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ORIGINAL

Exploring the Role of Teaching Leadership in Enhancing Deep Learning Among Chinese Vocational Students: Mediating Effects of Academic Self-Efficacy and Teacher-Student Interaction in Blended Learning

Explorar el papel del liderazgo docente en la mejora del aprendizaje profundo entre los estudiantes vocacionales chinos: mediar los efectos de la autoeficacia académica y la interacción profesor-estudiante en el aprendizaje combinado

Qiujin Lu[1,2], Chunying Wang[1]

[1]Universidad Técnica de Ambato. Facultad de Ciencias de la Salud, Carrera de Licenciatura en Enfermería. Latacunga, Ecuador.

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Corresponding author: Chunying Wang

ABSTRACT

Introduction: this study investigates the relationship between perceived teaching leadership and deep learning within a blended learning environment among vocational students in Zhejiang Province, China.
Objectives: the primary aim is to examine how academic self-efficacy and teacher-student interaction mediate the relationship between perceived teaching leadership and deep learning.
Method: utilizing convenience sampling, the study collected data through 1129 valid online questionnaires from vocational students in Zhejiang Province.
Results: findings reveal that academic self-efficacy significantly mediates the relationship between perceived teaching leadership and deep learning. Furthermore, teacher-student interaction also functions as a mediator in this dynamic. Notably, a chain mediation effect involving both academic self-efficacy and teacher-student interaction is evident.
Conclusions: the results underscore the crucial role of perceived teaching leadership in enhancing deep learning among vocational students. Importantly, the study highlights the mediating effects of academic self-efficacy and teacher-student interaction, providing valuable insights for improving practices in vocational education .

Keywords: Blended Learning Environment; Perceived Teaching Leadership; Academic Self-Efficacy; Teacher-Student Interaction; Deep Learning.

RESUMEN

Introducción: este estudio investiga la relación entre el liderazgo docente percibido y el aprendizaje profundo dentro de un ambiente de aprendizaje mixto entre estudiantes vocacionales en la provincia de Zhejiang, China.
Objetivos: el objetivo principal es examinar cómo la autoeficacia académica y la interacción profesor-alumno median la relación entre el liderazgo docente percibido y el aprendizaje profundo.
Método: utilizando un muestreo por conveniencia, el estudio recogió datos a través de 1129 cuestionarios válidos en línea de estudiantes de formación profesional en la provincia de Zhejiang.
Resultados: los hallazgos revelan que la autoeficacia académica media significativamente la relación entre el liderazgo docente percibido y el aprendizaje profundo. Además, la interacción profesor-alumno también funciona como mediador en esta dinámica. En particular, es evidente un efecto de mediación en cadena que

involucra tanto la autoeficacia académica como la interacción profesor-alumno.
Conclusiones: los resultados subrayan el papel crucial de la percepción del liderazgo docente en la mejora del aprendizaje profundo entre los estudiantes de formación profesional. Es importante destacar que el estudio destaca los efectos mediadores de la autoeficacia académica y la interacción entre el profesor y el alumno, lo que proporciona información valiosa para mejorar las prácticas en la formación profesional.

Palabras clave: Ambiente de Aprendizaje Mixto; Percepción del Liderazgo Docente; Autoeficacia Académica; Interacción Profesor-Alumno; Aprendizaje Profundo.

INTRODUCTION

In today's information age, higher education is undergoing unprecedented changes.[1] The rapid development of information technology has introduced new learning methods and platforms into the education field.[2] Blended Learning, which combines traditional face-to-face teaching with online learning, has become an important way for students to acquire knowledge.[3,4] Additionally, blended learning can cultivate students' critical thinking and problem-solving skills, enabling them to better meet the demands of the future job market for highly skilled and high-quality talent.[5,6,7]

However, with the diversification of educational formats, fostering students' deep learning abilities has become increasingly important. Deep learning emphasizes learners' ability to integrate new information organically into their existing cognitive frameworks based on a deep understanding of knowledge, and to solve real-world problems through critical thinking.[8] Abbasi and Shi Lili point out that the application of deep learning in vocational education not only helps stimulate innovative thinking and entrepreneurial awareness but also better aligns with social and industrial development trends.[9,10]

Teaching leadership is also considered an important factor in shaping students' learning experiences and achievements.[11] Hadad noted that teaching leadership is a key factor in promoting students' deep learning.[12] Teachers can enhance academic self-efficacy and influence teacher-student interactions through clear learning objectives, personalized learning paths, stimulating academic interest, providing diverse academic resources, guiding in-depth discussions and interactions, and encouraging critical thinking.[13] Teaching leadership affects teacher-student interaction by enhancing students' academic self-efficacy, and teacher-student interaction promotes deep learning through positive interactions, while academic self-efficacy directly influences students' deep learning.[14] With the growth of online learning, the research by Liu Geping focuses on the roles of academic self-efficacy, teacher-student interaction, and deep learning in virtual learning environments, exploring how interactions between teachers and students in online teaching affect students' academic performance and deep learning.[15] Helping students build positive academic self-efficacy, improving teacher-student interaction, and creating a positive teaching environment are crucial for promoting deep learning.[16,17]

Zhejiang Province has established an educational database that enables continuous data collection and one-source data usage, with various regions and schools actively promoting blended learning and other teaching practices. Therefore, this study focuses on vocational students in Zhejiang Province, China, to explore the impact of perceived teaching leadership, academic self-efficacy, and teacher-student interaction on students' deep learning in a blended learning environment. The study aims to provide targeted methods for enhancing deep learning in blended learning environments, thereby offering theoretical support for improving the quality of vocational education.

Social cognitive theory emphasizes that cognitive development and knowledge acquisition result from social interactions. Individuals influence each other through observation, imitation, collaborative learning, and cognitive mediation.[18] Additionally, this theory highlights the importance of social interaction between teachers and learners, as well as among learners, on students' learning and course completion. It also significantly impacts students' learning motivation.[19] Social and peer recognition plays a powerful role in education, increasing the likelihood of students adopting effective learning behaviors.[20]

In a blended learning environment, students' perceived teaching leadership can influence their learning motivation, as they believe the teacher's guidance in the course is valuable. This belief can inspire students to actively engage in deep learning.[21] Students' academic self-efficacy can be seen as a cognitive tool influencing their perception of teaching leadership.[22] Students with strong academic self-efficacy are more likely to believe they can fully utilize the teacher's guidance, thus engaging more actively in deep learning.[23,24] Social cognitive theory supports the concept of collaborative learning, and teacher-student interaction often involves a form of collaborative learning. In a blended learning environment, teacher-student interaction can facilitate collaborative learning, helping students deeply understand course content through discussion, questioning, and interaction.[25,26]

In summary, this study aims to better understand educational phenomena in blended learning environments,

providing a deeper theoretical foundation for educational policies and practices. Thus, social cognitive theory serves as the theoretical basis for this research.

The Impact of Perceived Teaching Leadership on Deep Learning

Teaching leadership has long been regarded as a core feature of effective schools, particularly in educational research in the United States and other Western countries.[27] This focus on teaching leadership stems from the belief that it can positively impact students' academic achievements.[28] Hattie introduced the concept of visible learning, exploring the effects of different teaching strategies and leadership styles on student learning outcomes.[29] Li Qiongfeng found that the cultivation of key teacher competencies, i.e., teaching leadership, is a prerequisite and guarantee for achieving deep learning among students.[30] High-quality teachers can drive high-quality student learning, promoting the implementation of core competencies. The introduction of key teacher competencies (teaching leadership) supports and guarantees the promotion of deep learning, necessitating teachers to have key competencies for designing deep learning objectives and advancing educational reforms.[31] Students' perceived teaching leadership positively impacts their deep learning because it provides clear vision, resource support, professional development, and a positive school culture, all of which collectively promote the practice of deep learning.[32,33] Therefore, this study proposes Hypothesis H1.

H1: Perceived teaching leadership has a significant positive impact on deep learning among Chinese vocational students.**

The Mediating Role of Academic Self-Efficacy in the Relationship Between Perceived Teaching Leadership and Deep Learning

Teaching leadership directly promotes deep learning by stimulating students' interest, clarifying teaching objectives, and flexibly utilizing personalized teaching methods.[34,35] Positive feedback and guidance help students understand knowledge, create a positive classroom atmosphere, encourage participation in discussions, and promote active learning, which facilitates deep learning.[36] High academic self-efficacy can enhance student confidence, increase engagement, and foster positive perceptions of teaching leadership.[37] Deep learning requires a thorough understanding of complex concepts, and high self-efficacy drives students to actively explore new knowledge, believe in effective learning, and face academic challenges.[38] High academic self-efficacy also influences students' choice of learning strategies, making them more inclined to adopt deep-level strategies such as deep thinking, connecting knowledge, and actively seeking help. These strategies aid in achieving deep learning goals and reinforcing a profound understanding of subject knowledge.[39]

Academic self-efficacy, as students' internal belief system, connects teaching leadership and deep learning.[40] It plays an indispensable mediating role in fostering students' confidence, motivating learning, guiding the selection of learning strategies, and forming attitudes towards academic challenges, providing a solid foundation for achieving deep learning goals.[41] Tang et al. found that academic self-efficacy mediates the relationship between perceived teaching leadership and deep learning. Therefore, this study proposes Hypothesis H2.[42]

H2: Academic self-efficacy mediates the relationship between perceived teaching leadership and deep learning among Chinese vocational students.

The Mediating Role of Teacher-Student Interaction in the Relationship Between Perceived Teaching Leadership and Deep Learning

In teacher-student interaction, teachers play a crucial role. Teachers' ability to actively engage the classroom and enhance student participation is vital for improving learning abilities in a blended learning model, and these abilities fall under leadership.[43] Enhancing teaching leadership naturally benefits the level and quality of classroom interaction.[44] Teaching leadership can enhance deep learning by promoting higher levels of teacher-student interaction.[45] The impact of teaching leadership on student academic achievement is partly realized through increased teacher-student interaction. Teacher-student interaction is considered an important pathway to achieving deep learning.[46] Mensah and Koomson used semi-structured interviews and questionnaires to explore the relationship between high school teachers' teaching leadership, teacher-student interaction, and student deep learning.[47] They found that teacher-student interaction mediates the relationship between perceived teaching leadership and student deep learning. Therefore, this study proposes Hypothesis H3.

H3: Teacher-student interaction mediates the relationship between perceived teaching leadership and deep learning among Chinese vocational students.

The Chain Mediating Role of Academic Self-Efficacy and Teacher-Student Interaction in the Relationship Between Perceived Teaching Leadership and Deep Learning

Bandura's self-efficacy theory emphasizes the belief in one's abilities.[48] Academic self-efficacy is linked to learning behaviors and academic performance. It may influence students' motivation and ability for deep

learning.[49] Students' perceived teaching leadership can influence their behavioral choices and emotional states.[50] Dignath and Büttner found that students' self-assessment is influenced by teachers, and students can gain indirect reinforcement of self-assessment through observing teachers' behaviors and daily demonstrations.[51]

Song Jia et al. found through questionnaire analysis that instructional interaction directly and positively affects immersive experiences, and instructional interaction indirectly and positively affects higher-order thinking through immersive experiences.[52] Shen Xiajuan concluded from experiments that active interactions among teachers, students, and machines enable learners to participate actively, fostering broad thinking and strong initiative, thereby promoting deep learning.[53] Teacher questioning, teacher-student interaction, and student discussion and reflection all promote deep learning.[54] Xiong Ying and Liu Yongquan found that effective interaction is key to distance education.[55] Bai Jingwei showed that learners rely on teacher interaction when assessing academic self-efficacy.[56] Similarly, teacher-student interaction influences students' academic self-efficacy to varying degrees. Students with higher academic self-efficacy are more inclined to interact with teachers enthusiastically in class.[57] Academic motivation and achievement are jointly influenced by academic self-efficacy and teacher-student interaction, which may affect deep learning. Therefore, this study proposes Hypothesis H4.[58,59]

H4: Academic self-efficacy and teacher-student interaction have a chain mediating effect in the relationship between teaching leadership and deep learning among Chinese vocational students.

In summary, this study establishes a hypothetical model, as shown in Figure 1.

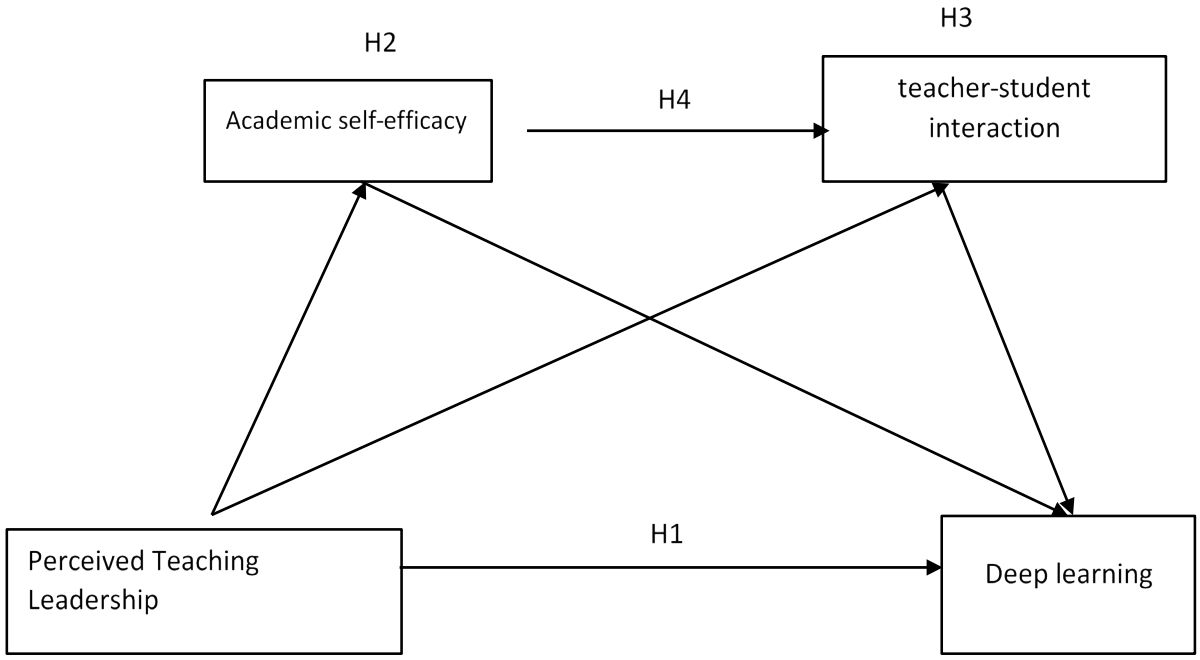

Figure 1. Research Framework

METHOD

Research Subjects and Sample

This study employed convenience sampling to distribute a total of 1 200 questionnaires across six vocational colleges in China, successfully gathering 1 129 valid responses. The effective response rate was an impressive 99 %, far exceeding the predetermined sampling standards, which reinforces the reliability and representativeness of the research data.

Research Instruments

The measurement scales for core variables in the questionnaire were adapted from established scales found in both domestic and international literature. All scales utilized a 5-point Likert scale, where 1 represented "strongly disagree" and 5 represented "strongly agree."

Perceived Teaching Leadership Scale: Adapted from the Student Perception of Teaching Leadership Cognitive Scale by Chen Yijun, this scale consists of 25 items divided into five dimensions: stimulating students' desire to learn, achieving quality educational behavior, providing positive guidance and correct learning direction, helping students overcome learning obstacles, and motivating students to enhance satisfaction.[60] The Cronbach's Alpha value for this scale is ,940.

Academic Self-Efficacy Scale: This scale is based on the Adult Online Learning Self-Efficacy Scale developed

by Wang Cixiao and Wu Feng.[61] It includes 23 items that are categorized into three dimensions: self-efficacy of learning ability, self-efficacy of learning will, and self-efficacy of learning technology. This scale achieved a Cronbach's Alpha value of ,946, with a KMO value of ,927, indicating high reliability.

Teacher-Student Interaction Scale: This scale was developed from the Online Teaching Teacher-Student Interaction Scale by Song Jia et al.[62] It comprises 20 items across two dimensions: instructional interaction and social interaction. The scale exhibits a Cronbach's Alpha value exceeding ,900, reflecting high reliability.

Deep Learning Scale: Adapted from the Deep Learning Scale for Students in a Blended Learning Environment by Zheng and Guo[63], this scale consists of 26 items distributed across three dimensions: knowledge transfer, emotional and psychological factors, and cognitive abilities. The overall Cronbach's Alpha value is ,899, with individual dimension values of ,831, ,824, and ,831, respectively, demonstrating high reliability.

RESULTS

Reliability Analysis

Among the respondents, 546 were male (48,4 %) and 583 were female (51,6 %). In terms of grade level, 556 were first-year students (49,2 %), 448 were second-year students (39,7 %), and 125 were third-year students (11,1 %). Detailed demographics are presented in table 1.

Table 1. Summary of Descriptive Statistics for Background Variables

Background Variables	Category	Number of People	Percentage
Gender	Male	546	48,4 %
	Female	583	51,6 %
Grade	Freshman	556	49,2 %
	Sophomore	448	39,7 %
	Junior	125	11,1 %

The Cronbach's Alpha values for the scales were as follows: Perceived Teaching Leadership Scale (,978), Academic Self-Efficacy Scale (,975), Teacher-Student Interaction Scale (,975), and Deep Learning Scale (,955). All values exceeded ,700, indicating good internal consistency for the scales. Detailed reliability statistics are presented in table 2.

Table 2. Summary of Reliability Analysis for Each Scale

Dimension	Number of Items	Cronbach's Alpha
Perceived Teacher Instructional Leadership	25	,978
Learning Self-Efficacy	23	,975
Teacher-Student Interaction	20	,975
Deep Learning	26	,955

Confirmatory Factor Analysis

The confirmatory factor analysis (CFA) results for the Perceived Teaching Leadership Scale showed x^2/df = 2,318, RMR = ,040, GFI = ,982, NFI = ,982, TLI = ,989, CFI = ,990, PNFI = ,868, and RMSEA = ,030. For the Academic Self-Efficacy Scale, the results were x^2/df = 2,216, RMR = ,021, GFI = ,980, NFI = ,980, TLI = ,988, CFI = ,989, PNFI = ,850, and RMSEA = ,033. The Teacher-Student Interaction Scale results were x^2/df = 2,653, RMR = ,015, GFI = ,979, NFI = ,979, TLI = ,985, CFI = ,987, PNFI = ,847, and RMSEA = ,038. The Deep Learning Scale results were x^2/df = 1,941, RMR = ,017, GFI = ,980, NFI = ,980, TLI = ,989, CFI = ,990, PNFI = ,868, and RMSEA = ,029. All fit indices met the reference values (Harrington, 2009), indicating a good model fit. Detailed CFA results are presented in table 3.

Table 3. Fit Indices for Four Scales Model

Fit Index	x^2/df	RMR	NFI	TLI	CFI	PNFI	RMSEA
Fit Criteria	<5,000	<,050	≥,900	>,900	>,900	>,500	<,080
TL	2,318	,040	,982	,989	,990	,868	,030
SE	2,216	,021	,980	,988	,989	,850	,033
TS	2,653	,015	,979	,985	,987	,847	,038
DL	1,941	,017	,980	,989	,990	,868	,029

Common Method Bias Test

The Harman's single factor test was used to assess common method bias. The KMO value was ,921, exceeding

the reference value of ,800, and the Bartlett's test of sphericity was significant (p < ,001), meeting the standards proposed by Podsakoff et al.[64] Thirteen factors with eigenvalues greater than 1 were extracted, with the first factor explaining 20,098 % of the variance, below the reference value of 50 %, indicating no serious common method bias.[65]

Correlation Analysis

Pearson correlation analysis was conducted to examine the correlations between variables. The discriminant validity of the measurement model was evaluated by comparing the square roots of the AVE values with the correlation coefficients between constructs. According to Fornell and Larcker (1981), discriminant validity is supported if the square root of the AVE for each construct is greater than the correlations with other constructs. The results indicated significant correlations between perceived teaching leadership, academic self-efficacy, teacher-student interaction, and deep learning, with all correlation coefficients less than the AVE square roots, demonstrating high discriminant validity.[66] Detailed correlation statistics are presented in table 4.

Table 4. Summary of Correlation Analysis Between Four Scales

Variable	Mean	SD	TL	SE	TS	DL
TL	4,058	0,646	,866			
SE	3,956	0,658	,816***	,816		
TS	4,074	0,644	,754***	,783***	,752	
DL	4,053	0,533	,738***	,754***	,730***	,836

Notes: ***p<,001; TL = Perceived Teacher Leadership; SE = Learning Self-Efficacy; TS = Teacher-Student Interaction; DL = Deep Learning.
Values on the diagonal (in bold) are the square roots of the Average Variance Extracted (AVE) for each construct.
Data sourced from this study's analysis.

Hypothesis Testing

Main Effect Model

The structural equation model (SEM) was used to construct the main effect model of perceived teaching leadership on students' deep learning, as shown in Figure 2. The fit indices were: RMSEA = ,068, RMR = ,031 (both below the standard value of ,080), GFI = ,990, AGFI = ,906, NFI = ,990, IFI = ,992, TLI = ,988, RFI = ,985, CFI = ,992 (all above the standard value of ,900), PNFI = ,554, and PCFI = ,555 (both above the standard value of ,500), indicating good model fit.[67]

The study found that perceived teaching leadership significantly positively influenced students' deep learning (r = ,919, p < ,001), indicating that higher perceived teaching leadership corresponds to higher deep learning abilities among students. Thus, Hypothesis H1 is supported: perceived teaching leadership significantly positively affects deep learning among vocational students in Zhejiang Province, China.

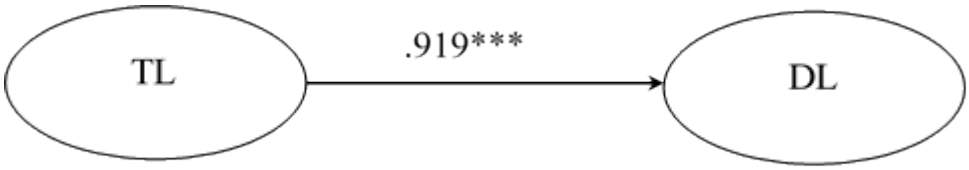

Figure 2. Main Effect Model of Perceived Teacher Leadership on Students' Deep Learning

Direct Effect Path Analysis

Path analysis results indicated that perceived teaching leadership significantly positively affected academic self-efficacy (r = ,851, p < ,001), suggesting that higher perceived teaching leadership corresponds to stronger academic self-efficacy among students.

Further path analysis showed that perceived teaching leadership significantly positively affected teacher-student interaction (r = ,720, p < ,001), indicating that higher perceived teaching leadership leads to stronger teacher-student interaction.

Additionally, academic self-efficacy significantly positively influenced deep learning (r = ,534, p < ,001), suggesting that stronger academic self-efficacy corresponds to higher deep learning abilities.

Teacher-student interaction also significantly positively influenced deep learning (r = ,317, p < ,001), indicating that stronger teacher-student interaction leads to higher deep learning abilities.

Moreover, academic self-efficacy significantly positively affected teacher-student interaction (r = ,215, p < ,001), suggesting that higher academic self-efficacy leads to stronger teacher-student interaction. Detailed

path analysis results are presented in table 3.

Table 5. Path Analysis of Structural Equation Model

Path	r	S.E.	C.R.
TL-DL	,119**	,050	2,661
TL-SE	,851***	,033	30,518
TL-TS	,720***	,042	19,628
SE-DL	,534***	,030	16,346
SE-TS	,215***	,033	6,396
TS-DL	,317***	,039	7,774

Notes: TL is Perceived Teacher Leadership, SE is Learning Self-Efficacy, TS is Teacher-Student Interaction, DL is Deep Learning.
***p<,001; r is the standardized coefficient; S.E.= Standard Error; C.R.= Critical Ratio.
Data source: This study.

Bootstrap Mediation Effect Test

According to Mackinnon, the Bootstrap method was used to test the stability of the mediation model. As shown in figure 3, perceived teaching leadership had a significant positive direct effect on students' deep learning (r = ,119, p < ,01). The 95 % confidence interval for the direct effect of perceived teaching leadership on students' deep learning, tested using the bias-corrected non-parametric percentile Bootstrap method, was ,010 to ,265, excluding 0, as shown in table 6[26] This indicates that the direct effect of perceived teaching leadership on deep learning remains significant after adding academic self-efficacy and teacher-student interaction as mediators, although the path coefficient decreased from ,919 (p < ,001) in the main effect model to ,119 (p < ,001) in the chain mediation structure model. This suggests that academic self-efficacy and teacher-student interaction have significant mediation effects between perceived teaching leadership and deep learning, with the overall model being partially mediated.

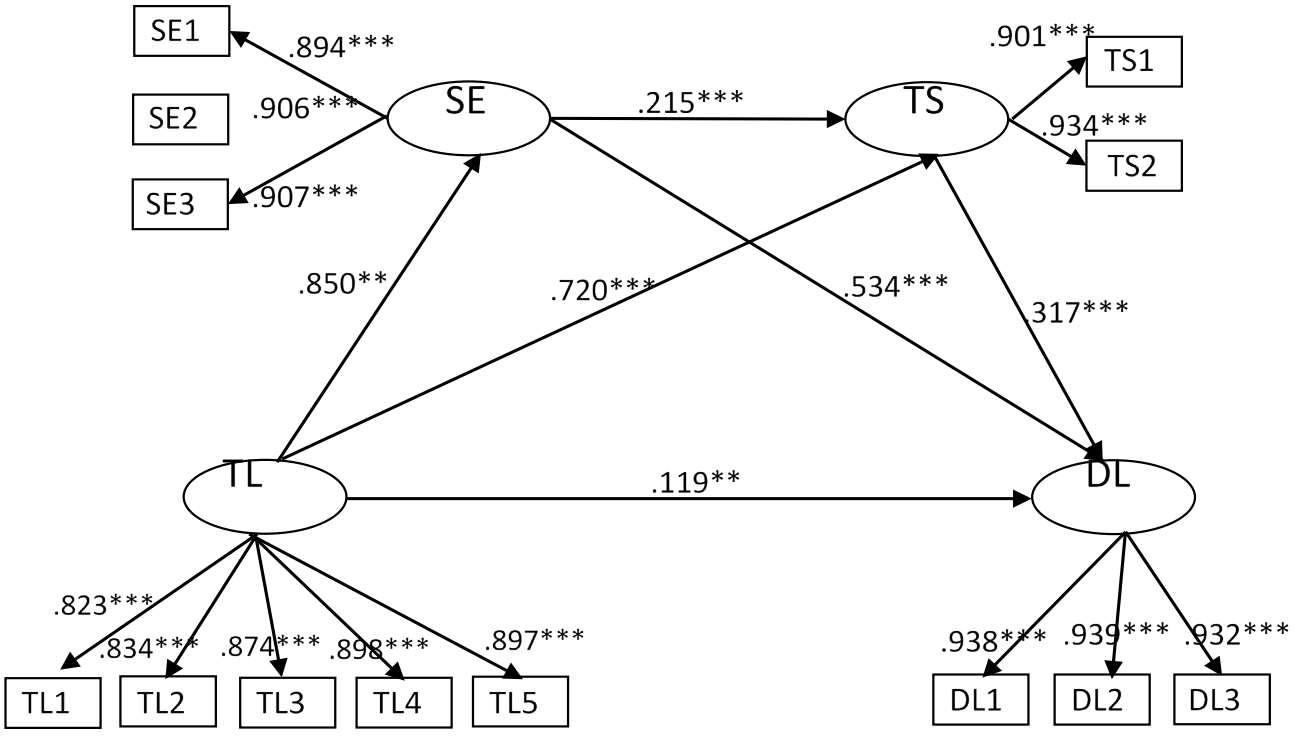

Figure 3. Mediating Model Diagram

Notes: ***p<,001. TL represents Perceived Teacher Teaching Leadership; SE represents Learning Self-Efficacy; TS represents Teacher-Student Interaction; DL represents Deep Learning. Data source is from this study.

Based on the mediating model constructed for this study, there are three indirect paths through which teaching leadership influences students' deep learning:

Firstly, indirect Effect through Academic Self-Efficacy: The indirect effect of teaching leadership on students' deep learning through academic self-efficacy is ,503 (p < ,001). Using the bias-corrected non-parametric percentile Bootstrap method, the 95 % confidence interval for this indirect effect is ,364 to ,646, which does not include 0 (as shown in table 6).[25] This indicates that academic self-efficacy has a significant mediating effect in the first indirect path. Specifically, perceived teaching leadership enhances students' deep learning abilities by improving their academic self-efficacy. This confirms that academic self-efficacy mediates the relationship between perceived teaching leadership and deep learning, supporting Hypothesis H2: Academic self-efficacy plays a mediating role between teaching leadership and deep learning among vocational students in Zhejiang Province, China.

Secondly, indirect Effect through Teacher-Student Interaction: The indirect effect of perceived teaching leadership on students' deep learning through teacher-student interaction is ,253 (p < ,010). Using the bias-corrected non-parametric percentile Bootstrap method, the 95 % confidence interval for this indirect effect is ,106 to ,408, which does not include 0 (as shown in table 4).[25] This indicates that teacher-student interaction has a significant mediating effect in the second indirect path. Specifically, perceived teaching leadership enhances students' deep learning abilities by strengthening teacher-student interaction. This confirms that teacher-student interaction mediates the relationship between perceived teaching leadership and students' deep learning, supporting Hypothesis H3: Teacher-student interaction plays a mediating role between teaching leadership and deep learning among vocational students in Zhejiang Province, China.

Thirdly, indirect Effect through Academic Self-Efficacy and Teacher-Student Interaction: The indirect effect of perceived teaching leadership on students' deep learning through both academic self-efficacy and teacher-student interaction is ,064 (p < ,050). Using the bias-corrected non-parametric percentile Bootstrap method, the 95 % confidence interval for this indirect effect is ,007 to ,150, which does not include 0 (as shown in table 6). This indicates that the chain mediating effect of academic self-efficacy and teacher-student interaction is significant in the third indirect path. Specifically, this confirms the chain mediating role of academic self-efficacy and teacher-student interaction in the relationship between perceived teaching leadership and students' deep learning. Supporting Hypothesis H4: There is a chain mediating effect of academic self-efficacy and teacher-student interaction between teaching leadership and deep learning among vocational students in Zhejiang Province, China.

Table 6. Mediation Effects Bootstrap Test Analysis

Effect	Path	Effect number	95 %LLCI	95 %ULCI
Direct Effect	TL▫DL	,119***	,010	,265
Indirect Effect 1	TL▫SE▫DL	,503***	,364	,646
Indirect Effect 2	TL▫TS▫DL	,253**	,106	,408
Indirect Effect 3	TL▫SE▫TS▫DL	,064***	,007	,150
Total Indirect Effect	TL▫DL	,820***	,462	,900
Total Effect	TL▫DL	,919***	,796	,914

Notes: TL refers to perceived teacher teaching leadership, SE refers to self-efficacy in learning, TS refers to teacher-student interaction, and DL refers to deep learning.
** p < ,01, *** p < ,001.
Data source is from this study.

DISCUSSION

This study conducted Cronbach's Alpha reliability test and confirmatory factor analysis on the sample data. The results show that the formal data for the four scales—perceived teaching leadership, academic self-efficacy, teacher-student interaction, and deep learning among vocational students in Zhejiang Province, China—exhibit good reliability and validity in a blended learning environment. Additionally, the use of exploratory factor analysis Harman's test and confirmatory factor analysis for the formal sample confirmed that common method variance (CMV) is not a significant issue in this study. The hypothesis model was tested using AMOS, and the results indicate that in a blended learning environment, perceived teaching leadership has a significant positive impact on students' deep learning. Academic self-efficacy mediates the relationship between perceived teaching leadership and students' deep learning, as does teacher-student interaction. Furthermore, academic self-efficacy and teacher-student interaction together form a chain mediation effect between perceived teaching leadership and students' deep learning.

The Impact of Perceived Teaching Leadership on Deep Learning

The study results indicate that H1: Perceived teaching leadership among vocational students in Zhejiang Province, China, has a significant positive impact on deep learning, confirming the research hypothesis. This is consistent with the findings of Xu Zhenguo (2023), which demonstrate that perceived teaching leadership

has a positive and significant impact on deep learning. Aslan et al. (2020) define teaching leadership as the professional knowledge, skills, and values related to successful teaching implementation. When teachers possess these abilities at a high level, they can positively motivate students and provide a more comprehensive and detailed knowledge system, guiding students to engage in in-depth exploration and thus enhancing their deep learning outcomes. Chen Yuping (2006) found that when teachers' individual levels (i.e., teaching leadership) are higher, students are more willing to invest in learning, thereby improving their deep learning levels. This may be because students interact most frequently with teachers; higher levels of teaching leadership lead students to be more willing to engage in learning. Teachers with higher leadership abilities can help students find learning goals, which is more conducive to student engagement, thereby improving their deep learning levels.

To enhance vocational students' deep learning, vocational colleges should emphasize the professional development of teachers, particularly in enhancing teaching leadership. Through training and teaching development programs, teachers can update their teaching methods and improve classroom management and student guidance abilities. Additionally, establishing evaluation and feedback mechanisms to regularly assess teaching leadership ensures that teaching methods align with students' needs. In teaching, interactive and participatory approaches, such as group discussions and project-based learning, should be encouraged to enhance students' deep learning experiences.

The Mediating Effect of Academic Self-Efficacy

The study found that H2: Academic self-efficacy among vocational students in Zhejiang Province, China, mediates the relationship between perceived teaching leadership and deep learning, supporting the research hypothesis H2. This study also indirectly supports previous empirical research findings. When students perceive strong teaching leadership, they often feel more support and encouragement (Goddard et al., 2021). Liu et al. (2022) suggest that teaching leadership, such as effective communication, encouraging feedback, and personalized teaching strategies, can significantly enhance students' academic self-efficacy. This enhancement not only boosts students' confidence in their learning abilities but also stimulates a positive attitude and sustained interest in learning (Akbari & Sahibzada, 2020). Students with high self-efficacy are more likely to engage in deep learning, which requires active participation, critical thinking, and creative problem-solving (Zhao & Qin, 2021). When students are confident in their learning abilities, they are more willing to tackle challenging tasks and complex problems, achieving deeper understanding and application in their learning process (WEI et al., 2021). Additionally, in the context of vocational education in Zhejiang Province, the education system emphasizes practical skills and applied knowledge. In this environment, teaching leadership is crucial in fostering students' academic self-efficacy. Effective leadership can help students better connect theory with practice, enhancing their confidence and abilities in practical applications (Puja Kesuma et al., 2021).

To further improve vocational students' deep learning levels, vocational colleges should emphasize effective communication, encouraging feedback, and the use of personalized teaching strategies in teacher training. Encouraging teachers to focus on cultivating students' academic self-efficacy through positive teaching interactions and support can boost students' confidence and interest in learning.

The Mediating Effect of Teacher-Student Interaction

The study found that H3: Teacher-student interaction among vocational students in Zhejiang Province, China, mediates the relationship between perceived teaching leadership and deep learning, supporting the research hypothesis H3. The analysis suggests that the enhancement of teacher-student interaction significantly improves both teaching initiative and student learning enthusiasm, which is crucial for deep learning. When teacher-student interaction decreases, teachers' teaching initiative and effort are insufficient, negatively impacting students' learning in a blended learning environment. Through leadership behaviors, teachers can guide students to participate more actively in exchanges, increasing the frequency and depth of teacher-student interactions. Moreover, teacher-student interaction serves as a bridge to achieve deep learning. In the learning environment of vocational students, positive teacher-student interaction helps students better understand and master deep learning-related knowledge. Teachers' guidance, answers, and encouragement can stimulate students to think actively and learn deeply, thereby promoting deep learning (Pires et al., 2020). Teacher-student interaction is not only a tool for knowledge transmission but also a medium for promoting deep thinking and subject understanding. Yokuş believes that teaching leadership can create a positive learning atmosphere, making teacher-student communication more open and constructive. This positive interaction environment helps stimulate students' interest in learning, guiding them to think deeply and explore, thus better achieving deep learning. Considering the characteristics of vocational education in Zhejiang Province, cultural factors, teaching concepts, and institutional arrangements might influence the relationship between perceived teaching leadership, teacher-student interaction, and deep learning.

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Based on these findings, vocational colleges should strengthen teacher-student interaction in blended learning environments by providing training and support to enhance teachers' initiative and interaction levels in teaching. Encouraging teachers to actively use leadership behaviors in teaching can stimulate students' positive attitudes towards deep learning. This will help create a more favorable teaching atmosphere, promote teacher-student interaction, and lead to more significant achievements in students' deep learning.

The Chain Mediation Effect of Academic Self-Efficacy and Teacher-Student Interaction

The study found that H4: Academic self-efficacy and teacher-student interaction among vocational students in Zhejiang Province, China, form a chain mediation effect between perceived teaching leadership and deep learning, supporting the research hypothesis H4. Talebizadeh et al. suggest that teachers' leadership, including communication skills, knowledge delivery methods, sensitivity to student differences, and motivational strategies, significantly impacts students' learning attitudes and behaviors. In the vocational education context of Zhejiang Province, this impact is particularly pronounced due to the emphasis on skills training and practical application, requiring teachers to have strong guidance and motivational abilities. When vocational students perceive strong teaching leadership, their confidence and sense of success in learning tasks are enhanced. This increased self-efficacy makes students more actively engage in the learning process and willing to explore new knowledge, thereby promoting deep learning. Teaching leadership not only enhances students' self-efficacy but also promotes positive teacher-student interaction. Good teacher-student interaction can provide more learning support and feedback, enhancing students' understanding and interest in the teaching content, further promoting deep learning. The improvement of vocational students' academic self-efficacy and the quality of teacher-student interaction leads to greater engagement and initiative in learning, fostering deep understanding and critical thinking, which are the core of deep learning.

To enhance the deep learning ability of vocational students in Zhejiang Province, it is recommended to strengthen teacher training in communication, knowledge delivery, and motivational strategies to stimulate students' learning interest and self-efficacy. By providing challenging learning tasks and positive feedback, students' academic self-efficacy can be cultivated. Personalized teaching strategies should be adopted, considering students' differences and meeting their individual learning needs. Regular evaluation and adjustment of teaching strategies should be conducted to ensure effective promotion of deep learning.

CONCLUSION

This study on factors influencing students' deep learning in a SPOC (Small Private Online Course) environment has several limitations. The sample, limited to vocational colleges in Zhejiang Province, restricts the generalizability of the findings to other regions. The use of a single questionnaire survey method, focusing mainly on vocational teachers and students, may introduce bias, and the research lacks dynamic tracking and in-depth analysis. Future research should expand the geographical scope, include diverse vocational institutions, and increase sample sizes for broader representativeness. A multi-perspective approach, incorporating factors like family background, social support, and school resources, is necessary. Additionally, employing mixed methods, including qualitative research and longitudinal studies, can provide richer insights into the long-term impact of SPOC environments on students' deep learning. Combining experimental designs with advanced data analysis techniques like structural equation modeling (SEM) could enhance the validity and comprehensiveness of future studies.

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The authors declare that there is no conflict of interest.

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Data curation: Qiujin Lu.
Methodology: Chunying Wang.
Formal analysis: Qiujin Lu.

Drafting - original draft: Qiujin Lu, Chunying Wang.
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