly answered two logical questions. A total of 513 original questionnaires were collected. After excluding 183 invalid responses, 330 valid questionnaires were retained for analysis.

2.4 Data analysis

Data preprocessing and analysis were conducted using IBM SPSS Statistics for Windows, version 22.0, and Python for Windows, version 3.10. Descriptive statistics were used to summarize the demographics of the participants, including means and standard deviations to determine central tendencies and variability. Advanced inferential techniques, such as Analysis of Variance (ANOVA), regression analysis, and K-Means Clustering, were applied to identify significant patterns and predictive relationships. Principal Component Analysis (PCA) was employed to reduce the dimensionality of complex datasets, aiding in clearer interpretation of results. Correlation analysis was conducted to explore relationships between different variables related to learning outcomes and career development. Visual methods, including Heatmap Analysis, were used to represent correlations among various data points effectively. All analyses were conducted under a two-tailed test with a significance level set at a P-value of less than 0.05.

3. Results

3.1 Comprehensive descriptive statistics and usage of teaching methods

The survey sample includes more female respondents (177, 53.64%) than male respondents (153, 46.36%). Juniors form the largest group (116, 35.15%), followed by sophomores (74, 22.42%), seniors (59, 17.88%), freshmen (44, 13.33%), and fifth-year students (37, 11.21%). Clinical Medicine is the most common major (159 students, 48.18%), with significant representation from Anesthesiology (72 students, 21.82%). Pharmacy (21 students, 6.36%), Public Health (5 students, 1.52%), and Biomedical Engineering (1 student, 0.30%) are less represented. The participants' ages ranged from 18 to 25 years, with a mean of 21.3 and a standard deviation of 1.2 years. The age distribution was uniform, with no significant deviations across groups. Regarding the adoption of a blended teaching model, 67.14% reported its adoption, 3.76% reported non-adoption, and 29.11% were unsure. Initially, 513 questionnaires were collected, but after excluding "No" and "Not sure" responses (183 total), the analysis was based on the remaining valid responses (The study focuses on analyzing the blended learning group). The usage frequency of teaching methods within the blended model shows the Flipped Classroom as the most used method (average frequency 0.75), followed by Face-to-Face Teaching (0.71) and Online MOOC Learning (0.68). One-on-One Tutoring is the least used method (0.25). Table 1 provides valuable insights into the demographic characteristics of the survey sample and highlights the varying usage frequencies of different teaching strategies within the blended teaching model (*Findings related to the single Biomedical Engineering student should be interpreted with caution due to the small sample size, which limits the generalizability of these results*).

3.2 Impact of the blended teaching model on student outcomes by gender, academic year, and major

This analysis examines the impact of the blended teaching model on students' knowledge acquisition, overall satisfaction, online resource helpfulness, and offline activity effectiveness, segmented by gender, academic year, and major. Female students reported average scores of 4.00±0.90 for knowledge impact, 4.33±0.77 for overall satisfaction, 4.34±0.78 for online resource helpfulness, and 4.23±0.83 for offline activity effectiveness. Male students had slightly higher averages in some areas, with scores of 4.08±0.93 for knowledge impact, 4.31±0.72 for overall satisfaction, 4.35±0.79 for online resource helpfulness, and 4.33±0.78 for offline activity effectiveness. Junior students recorded the highest scores in most categories, while Fifth Year students showed lower knowledge impact but higher overall satisfaction, aligning more with their academic and career goals. Clinical Medicine students had the highest scores among majors, with an overall satisfaction score of 4.44±0.66, indicating strong support for the blended learning approach. In contrast, Biomedical Engineering students exhibited unique, potentially outlier scores, suggesting variability in how the model is perceived across disciplines. All scores are reported as mean ± standard deviation (SD). Statistical analysis found no significant differences by gender or academic year, but significant differences in overall satisfaction among majors, highlighting the need for tailored approaches to maximize the blended model's effectiveness.

Satisfaction scores were calculated using a Likert scale from 1 (very dissatisfied) to 5 (very satisfied), with the total satisfaction for each group reflecting the sum of individual responses. In Fig. 1b, the bars represent male and female participants by academic year, while the dashed lines show total satisfaction scores for each gender. The right y- axis reflects the total satisfaction score, allowing for a comparison between male and female students across academic years (Fig. 1a, 1b).

3.3 Key correlations between blended teaching model factors and learning outcomes

The correlation analysis between factors of the blended teaching model and learning outcomes among clinical pharmacology students reveals significant associations. A moderate positive correlation (0.615) exists between students' perception of the model's impact on their knowledge and skills and their overall satisfaction, suggesting that a perceived positive impact on knowledge leads to higher satisfaction. Additionally, the correlation between knowledge impact and the helpfulness of online resources is also 0.615, indicating that students who find online resources helpful perceive significant knowledge gains. The effectiveness of offline activities shows a correlation of 0.552 with knowledge impact, highlighting that effective offline activities are associated with positive knowledge impacts. There is a strong positive correlation (0.854) between overall satisfaction and the helpfulness of online resources, and a strong correlation (0.803) between overall satisfaction and the effectiveness of offline activities, implying that helpful online resources and effective offline activities significantly contribute to satisfaction. Furthermore, the strong correlation (0.809) between the helpfulness of online resources and the effectiveness of offline activities suggests that students who find online resources helpful also perceive offline activities as effective. These findings underscore the crucial role of both online resources and offline activities in enhancing student satisfaction and knowledge gains, leading to better learning outcomes (Fig. 2).

3.4 Regression coefficients for predicting impact on knowledge

Fig. 3 illustrates the regression coefficients for various teaching methods employed in the blended teaching model predicting their impact on students' knowledge. The coefficients for "Online MOOC Learning"

(0.260) and "Face-to-Face Teaching" (0.201) are statistically significant, suggesting a positive impact on students' knowledge acquisition. In contrast, other methods such as "Group Discussion", "Live Video Teaching", "Educational Technology Tools", "One-on-One Tutoring", and "Social Media Forums" did not demonstrate significant effects. These findings highlight the critical role of both online and face-to-face components in enhancing knowledge acquisition within the blended teaching model.

3.5 Impact analysis of innovative blended teaching models on knowledge grasp and career interest

This study evaluated the impact of various teaching methods within an innovative blended teaching model on students' grasp of clinical pharmacology knowledge (Knowledge Grasp) and their interest in pursuing a medical career (Career Interest) through regression analysis. The Knowledge Grasp model had an R-squared value of 0.037 and an adjusted R-squared value of 0.016, with significant predictors being online MOOC learning (coefficient = 0.1865, p-value = 0.088) and live video teaching (coefficient = 0.2336, p-value = 0.053). The Career Interest model had an R-squared value of 0.049 and an adjusted R-squared value of 0.028, with live video teaching as the only significant predictor (coefficient = 0.2621, p-value = 0.009). These findings suggest that online MOOC learning and live video teaching positively impact both students' knowledge grasp and career interest. Other teaching methods, such as face-to-face teaching and group discussion, did not show statistically significant effects. Further development of online MOOC content and live video teaching is recommended to enhance learning outcomes and career interest. The relatively low R-squared values indicate other factors may also play significant roles, warranting further investigation (Fig. 4).

3.6 Clustering analysis of student feedback on blended teaching models

The cluster analysis identified three distinct clusters based on students' responses to survey questions related to the blended teaching model. Cluster 0 comprises students who exhibited moderate reactions to the blended teaching model. They rated their total score (mean score = 62.35), the helpfulness of online learning resources (mean score = 3.64), the effectiveness of offline practical activities (mean score = 3.51), and the overall improvement in learning efficiency (mean score = 3.48) moderately. Cluster 1 includes students with more negative feedback, with considerably lower ratings across all metrics: total score (mean score = 51.53), helpfulness of online learning resources (mean score = 2.80), effectiveness of offline practical activities (mean score = 3.17), and the overall improvement in learning efficiency (mean score = 3.14). Cluster 2 consists of students who exhibited very positive reactions to the blended teaching model. They rated their total score (mean score = 74.56), the helpfulness of online learning resources (mean score = 4.30), the effectiveness of offline practical activities (mean score = 4.09), and the overall improvement in learning efficiency (mean score = 4.06) very highly. This clustering reveals diverse student experiences and perceptions regarding the blended teaching model. Cluster 0 indicates a group with moderate satisfaction with all aspects of the model, Cluster 1 highlights a group with significant dissatisfaction, and Cluster 2 shows high satisfaction. These insights can guide targeted improvements in teaching methods and resources to better cater to the varying needs of different student groups (Fig. 5).

3.7 Factor analysis: unveiling the underlying mechanisms in student responses

Factor analysis was conducted to identify the underlying relationships among variables, extract common factors, simplify the data structure, and reveal potential mechanisms of influence. Using survey data from items related to professional skills

(Question 15) and clinical pharmacology applications (Question 17), we performed a principal component analysis (PCA) followed by Varimax rotation to clarify the factor structure. Bartlett's test for sphericity yielded a Chi-square value of 1933.67 with a P-value of 0.0, indicating that the data were suitable for factor analysis. The analysis extracted two factors that explained the variance in student responses. Factor 1 (in navy) primarily captures loadings related to "Professional Knowledge and Self- directed Learning", including items like "Application of Professional Knowledge" and "Self- learning". Factor 2 (in dark orange) encompasses loadings related to "Communication and Coordination Skills", with significant contributions from items such as "Communication Skills" and "Critical Thinking". Through Fig. 6, educators can identify the key factors influencing student learning and adjust their teaching strategies accordingly. For example, they can focus on enhancing self- directed learning and professional knowledge, or improving communication and critical thinking skills based on factor performance. This analysis highlights the strengths and areas for improvement in the blended teaching model, helping educators tailor their approaches to better meet student needs and improve educational outcomes.

3.8 The Influence of Blended Teaching Methods on Academic and Career Success

Fig. 7 illustrates the relationship between blended teaching methods, learning outcomes, and career development. The blue markers and regression line represent the effect of blended teaching methods on learning outcomes, showing a positive trend that suggests increased implementation of blended teaching methods is associated with improved learning outcomes. Conversely, the green markers and regression line depict the relationship between learning outcomes and career development. Although a positive trend is observed, it is less pronounced than the relationship between blended teaching methods and learning outcomes. This indicates that while blended teaching significantly enhances learning outcomes, the translation of these improvements into career development is less direct and may be influenced by additional factors. Therefore, educational institutions should not only focus on innovative teaching methods but also provide comprehensive support to help students leverage their academic success into career advancements.

4. Discussion

4.1 Enhancing student engagement and knowledge acquisition through diverse blended learning methods

The findings of this study underscore the significant impact of the blended learning model on enhancing student engagement and knowledge acquisition in clinical pharmacology. The high frequency of usage of the Flipped Classroom, Face- to- Face Teaching, and Online MOOC Learning methods highlights the effectiveness of these approaches in creating interactive and engaging learning environments.[10] These methods cater to different learning styles and promote active participation, which is essential for mastering complex pharmacological concepts. The widespread adoption of these methods across various schools reflects a positive shift towards integrating technology with traditional teaching practices, aligning with global trends in medical education. This comprehensive approach ensures that students receive a well- rounded education that combines theoretical knowledge with practical application.[11-12]

4.2 Evaluating the broad applicability of blended learning across gender and academic years

The impact of the blended teaching model was found to be broadly applicable across different demographics, including gender and academic year. Both male and female students reported similar levels of knowledge acquisition, overall satisfaction, and the helpfulness of online resources.[13] This finding suggests that the blended learning approach is effective irrespective of

gender, providing an inclusive educational experience. Furthermore, the consistency of results across different academic years indicates that the benefits of blended learning are sustained throughout the medical education journey.[14] However, the significant differences observed among different majors highlight the need for tailored approaches to maximize the benefits for specific fields of study. Customizing educational strategies to address the unique challenges and requirements of each discipline can enhance the overall effectiveness of the blended teaching model.[15]

4.3 The critical role of balanced integration between online and offline learning components

The correlation analysis underscores the importance of balanced integration between online and offline components in the blended teaching model. The strong positive correlations between the helpfulness of online resources, the effectiveness of offline activities, and overall student satisfaction emphasize the need for a well-rounded approach.[16-17] Effective offline activities such as practical sessions and interactive discussions are crucial for reinforcing theoretical knowledge and enhancing practical skills. Meanwhile, high-quality online resources provide flexibility and accessibility, enabling students to learn at their own pace. This balanced integration ensures that students benefit from the strengths of both online and offline learning, leading to improved educational outcomes and greater satisfaction.[18]

4.4 Identifying key predictors of academic success in blended learning environments

Regression analysis identified Online MOOC Learning and Face-to-Face Teaching as significant predictors of knowledge acquisition. These findings highlight the critical role of these methods in enhancing students' understanding of clinical pharmacology.[19] The positive impact of Live Video Teaching on career interest suggests that dynamic and engaging video content can inspire students to pursue careers in related fields.[20] This indicates that while various teaching methods contribute to learning, certain approaches have a more pronounced impact on specific outcomes. Educational institutions should prioritize these effective methods to maximize knowledge acquisition and career development. Additionally, continuous improvement of online MOOC content and interactive face-to-face sessions can further enhance the learning experience.[21-22]

4.5 Addressing diverse needs and preferences through tailored blended learning approaches

Cluster analysis revealed diverse student experiences and perceptions regarding the blended teaching model. Three distinct clusters were identified: students with moderate satisfaction, those with significant dissatisfaction, and those with high satisfaction.[23] This diversity suggests that while the blended learning model is broadly effective, its implementation may need to be adjusted to cater to the specific preferences and needs of different student groups. Tailoring the approach based on feedback from distinct student clusters can enhance the overall effectiveness of the model.[24] By addressing the unique challenges and leveraging the strengths identified by different student groups, educators can optimize the blended learning experience for all students. This targeted approach ensures that all students, regardless of their background or learning style, can benefit from the blended teaching model.[25]

4.6 Linking blended learning methods to improved academic and career success

The scatter plot analysis illustrating the relationships between blended teaching methods, learning outcomes, and career development revealed that increased implementation of blended teaching methods is associated with improved learning outcomes.[26] The positive trend between these variables suggests that the blended learning model significantly enhances academic success. However, the less pronounced relationship between learning outcomes and career development indicates that while blended learning improves academic

performance, its translation into career success is influenced by additional factors.[27] This finding emphasizes the need for educational institutions to provide comprehensive support that helps students leverage their academic achievements into career advancements. By focusing on both academic and professional development, educators can ensure that students are well- prepared for their future careers.[28]

Table 1. Descriptive Statistics of Survey Sample with Proportions.

Category	Count / Percentage	Proportion (%)
Gender Distribution		
Male	153	46.36
Female	177	53.64
Year Distribution		
Freshman	44	13.33
Sophomore	74	22.42
Junior	116	35.15
Senior	59	17.88
Fifth Year	37	11.21
Major Distribution		
Clinical Medicine	159	48.18
Anesthesiology	72	21.82
Pharmacy	21	6.36
Public Health	5	1.52
Biomedical Engineering	1	0.30
Other (General Medicine, Optometry and Ophthalmology Medicine, Pediatrics, and Clinical Pharmacy, etc.)	72	21.82
Blended Model Implementation		
Yes	330	64.33
No	19	3.70
Not sure	164	31.97
Average Usage Frequency of Teaching Methods		
Online MOOC Learning	0.68	67.88
Flipped Classroom	0.75	74.85
Face-to-Face Teaching	0.71	71.21
Group Discussion	0.73	73.03
Live Video Teaching	0.45	44.55
Educational Technology Tools	0.49	48.79
One-on-One Tutoring	0.25	24.55
Social Media and Forums	0.35	35.45

4.7 Limitations and directions for future research

While this study provides valuable insights into the impact of blended learning on clinical pharmacology education, several limitations must be acknowledged. The cross- sectional design limits the ability to infer causality, and the reliance on self-reported data may introduce response bias. Additionally, the focus on a single academic

year may not capture the long-term effects of blended learning on career development. Future research should consider longitudinal designs to assess the sustained impact of blended learning over time. Incorporating qualitative methods such as interviews and focus groups could also provide deeper insights into students' experiences and perceptions, complementing the quantitative findings. Furthermore, exploring the effectiveness of blended learning across different educational contexts and disciplines can help generalize the findings and inform best practices in medical education.

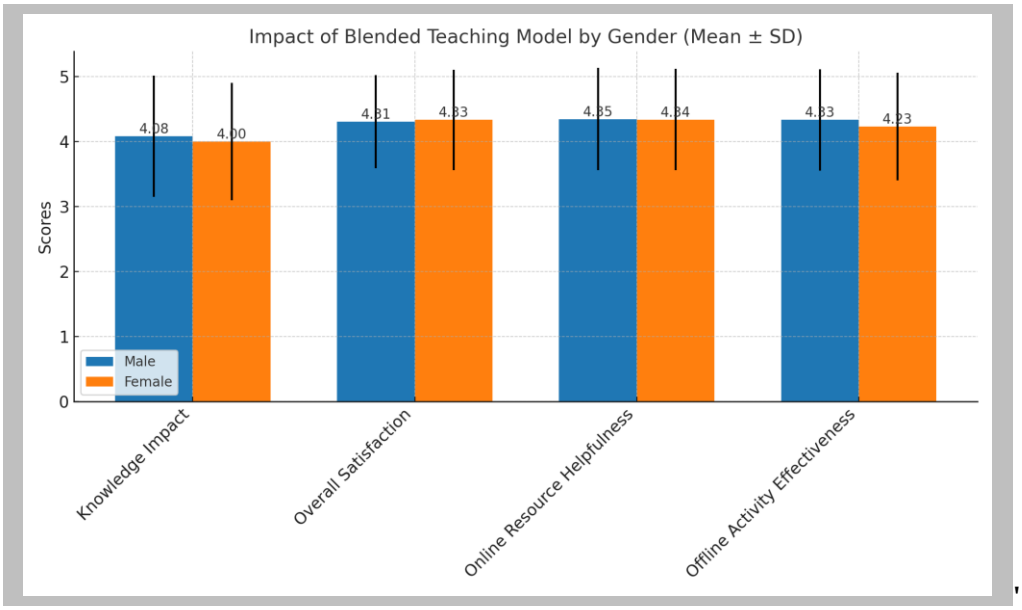

Fig. 1a. Impact of the blended teaching model on knowledge acquisition, satisfaction, and resource effectiveness by gender.

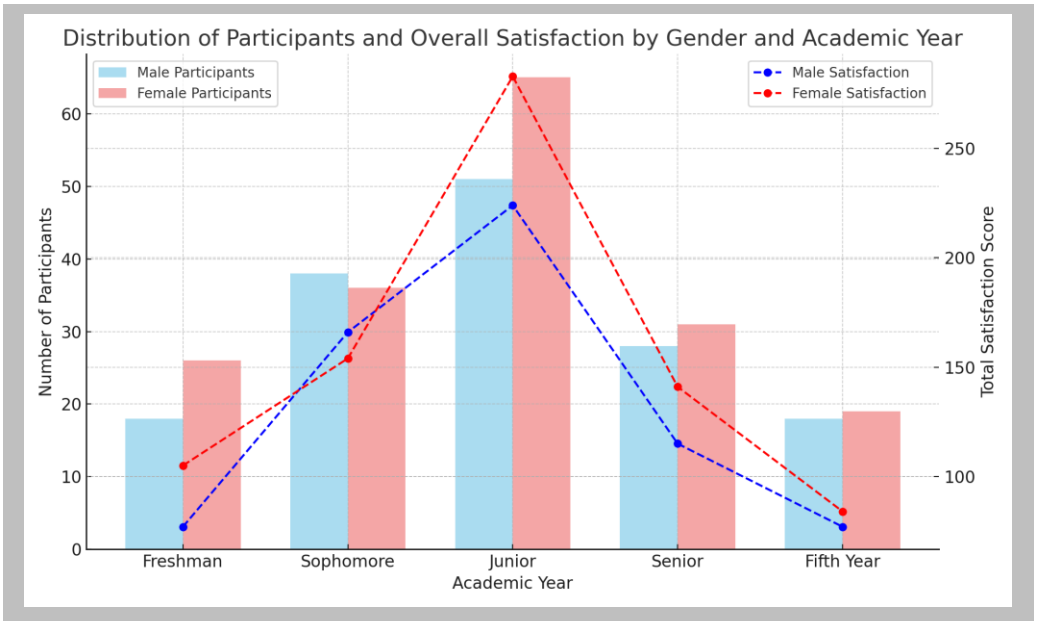

Fig. 1b. Gender and academic year distribution of participants in the blended teaching model study.

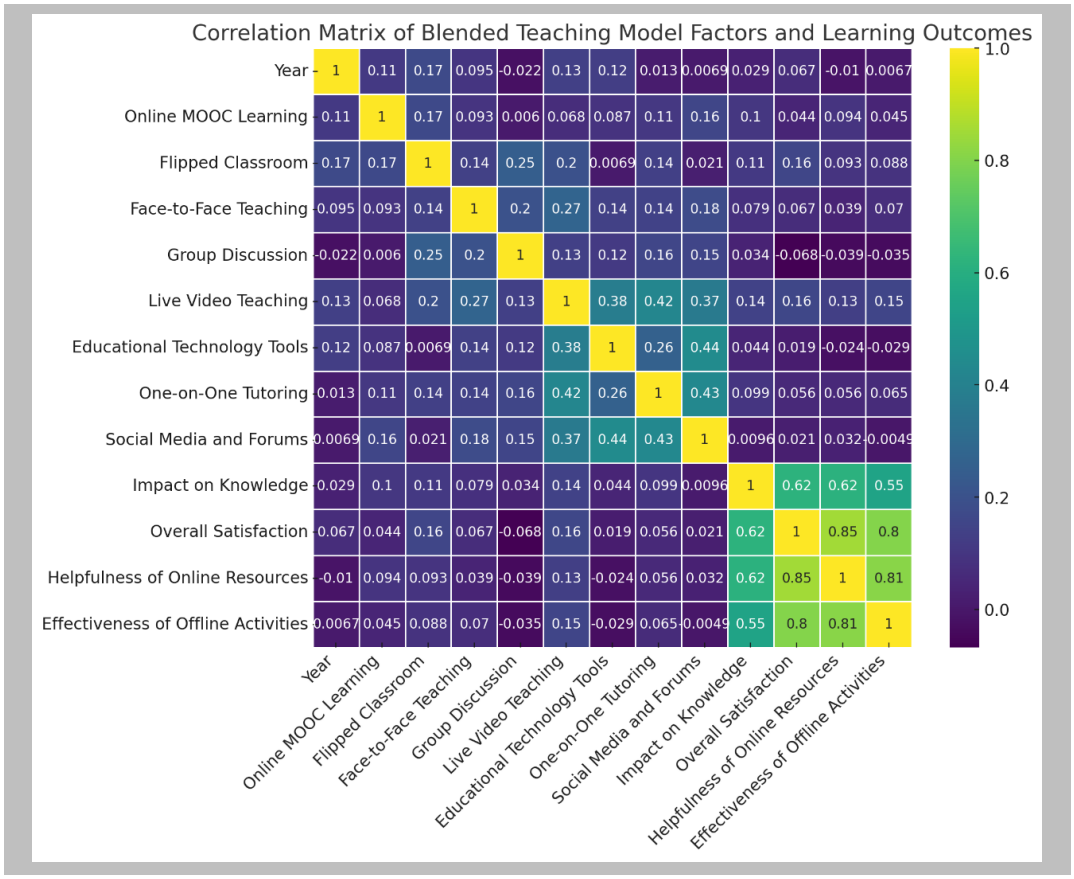

Fig. 2. Correlation matrix of blended teaching model factors and learning outcomes.

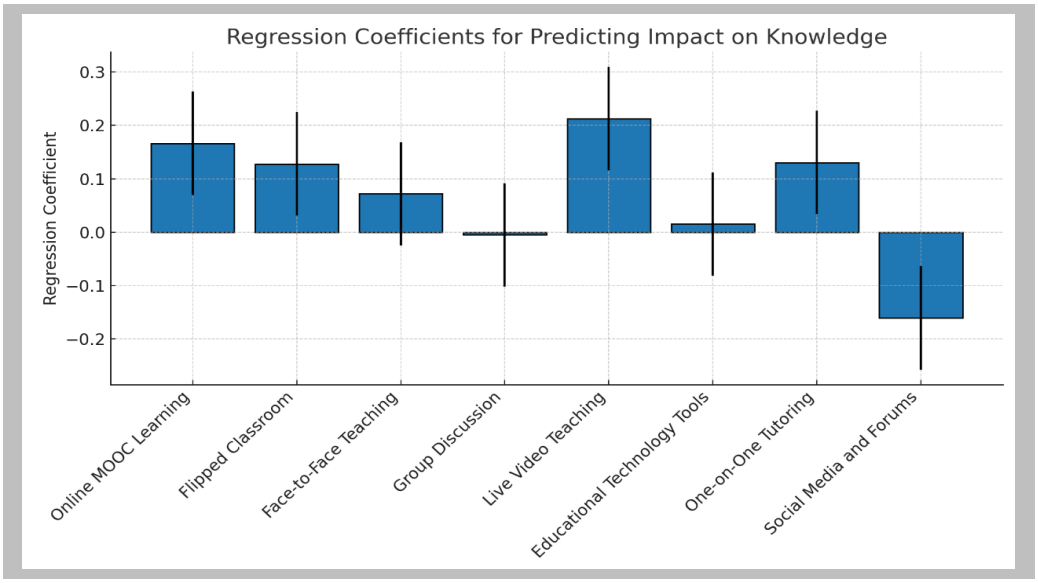

Fig. 3. Regression coefficients of teaching methods on knowledge impact.

(Note: The error bars indicate the 95% confidence intervals for each coefficient).

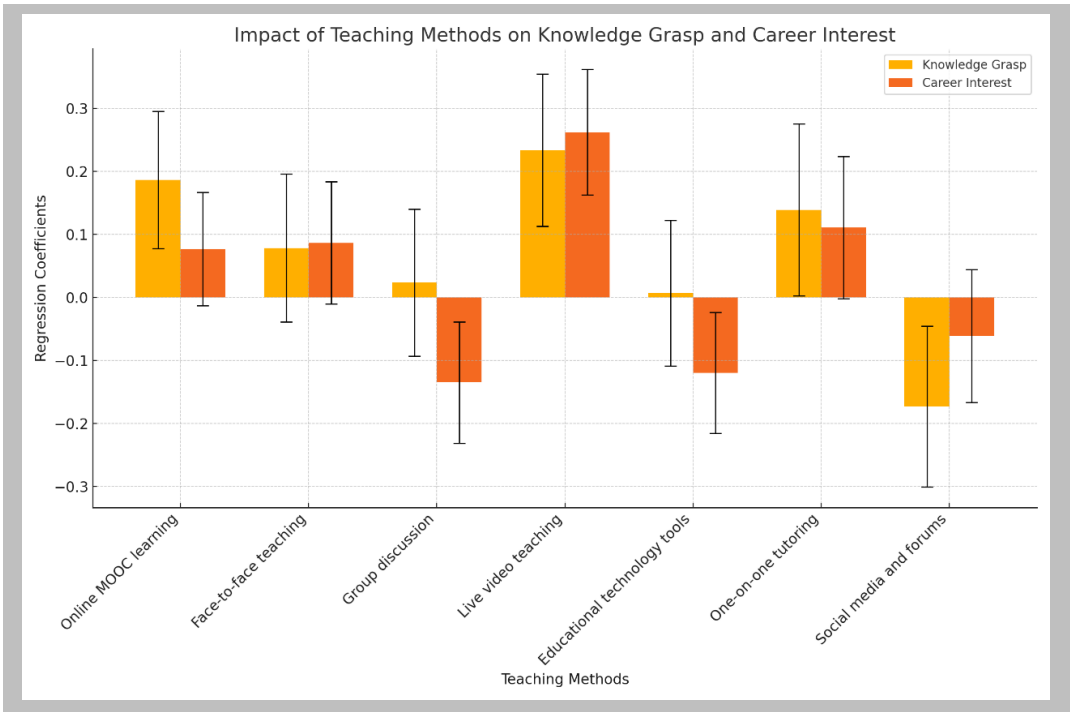

Fig. 4. Regression coefficients of teaching methods for predictors of knowledge grasp and career interest.

(Note: The error bars indicate the 95% confidence intervals for each coefficient)

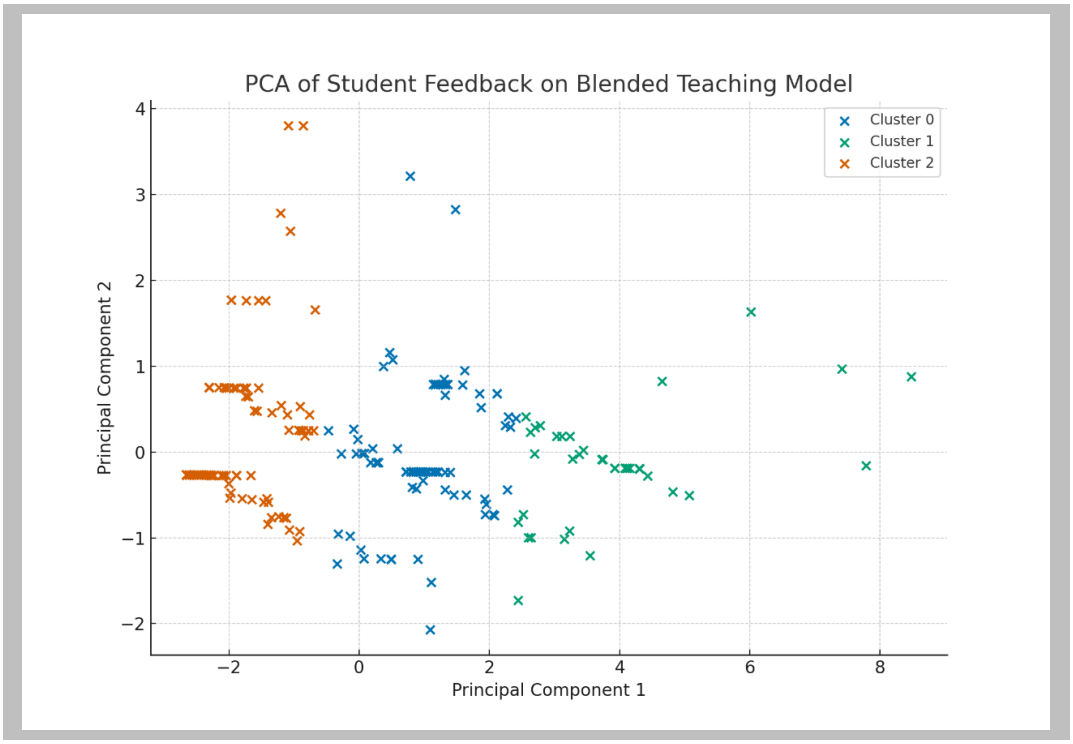

Fig. 5. PCA of student feedback on blended teaching model.

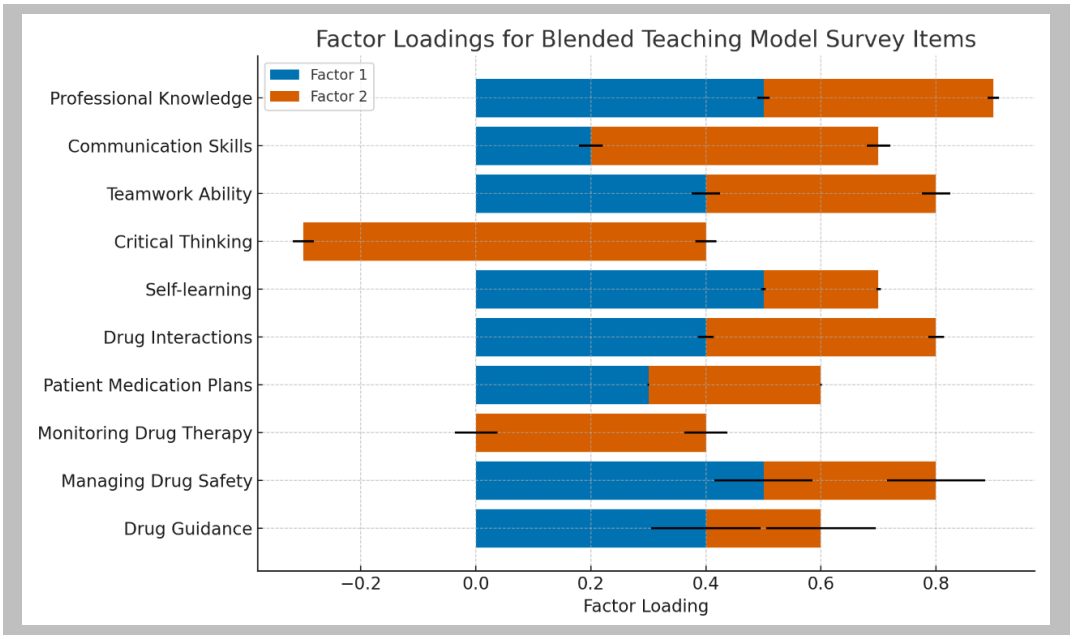

Fig. 6. Factor loadings for blended teaching model survey items.

(*Note*: The error bars indicate the standard errors (SE) for each factor loading)

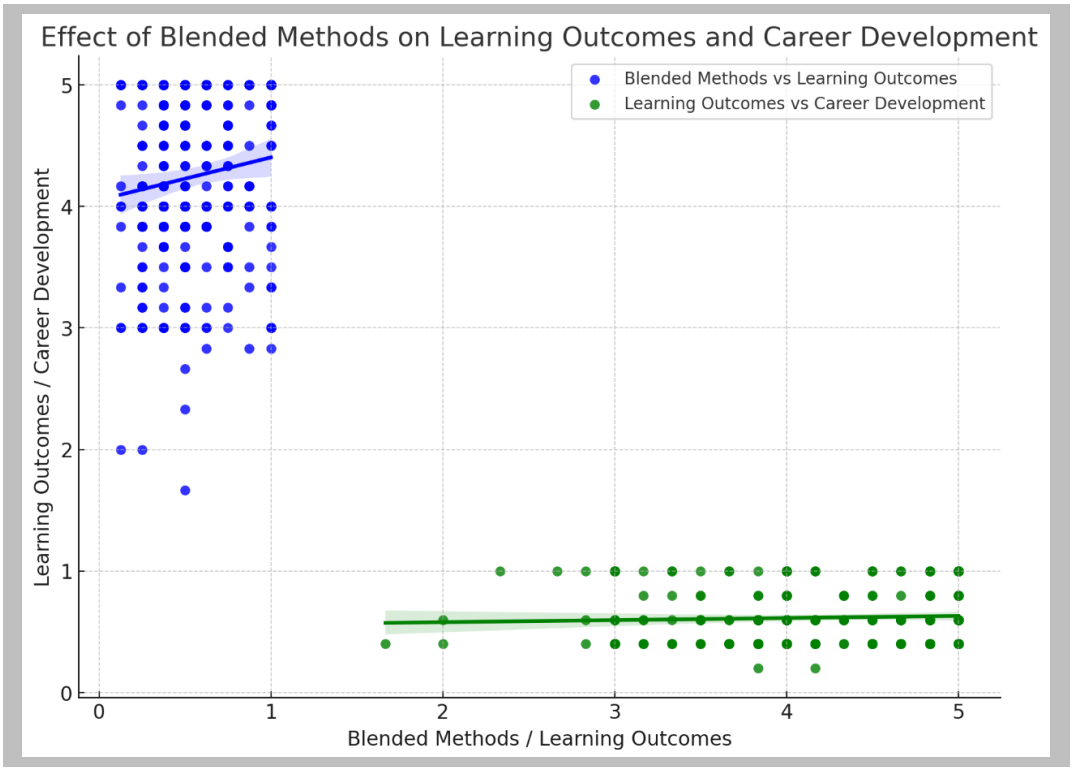

Fig. 7. Combined analysis of blended teaching methods on learning outcomes and career development.

5. Conclusion

This study provides compelling evidence of the positive impact of blended learning on clinical pharmacology education and career development among undergraduate healthcare students. The findings highlight the importance of a well-balanced approach that integrates both online and offline components to enhance learning outcomes and student satisfaction. While there are challenges to address, the overall benefits of blended learning make it a valuable pedagogical strategy in medical education. Future research should continue to explore and refine this approach to maximize its potential and support the professional growth of healthcare students.

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Conflicts of Interest

The authors affirm that there are no conflicts of interest associated with this publication. This research was conducted adhering to the highest standards of integrity and objectivity, ensuring an impartial and accurate representation of the results.

Author Contributions

Beibei Ye (B.Y.) and Lanjie Huang (L.H.) conceptualized and designed the study. Keyi Peng (K.P.) and Yang Liu (Y.L.) performed data curation and drafted the initial manuscript. Xin Chen (X.C.) contributed to visualization and investigation, while Bingliang Li (B.L.) and Ji Li (J.L.) handled software and validation. Jian Yang (J.Y.) and Ji Li (J.L.) provided supervision. All authors reviewed and edited the manuscript and approved the final version for submission.

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Ethical Considerations

This study was approved by the Institutional Review Board (IRB) of Kunming Medical University (Approval No. 20240117), granted on March 15, 2024. Conducted in line with the Declaration of Helsinki, the study involved anonymous surveys without interventions or sensitive data, qualifying for ethical review exemption. Participation was voluntary, informed consent was obtained, and no personal identifiers were collected, ensuring anonymity and confidentiality.

Questionnaire Availability

The questionnaire was designed through literature review and expert consultations to ensure relevance and comprehensiveness. It is not publicly available but can be provided upon request for research purposes.

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