

Research on the Interaction Mechanism of Presence Elements and Optimization Strategies in Blended Learning from the Perspective of Community of Inquiry

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Abstract: This research employs the Community of Inquiry theory to investigate the interactions among Social Presence (SP), Teaching Presence (TP), and Cognitive Presence (CP) in blended learning environments. The objective is to elucidate their causal and mediating effects and to offer guidance for the optimization of relevant strategies. A quantitative research design was implemented. A survey was conducted among vocational college students, resulting in 517 valid questionnaires. Subsequently, a Structural Equation Model was utilized to analyze the relationships among the variables. The research findings indicate that TP has a direct positive impact on SP, and SP exerts a positive influence on CP. Moreover, SP partially mediates the relationship between TP and CP, thereby uncovering dynamic interaction paths. However, this study has certain limitations. The sample is restricted to vocational students, which limits the generalizability of the results. Additionally, other potential influencing factors were not taken into account. The implications of this research suggest that educators should enhance TP through the design of instructional guidance and improve SP by creating interactive learning atmospheres to promote CP. This study enriches the application of the Community of Inquiry theory in vocational education, clarifies the empirical causal relationships, and provides targeted strategies for enhancing the quality of blended learning.

Keywords: Blended Learning, Community of Inquiry, Presence Elements, Teaching Optimization.

1. Introduction

Blended learning, which combines online digital resources' convenience and offline classroom interactions' depth, has become a core direction in higher education reform. This model offers significant advantages in enhancing teaching flexibility and expanding learning scenarios. However, in practice, most institutions' blended learning designs only achieve a superficial integration of "online resource accumulation + offline traditional lectures." Without systematic theoretical framework guidance, issues like insufficient alignment between teaching objectives and presence elements and disconnection in online-offline interaction design have emerged. These problems cause significant variations in teaching effectiveness among courses and institutions, making it hard to fully realize blended learning's potential value.

As an important theory explaining deep-learning mechanism, the Community of Inquiry theory identifies Social Presence (SP), Teaching Presence (TP), and Cognitive Presence (CP) as the three core elements of building a collaborative learning community. Teaching Presence ensures teaching guidance effectiveness, Social Presence strengthens learning community interaction quality, and Cognitive Presence reflects deep-learning achievement.

However, existing studies mostly focus on single presence elements. No systematic conclusions have been formed about the dynamic relationships, influence paths, and effect intensities of the three elements in the “online-offline” dual scenarios of blended learning. There are still theoretical gaps in the interaction mechanism between elements.

Based on this, this study focuses on vocational education, an educational scenario centered on practical ability cultivation. Aiming at the learning characteristics of vocational college students and the practical needs of blended learning, it analyzes the internal connections of the three presence elements via quantitative research methods, reveals their dynamic interaction paths accurately, and finally offers solid theoretical support and actionable practical basis for enhancing the scientificity and pertinence of blended learning design.

2. Literature Review

2.1. Blended Learning

Blended learning (BL), combining traditional face-to-face instruction with online synchronous and asynchronous learning, has become crucial in higher education, offering flexibility and interactivity (Ayob et al., 2021). Recent trends involve institutional adoption with strategic planning, infrastructure investment, and lecturer support (Ali & Georgiou, 2025); integration of inclusive practices and emerging technologies (Moriña & Perera, 2025); and application of theoretical frameworks like UDL to optimize design and improve participation (Altowairiki, 2025). However, implementation has challenges. Teachers face skill gaps, administrative barriers, and resistance to change (Shah et al., 2024), and learners show low engagement in blended synchronous learning due to insufficient interaction, technical constraints, conceptual ambiguity, and inadequate institutional frameworks (McCarthy & Palmer, 2023; Wang & Huang, 2023). To address these, innovations have been developed, such as teaching strategies by van der Stap et al. (2024b) for adult learners, strategies by Wang and Huang (2023) to boost BSL engagement, and sustainability-oriented design principles by Versteijlen and Wals (2023). Empirical evidence from Ayob et al. (2021) shows BL's positive impact on student performance. In the current educational environment, BL is a key reform direction, enriching teaching, providing more learning choices, and cultivating students' abilities for future development.

2.2. Community of Inquiry

The Community of Inquiry framework, centered on teaching, social, and cognitive presences, enhances blended and online learning (van der Stap et al., 2024a; Yang & Lay, 2025; Zulu, 2024). Teaching presence scores high (avg. 4.6–4.9) due to clear guidance, social presence varies (avg. 3.6–4.7) with limited online engagement, and cognitive presence gets moderate-high ratings (avg. 4.0–4.6; Zulu, 2024). These presences indirectly promote deep learning, predict positive attitudes, and enhance collaboration (Maré & Mutezo, 2025; Teng et al., 2024; Yang & Lay, 2025).

The effectiveness of the Community of Inquiry framework varies by learning format. A study of 74 Japanese undergraduates showed that traditional blended learning was more effective in cultivating epistemic views than hybrid formats. Traditional learners prioritized cognitive presence, while hybrid learners focused on social presence (Oshima, Oshima &

Kayagi, 2025). In ODeL settings, self-regulation (SR) and co-regulation (CR) correlate with all three Community of Inquiry presences. SR strongly influences teaching and cognitive presence, and CR is closely linked to social presence (Maré & Mutezo, 2024).

However, the Community of Inquiry framework has challenges. Cross-cultural research of 202 Chinese EFL learners showed they prioritized teaching and cognitive presence over social presence due to cultural factors (Teng et al., 2024). Hybrid learning imposes a high cognitive load, requiring multimodal tools (Oshima et al., 2025). There are also research gaps, including a lack of studies on shared metacognition, limited exploration of application-oriented strategies, and no consensus on “learning presence.” Regional research imbalances exist, with fewer non-Western studies. In blended learning, exploring the three Community of Inquiry elements and coordinating them are crucial for students’ learning and growth (van der Stap et al., 2024a).

While studies such as Zulu (2024) and Yang and Lay (2025) have provided valuable insights into the application of the Community of Inquiry framework in higher education and online learning contexts, they mainly focus on academic or fully online settings and lack exploration in vocational blended education. Zulu (2024) emphasized how lecturers enhanced online course quality within a research module through Community of Inquiry principles, whereas Yang and Lay (2025) examined deep learning mechanisms mediated by academic buoyancy and learner interactions in general higher education. However, little is known about how the three presences dynamically interact in blended vocational contexts, where practical competence and applied learning are central. The present study fills this gap by employing Structural Equation Modeling (SEM) to quantify the causal and mediating relationships among teaching, social, and cognitive presences, and by proposing pedagogical optimization strategies tailored to vocational blended learning environments.

2.3. *Social Constructivist Theory*

Social constructivist theory, based on Vygotsky’s ideas, posits that knowledge is socially co-constructed through interaction, scaffolding, and collaborative inquiry, not transferred (Lehtinen, Kostainen & Näykki, 2023; Nithideechaiwarachok & Chano, 2024; Soundy, 2024). It emphasizes social context, active learning, and iterative meaning-making, with elements like the Zone of Proximal Development, tool-based mediation, and critical inquiry. In blended learning, this theory guides design. For example, pre-service teachers’ video-based online collaboration spurred by teacher educators’ dissonance prompts led to high-level knowledge negotiation and socioemotional interaction (Lehtinen et al., 2023). Soundy’s (2024) framework supports blended learning by synthesizing data from online and face-to-face tasks via iterative idea generation. Blended learning uses digital tools for mediation and adjusts scaffolding as learners progress. A Taiwanese university’s career course integrating cooperative work, simulated interviews, and digital tools improved student-teacher engagement, self-efficacy, reflection, career motivation, and skills (Hsu, 2025). Overall, social constructivist theory provides critical guidance for knowledge construction and interaction in blended learning, addressing passive learning issues.

2.4. *Connectivist Learning Theory*

Connectivism theory, proposed by Downes and Siemens, is a digital-age learning theory emphasizing knowledge construction through information networks and social connections (Lockey et al., 2021). It differs from traditional classroom-centric theories,

focusing on learners' ability to use multi-source knowledge. It features flexible learning and aligns with heutagogy. In Advanced Life Support (ALS) courses, it enables blended learning, addresses COVID-19 training challenges and suits diverse learning styles, but risks information overload and disadvantages those with low digital literacy. In blended teaching, connectivism offers guidance, especially in ESL writing instruction (Al Maawali, 2022). It emphasizes knowledge construction via social and digital networks. A case study of 43 Omani ESL students showed that combining connectivism with cognitive process theory in blended settings reduced writer's block, increased text length and enhanced reflective practice. Connectivism-guided collaborative tasks helped students build personal learning networks, share ideas across cultures and improve text formulation.

2.5. Structural Equation Modeling

SEM is a multivariate statistical method integrating factor and path analysis to test relationships between observed variables and latent constructs, addressing measurement error and multidimensionality (Gegenfurtner, 2022). It's a powerful tool for unpacking causal relationships and influencing factors in education, enabling simultaneous analysis of direct/indirect effects and latent constructs. In blended learning research, Liu (2022) used SEM to identify factors affecting primary students' acceptance of science curriculum blended learning, with community support as the strongest predictor. Karakose et al. (2024) explored how collective efficacy mediates the association between principal instructional leadership and teacher self-efficacy through meta-analytic structural equation modeling (MASEM). Han (2023) applied SEM to validate a 6-factor blended learning effectiveness scale and found its positive association with undergraduates' learning outcomes. Wu (2025) used SEM to explore blended collaborative learning's impact on deep learning, showing learner engagement drives deep learning directly and indirectly via self-regulated learning and group interaction. Thus, SEM clarifies complex educational mechanisms and guides targeted interventions. In this study, structural equation modeling will be used to deeply analyze the interaction mechanisms between social, cognitive, and instructional presence in blended learning. By constructing relevant models, it can quantitatively explore the direct and indirect influences between presence elements, clarify their comprehensive effects on teaching effectiveness, and offer strong data-analysis support for revealing the inherent laws of presence elements in blended learning, thus providing a scientific basis for teaching optimization.

3. Methodology

3.1. Research Design

Based on the Community of Inquiry theoretical model and related research, the following hypotheses regarding the relationships among the presence elements are proposed:

- H1: Teaching presence has a significant positive impact on social presence.
- H2: Teaching presence has a significant positive impact on cognitive presence.
- H3: Social presence has a significant positive impact on cognitive presence.
- H4: Teaching presence has a significant positive impact on learning outcomes.
- H5: Social presence has a significant positive impact on learning outcomes.

- H6: Cognitive presence has a significant positive impact on learning outcomes.
 H7: Social presence plays a mediating role between teaching presence and cognitive presence.

3.2. Data Collection

The study sample comprises 517 vocational college students majoring in AI who participated in blended teaching, covering three grade levels. A 1-5 Likert-scale questionnaire (Zhang et al., 2023) was used to collect data on participants' adoption intention attitudes. The questionnaire has four sections as shown in Table 1. The first section contains respondents' basic information like gender, grade, and preferred learning mode. The second section is a five-point scale for presence elements, with 3 latent variables: TP, SP, and CP, and item design covering core presence dimensions. The third section is a five-point scale for the interaction mechanism of presence elements, including causal relationships, mediating effects, and action path verification. The fourth section consists of open-ended questions to gather participants' suggestions on blended teaching and presence elements.

3.3. Research Methods

In this study, SPSS, AMOS, and Python programming were employed to conduct statistics and analysis on the questionnaire data. The main analytical procedures included reliability and validity tests, descriptive statistics, correlation analysis, structural equation model testing, mediating effect testing via the Bootstrap method, multi-group SEM and word frequency statistics.

Table 1: All Questions on the Questionnaire.

No	Category	Variables	Questions
1	Basic info	/	Gender
2		/	Grade
3		/	preferred learning mode
4	Teaching Presence (TP)	TP_1	The teacher clearly explained the learning objectives and tasks of the blended course.
5		TP_2	The teacher keeps track of my learning progress in a timely manner through online tools.
6		TP_3	The teacher provided targeted feedback on the homework or discussion I submitted.
7		TP_4	The resources of blended teaching help me understand the difficult points.
8	Social Presence (SP)	SP_1	I can sense the genuine emotions of my classmates through online interactions.
9		SP_2	I am willing to share my personal views or learning challenges in the discussion forum.
10		SP_3	Collaborating in online groups has given me a sense of belonging to the team.
11		SP_4	I can express my learning attitude through online tools.
12	Cognitive Presence (CP)	CP_1	The case analysis or project tasks in blended teaching prompt me to deeply reflect on my professional knowledge.
13		CP_2	I can apply the theories I learned online to offline practice.
14		CP_3	Through blended learning, I have built a systematic professional knowledge system.
15		CP_4	I am capable of critically analyzing complex issues within the curriculum.
16	Learning Effect (LE)	LE_1	Blended learning has improved my learning efficiency, enabling me to acquire more knowledge in a shorter timeframe.
17		LE_2	Blended learning approach has helped me better grasp the course content and improve my academic performance.
18	Suggestion	S_1	Which aspects of blended teaching do you think need the most improvement?
19		S_2	Do you have any specific suggestions for enhancing "teaching presence", "social presence", or "cognitive presence" in blended learning?

4. Results

4.1. Basic Information of Respondents

Descriptive statistical analysis was done on the data, and Table 2 shows the respondents' basic information.

Table 2: Basic Information of Respondents.

Questions	Contents	Sample Size	Sample Proportion
Gender	Male	302	58.41%
	Female	215	41.59%
Grade	Grade one	147	28.43%
	Grade two	221	42.75%
	Grade Three	149	28.82%
Preferred learning mode	Offline Classroom Learning	19	3.67%
	Online learning	67	12.96%
	Blended learning	431	83.37%

The characteristics of the respondents are presented as follows: In terms of gender, there are 302 male students, (accounting for 58.41%, and 215 female students, accounting for 41.59%. Regarding grade level, 147 students are in the first grade, accounting for 28.43%; 221 are in the second grade, accounting for 42.75%; and 149 are in the third grade, accounting for 28.82%. Concerning learning modes, only 19 students (3.67%) prefer offline learning, 67 (12.96%) select online learning, and 431 (83.37%) choose blended learning. Through the analysis of sample characteristics, it was discovered that the samples exhibit diversity in terms of gender, grade, and major, which can represent student groups with different backgrounds, ensuring the reliability of subsequent data analysis and research conclusions.

4.2. Reliability and Validity Testing

Reliability testing pertains to the evaluation of a questionnaire's reliability. Generally, the Cronbach's α coefficient is chosen as the testing indicator; a larger α coefficient implies a higher level of credibility for the questionnaire (Wati et al., 2025). SPSS was employed to carry out a reliability analysis on the latent variable data associated with the scale, and the results are presented in Table 3. All variables exhibited high internal consistency, with Cronbach's α values of 0.986, 0.987, 0.988, and 0.977 respectively, suggesting outstanding reliability. Validity serves to assess the accuracy of a questionnaire scale's measurement results in reflecting the actual situation; a higher validity implies a better measurement effect. The outcomes of the questionnaire validity test are presented in Table 4.

Table 3: Reliability Testing.

Variables	Items	Cronbach α
TP	4	0.986
SP	4	0.987
CP	4	0.988
LE	2	0.977

Table 4: Validity Testing.

Variables	Items	KMO	Approximate Chi-Square Value of Bartlett's Test of Sphericity	p-value
TP	4	0.882	3854.830	0.000
SP	4	0.858	3953.118	0.000
CP	4	0.887	4104.150	0.000
LE	2	0.500	1262.409	0.000

Validity verification was carried out via the KMO test and Bartlett's test. As shown in the table above, the KMO values of all latent variables exceed 0.5, and the p-values corresponding to Bartlett's test are all below 0.001. These findings suggest that the research data is highly appropriate for information extraction, demonstrating excellent validity.

4.3. Descriptive Statistical Analysis

A descriptive statistical analysis was carried out on four latent variables (TP, SP, CP, and LE), during which the mean and variance were computed. The outcomes are presented in Table 5.

Table 5: Rating of Latent Variables.

Variables	Mean	Var
TP	4.48	0.67
SP	4.38	0.79
CP	4.39	0.75
LE	4.43	0.70

The mean values of these variables span from 4.38 (for SP) to 4.48 (for TP), suggesting a relatively uniform central tendency among different variables. Among them, TP exhibits the highest mean value (4.48) and the lowest variance (0.67), indicating that its data distribution is more concentrated. Overall, the comprehensive assessment of each variable on the scale is at a "relatively high" level, and the score distribution is relatively concentrated.

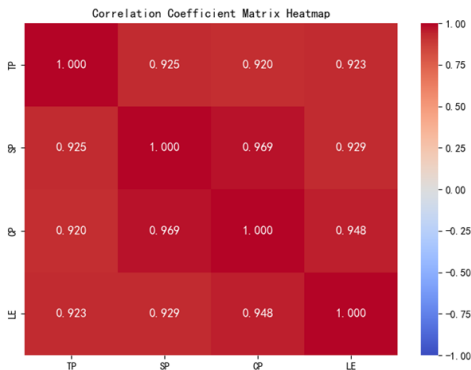
4.4. Correlation Analysis

For each latent variable, compute the average score according to the scores of the questions it encompasses, and adopt this average score as the comprehensive score value of that latent variable. Subsequently, reuse the score values of these latent variables for correlation analysis. The correlation coefficient among latent variables was calculated via Python, and the specific outcomes are presented in Table 6. Meanwhile, the variable heatmap based on the correlation coefficient is depicted in Figure 1.

Table 6: Correlation Coefficient between Latent Variables.

Variables	TP	SP	CP	LE
TP	1.00	0.925	0.920	0.923
SP	0.925	1.00	0.969	0.929
CP	0.920	0.969	1.00	0.948
LE	0.923	0.929	0.948	1.00

Figure 1: Correlation Coefficient Matrix Heatmap.



The values within the cell represent the correlation coefficients among the latent variables, which reflect the extent of linear correlation (the closer the value is to 1, the stronger the positive correlation). Generally speaking, the correlation coefficients among these variables predominantly range from 0.920 to 0.969, suggesting a high level of positive linear correlation among the variables.

4.5. Empirical Analysis of Structural Equation Modeling

Employing AMOS software, the latent variable path diagram is analyzed. The questionnaire items are imported into the software, and the maximum likelihood estimation method is utilized to compute the estimated values. Subsequently, an overall fit test of the structural equation model is carried out. The results are presented in Table 7. Evidently, all the evaluation indicators meet the evaluation criteria.

Table 7: Overall Goodness-of-Fit Test.

Indicators	RMR	CFI	NFI	NNFI	PGFI	IFI	SRMR
Criteria	<0.05	>0.9	>0.9	>0.9	>0.5	>0.9	<0.1
Results	0.007	0.969	0.965	0.960	0.584	0.969	0.010

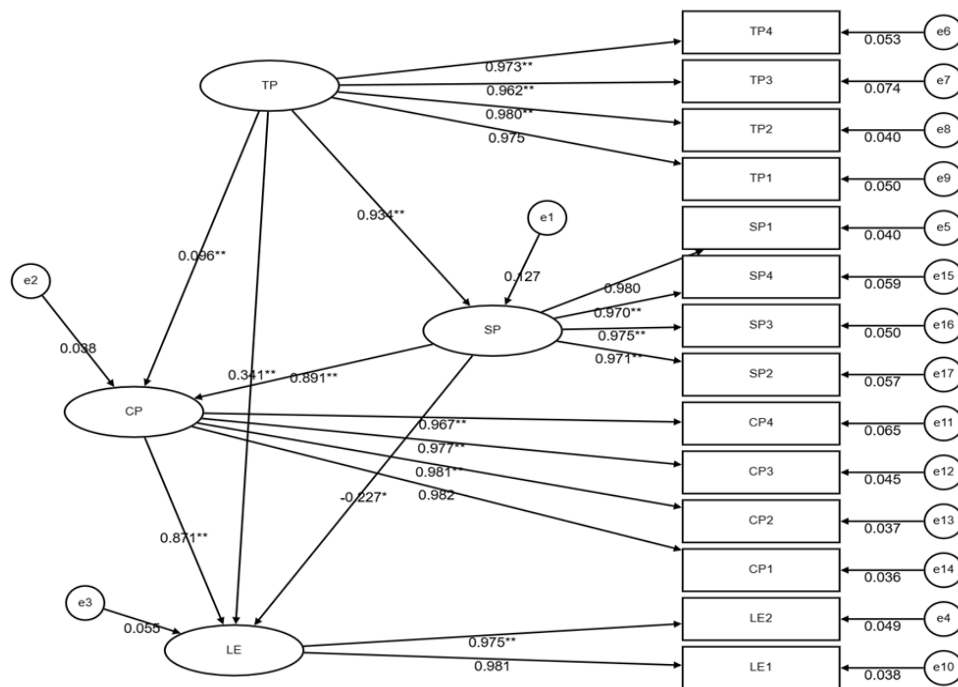
To more intuitively present the degree of influence among variables, this study collated the standardized coefficients and their significance values of each relevant path as presented in Table 8.

Table 8: Standardization Coefficient of SEM.

Path	Hypothesis	Standardization Coefficient β	p-value
TP --> SP	H1	0.934	0.000
TP --> CP	H2	0.096	0.004
SP --> CP	H3	0.891	0.000
TP -->LE	H4	0.341	0.000
SP -->LE	H5	-0.227	0.012
CP -->LE	H6	0.871	0.000

The table showcases the outcomes of path analysis within the framework of structural equation modeling, investigating the hypothesized associations among variables. Paths signify causal connections (for instance, TP --> SP implies that TP exerts an influence on SP), and each is associated with a hypothesis (H1-H6). Standardized coefficients (β) denote the strength and direction of the relationships: The relationship between TP and SP ($\beta = 0.934$) and that between SP and CP ($\beta = 0.891$) demonstrate strong positive effects; the relationships of TP --> CP ($\beta = 0.096$) and TP --> LE ($\beta = 0.341$) have moderate positive impacts; the relationship of CP --> LE ($\beta = 0.871$) reflects a strong positive link, whereas the relationship of SP --> LE ($\beta = -0.227$) exhibits a weak negative association. P - values are employed to evaluate significance: The relationships of TP --> SP ($p = 0.000$), TP --> CP ($p = 0.004$), SP --> CP ($p = 0.000$), TP --> LE ($p = 0.000$), and CP --> LE ($p = 0.000$) are significant. Nevertheless, the relationship of SP --> LE ($p = 0.012$) is not significant, indicating that the data do not support a significant relationship between SP and LE. The structural equation models of each influencing factor are depicted in Figure 2.

Figure 2: Structural Equation Modeling Diagram.



4.6. Mediating Effect Testing

The bootstrap approach is employed to conduct a test on the mediating effect of hypothesis H7 presented previously (Katıtaş, Coşkun & Karadaş, 2024). The number of sampling instances is set at 1000. The outcomes of the mediating effect test are presented in Table 9.

Table 9: Mediating Effect Test Results.

Path	Hypothesis	Indirect Effect	Boot SE	BootLLCI	BootULCI	p-value
TP --> SP--> CP	H7	0.888	0.082	0.674	0.989	0.000

In this study, the path “path” indicates that the tested path is TP → sp → CP, corresponding to Hypothesis H7. The value of “indirect effect” is 0.888, which represents the magnitude of the mediation effect under this path. “Boot se” is 0.082, which is utilized to measure the degree of indirect effect estimation. “Bootlci (lower limit of the bootstrap confidence interval)” is 0.674, and “bootulci (upper limit of the bootstrap confidence interval)” is 0.989, suggesting the possible range of indirect effects at a certain confidence level. The “P value” is 0.000, which is less than the commonly employed significance level (e.g., 0.05), indicating that the indirect effect of TP on CP through SP is statistically significant. That is, social presence plays a crucial intermediary role between teaching presence and cognitive presence. Therefore, Hypothesis H7 is considered to be valid.

4.7. Moderating Effect of Gender

As shown in Table 10, both the unconstrained model and the fully constrained model demonstrated acceptable model fit. The difference in CFI between these two models was 0.000, which is smaller than the recommended cutoff of 0.010 for testing model invariance (Cheung & Rensvold, 2002). This negligible change in CFI indicates that constraining the structural paths to be equal across gender did not significantly worsen the model fit. Therefore, the structural model was invariant across gender, suggesting that gender did not moderate the relationships among the variables.

Table 10: The Result of Structural Invariance Test.

Model	NFI	RFI	IFI	TLI	CFI	ΔCFI
Unconstrained	0.946	0.930	0.953	0.940	0.953	0.000
Fully constrained	0.945	0.936	0.953	0.946	0.953	

4.8. Word Frequency Analysis of Answers to Subjective Questions

In addressing subjective queries, this research utilizes the Python programming language to conduct pre-processing of text data. This pre-processing encompasses the removal of stop words and the implementation of word frequency analysis to determine the top 10 most frequently appearing words. The outcomes are presented in Table 11. The words with the highest frequencies, in descending order, are “teacher”, followed by “interesting”, “assessment”, “group”, “feedback”, “resources”, “practice”, “activities”, “cooperation”, and “communication”.

Subsequently, this study utilizes the innovative word cloud technology to visually represent and highlight the key terms extracted from the extensive text data. This graphical representation is meticulously illustrated in Figure 3, providing a clear and intuitive visual summary. Within the word cloud, the significance of each term is indicated by both the size of the font and the intensity of the color: the larger the font size and the darker the color, the more frequently that particular word appears in the

students' in-depth reflection, integration, and application of knowledge through reflection, discussion, and practice to achieve meaning construction.

However, the path analysis revealed that SP did not show a significant direct effect on LE. This result may be explained by cultural and contextual characteristics of Chinese vocational education. In such learning environments, students tend to prioritize task completion and teacher authority over peer interaction, which may weaken the direct influence of social presence on measurable learning outcomes. Nevertheless, social presence may still play an indirect role by promoting cognitive engagement, collaborative inquiry, and emotional support, thereby contributing to learning performance through cognitive presence rather than directly affecting it. This interpretation aligns with previous cross-cultural Community of Inquiry findings and offers a culturally grounded understanding of the observed non-significance.

5.2. Exploration of Teaching Optimization Strategies

Educators serve as the core determinant in the successful execution of blended teaching. Initially, teachers ought to place emphasis on the augmentation of teaching presence. To facilitate interaction among students, teachers can devise a variety of interactive activities. Timely and efficient guidance and feedback from teachers are pivotal for strengthening teaching presence. Teachers can establish a positive teaching ambiance through diverse approaches, which is of great significance for enhancing social presence. Group activities represent an effective approach to enhancing social presence. Through group activities, students can perceive the strength and warmth of the team during cooperation with others, thus enhancing social presence. Promoting emotional communication among students is also a significant aspect of enhancing social presence. Creating an inspiring problem-solving context is an important measure to promote cognitive presence. Encouraging students to engage in reflective discussions can effectively enhance cognitive presence. Teachers should also guide students to integrate knowledge, assisting them in constructing fragmented knowledge into a systematic knowledge framework.

Constructing a multi-dimensional teaching evaluation system is an essential part of teaching optimization. Adopting diversified evaluation methods can assess students' learning more comprehensively and objectively. Leveraging teaching evaluation results to improve teaching is the ultimate objective of teaching evaluation. In the context of blended learning, evaluation should not only measure academic performance but also capture learners' engagement, interaction, and digital literacy. A comprehensive evaluation framework can provide feedback for both teachers and students, guiding continuous improvement and personalized learning.

To further refine blended teaching practices, these strategies can be aligned with digital pedagogical frameworks such as the Universal Design for Learning (UDL) and the Technological Pedagogical Content Knowledge (TPACK) model. UDL emphasizes inclusive design through multiple means of engagement, representation, and expression, while TPACK integrates technology, pedagogy, and content knowledge to enhance instructional innovation. In addition, a distinction can be made between teacher-centered interventions (e.g., structured guidance, formative assessment, and feedback) and learner-centered interventions (e.g., collaborative inquiry, reflection, and self-regulated learning). This differentiation ensures that blended teaching supports both instructional effectiveness

and learner autonomy, forming a balanced and sustainable learning ecosystem.

5.3 Pedagogical Implications

The findings of this study provide several practical implications for blended teaching in vocational education. First, teachers should design task-driven learning activities that combine authentic workplace scenarios with online discussion, thereby fostering both teaching and cognitive presence. Second, instructors can leverage social media platforms or learning communities to enhance social presence and sustain motivation. Third, formative assessment and real-time feedback mechanisms should be integrated into the blended learning process to strengthen students' reflection and self-regulation. Finally, institutions should provide professional development programs to help teachers improve their ability to design, facilitate, and assess blended learning, ensuring that the Community of Inquiry framework is effectively operationalized in vocational contexts.

6. Conclusion

This research undertakes an in-depth exploration of blended teaching. By leveraging methods such as structural equation modeling and based on the exploratory community theory model, it unveils the interactive mechanism of presence elements in blended teaching. Subsequently, corresponding teaching optimization strategies are proposed. By concentrating on the interaction dynamics of presence elements in the blended learning of vocational college students, this study enriches the application research of the Community of Inquiry theory within the context of vocational education. Empirically, it clarifies the specific causal pathways and mediating functions among SP, TP, and CP, offering distinctive theoretical perspectives on the operation of presence elements in blended learning. Practically, it provides targeted strategies for optimizing blended learning, which holds significant value for enhancing the quality of blended learning in vocational education.

This study has two main limitations. First, the sample consisted solely of vocational college students from a single institution, which may constrain the generalizability of the findings to other educational levels and learning contexts. Future research will expand the sample across multiple institutions and educational levels to enhance external validity and cross-context applicability while verifying the robustness of the current findings. Second, the research mainly focused on the interactive mechanism among teaching, social, and cognitive presences, without including other potential influencing factors such as learner motivation, technological readiness, or institutional support. Future studies may incorporate these additional variables into the analytical framework to develop a more comprehensive understanding of the factors shaping blended learning effectiveness and to provide stronger empirical guidance for optimizing blended learning design.

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5.2. Data Availability Statement

Data sets generated during the current study are available from the author on reasonable request.

5.3. Conflicts of Interest

The author declares that she has no competing interest.

5.4. Acknowledgement

Not applicable.

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