
Research article

Enhancing learning effectiveness in livestream teaching: Investigating the impact of teaching, social, and cognitive presences through a community of inquiry lens

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Abstract: Presence can promote online learners' learning effectiveness in higher education, but in livestream teaching, the influential relationship between different types of presence and learning effectiveness is unclear. Therefore, based on the Community of Inquiry (CoI) Framework, we used structural equation, hierarchical regression, and the Bootstrap self-serving method to conduct a survey on college students participating in livestream teaching practice. The research findings revealed that livestream teaching substantially impacts learning effectiveness, with teaching presence,

social presence, and cognitive presence all playing crucial roles. Notably, teaching presence has a significant positive influence on learning effectiveness through two key mediating factors: Social presence and cognitive presence. Consequently, three distinct mediating paths are identified. Among these three mediating paths, the most optimal route for teaching presence to enhance learning effectiveness is mediating cognitive presence. In conclusion, we recommend improving the livestream teaching environment, guiding learners toward active participation to promote a sense of embodiment, and elaborately designing livestream learning activities to improve interactivity. Finally, this paper offers evidence and insights for the improvement of livestream teaching in colleges, which will enhance learners' overall learning effectiveness.

Keywords: livestream teaching, teaching presence, social presence, cognitive presence, Community of Inquiry Framework (CoI), learning effectiveness

1. Introduction

Online education integrating "Internet plus" and "intelligence+" technologies has changed from emergency measures during the prevention and control of COVID-19 epidemic to the needs of connotative development of higher education and international development of education [1,2]. The Global Education Monitoring Report 2023 released by UNESCO pointed out that in 2021 alone, more than 220 million students participated in online learning [3]. How to ensure the learning effectiveness of online learners has always been a key research topic in the field of education. Online education teaching forms include livestream teaching, recorded stream teaching and MOOC teaching [4]. As an important form of online education, livestream teaching is an online teaching activity of real-time interaction between teachers and students relying on "Internet plus+" and "intelligence+" technology. It can enable teachers and students in different geographical locations to log in to the special network teaching platform or the general video and audio communication platform to carry out teaching across fields. It has three typical characteristics: the separation of teachers and students in space, the synchronization of teaching and learning time, and relying on digital resources and online communication media. In recent years, researchers have mainly focused on the construction of livestream teaching mode, the design of livestream teaching scenes, the optimization strategy of livestream teaching, and the effectiveness of livestream learning, and have accumulated certain research results. Research achievements of livestream teaching mode include the O2O livestream teaching mode, the teacher-student dialogue interaction mode [5], and so on. In the design research of livestream teaching scenes, it is proposed to make good use of the advantages of mobile media to design livestream teaching scenes [6] and pay attention to the advanced nature of livestream teaching tools and evaluate them [7]. The research on the optimization strategy of livestream teaching points out that we need to optimize the teaching concept, teaching methods, etc. [8] from the perspective of livestream teaching, establish an encouraging and supportive learning community, and achieve complete and flexible teaching preparation [9]. It also proposes the optimization strategies of effectively embedding questions in the context, promoting self-regulated learning through a task-driven approach, group cooperative learning based on peer assessment, providing appropriate learning support, and promoting thinking expansion through collaborative debate [10].

The learning effectiveness of livestream teaching refers to the benefits that learners gain through learning, including their subjective feelings and objective cognitive gains [11]. Existing research has compared livestream teaching with other teaching forms, such as recorded stream teaching, MOOC teaching, and traditional classroom teaching. The results have shown that students' satisfaction and learning effectiveness in livestream teaching are higher than in other teaching forms [4]. In addition, multiple studies have suggested that the sense of immediacy can enhance the learning effectiveness of learners in the online teaching [12–14].

Yet, we have identified two gaps in the existing studies: (1) For livestream teaching with high student' satisfaction and learning effectiveness, the relationship between the influence of different types of sense of presence and learners' learning effectiveness is not clear. There is a lack of practical guidance on further enhancing student satisfaction and learning effectiveness through increasing the sense of presence. (2) Researchers have used the Community of Inquiry framework to guide online teaching and have accumulated a number of research results, but there are no retrieved studies that focus on this theory to conduct research on livestream teaching. Therefore, conducting research on the relationship and effect of presence on college students' learning effectiveness has theoretical significance for enriching the CoI framework. Community of Inquiry (CoI) framework, as an important theory in the field of distance education, provides a detailed description of the interaction of different types of presence [15]. Therefore, exploring the relationships and effects of presence on livestream learning effectiveness based on the Community of Inquiry framework not only has theoretical compatibility and offers different perspectives for the attribution analysis of livestream learning effectiveness, but also provides understandable and operable strategy suggestions for effectively improving livestream teaching in practice.

2. Theoretical framework

2.1. Theoretical basis and problem focus

The Community of Inquiry Framework (CoI framework), co-founded by Canadian scholars Randy Garrison, Terry Anderson, and Walter Archer, holds a critical position in the field of distance education and has profoundly influenced the practice of teaching and learning in online education [16,17]. The Community of Inquiry Framework (CoI) (see Figure 1) integrates teaching presence, social presence, and cognitive presence based on the core of the educational experience, making it a guiding principle for the development of livestream teaching practices.

Teaching presence involves the design, facilitation, and direction of cognitive and social processes of the learners to foster meaningful and valuable learning outcomes, including three categories: design and organization, facilitating discourse, and direct instruction. Social presence is the ability of learners to develop interpersonal relationships through purposeful communication by demonstrating personal characteristics that are recognized by the group, including three categories: open communication, group cohesion, and effective expression. Cognitive presence refers to the degree to which learners construct meaning through continuous reflection and dialogue in the Community of Inquiry, encompassing four distinct phases: Triggering event, exploration, integration, and resolution, respectively. In the CoI framework, teaching presence, social presence, and cognitive presence intersect collaboratively to shape the educational experience in livestream teaching.

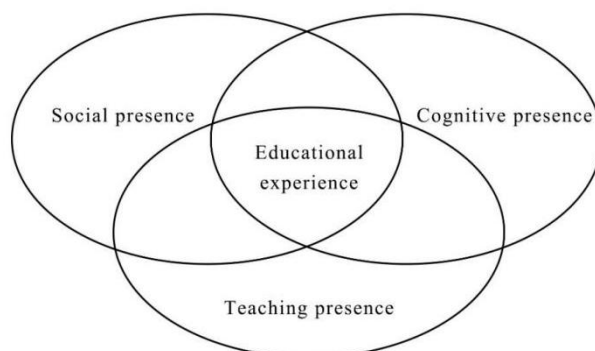


Figure 1. The Community of Inquiry Framework (CoI).

Since its introduction, the Community of Inquiry framework has received widespread attention from scholars and has now developed into a mature theory guiding online learning and blended learning [18]. Through reviewing relevant literature, it was found that many researchers have studied the three types of presence described by the Community of Inquiry framework and other variables related to online learning, such as online learning satisfaction, self-efficacy, critical thinking, etc. However, it is unclear how the influence relationship between different types of presence and learning effectiveness in livestream teaching is, which makes it impossible to improve learning effectiveness through targeted creation of presence.

Therefore, we attempt to build a theoretical model of the influence of teaching presence, social presence and cognitive presence on college students' learning effectiveness based on the Community of Inquiry Framework, and analyzes the relationship and effect of various types of presence on college students' learning effectiveness in livestream teaching, so as to provide some references for build the senses of presence in livestream teaching to promote the learning effectiveness. These are the questions to be explored in this study:

- (1) What is the impact and effect of teaching, social, and cognitive presence on the learning effectiveness of college students in livestream teaching?
- (2) How to build the senses of presence in livestream teaching to promote the learning effectiveness according to the analysis results?

2.2. Research framework

Through an examination of the relationship between teaching presence, social presence, and cognitive presence and their categories in the CoI framework, it can be found that the three types of presence have rich connotations and interact with each other to jointly form the teaching experience of livestream teaching. However, the community theory framework of these three types of presence lacks sufficient attention to the behavior and characteristics of learners in livestream teaching [19]. Under the system where exam is the main standard to measure learners' performance, it is difficult to explain the relationship between presence and learners' learning effectiveness. This study introduces learning effectiveness and explores the impact of teaching presence, social presence, and cognitive presence on learners' learning effectiveness in livestream teaching.

2.2.1. Interactions within the CoI framework

To study the impact of various elements within the CoI framework on learners' learning effectiveness in livestream teaching, it is first necessary to clarify the interactive relationship between teaching presence, social presence, and cognitive presence within the CoI framework. Teaching presence with its three categories of design and organization, facilitating discourse, and direct instruction, holds a central position in the community of inquiry framework, playing an important role in sustaining the entire community as well as social presence and cognitive presence. Social presence contains three categories: Open communication, group cohesion, and effective expression, which can effectively mitigate learners' sense of disconnection by improving their social interactions in online learning communities. Cognitive presence includes four sub-dimensions of triggering events, exploration, integration, and resolution, which reveals the extent to which learners acquire and apply knowledge through critical dialogue and reflection [19]. Goshtasbpour et al. used self-reported methods, combined with transcript analysis and in-depth interviews. They found that the majority of instructors' contributions to learner conversations are related to social presence, followed by teaching and cognitive contributions [20]. In a comprehensive study, Shea et al. examined a substantial research cohort comprising 2159 online learners. They concluded that students need to cultivate their individual sense of social presence, a factor intricately intertwined with their comprehension of teaching [21]. Hardin-Pierce et al. proposed that the establishment of the teaching presence can enhance students' immersive participation and improve learning outcomes. They noted that immersive online classes facilitate simulation and skills practice [22]. In their study of the online course "Modern Educational Technology," Bai Xuemei et al. established a significant connection between teaching presence and cognitive presence. Expanding on this, their subsequent investigation into sub-dimensions revealed that design and organization significantly impact the triggering event of cognitive presence, whereas facilitating discourse and direct instruction exert substantial influence over all four phases of cognitive presence [23]. In a related investigation, Rolim et al. explored the relationship between the categories of social and cognitive presences. They found that open communication significantly influences the triggering event and exploration phases, group cohesion exerts an impact on the exploration and integration phases of cognitive presence, and effective expression plays a significant role in the integration and resolution phases [24].

The aforementioned researches show that teaching presence, as a core component of the CoI framework, forms learners' initial perception of classroom teaching experience, positively impacting subsequent social presence and cognitive presence. In other words, teaching presence is the starting point of the entire CoI framework. Cognitive presence focuses on the embodied cognition of learners, which is the process of learners acquiring knowledge based on the interaction between their body, mind, and external experiences. It emphasizes learners' ability to discover problems in classroom teaching, explore and integrate experiences through collaboration, and solve problems. Therefore, it is influenced by social presence. Thus, the following hypotheses are proposed:

- H1: Teaching presence has a positive effect on cognitive presence.
- H2: Teaching presence has a positive effect on social presence.
- H3: Social presence has a positive effect on cognitive presence.

2.2.2. The relationship between CoI framework and learning effectiveness

Learning effectiveness refers to the benefits that learners obtain through livestream teaching,

which is an important indicator for measuring individual learner engagement and the quality of livestream teaching. The CoI framework starts with teaching presence, enhances students' perception of the livestream teaching classroom environment through the design and organization of courses, classroom interaction and dialogue, teaching and feedback, promotes their communication and cooperation in activities, compensates for the emotional loss during cross-field learning, and ultimately achieves the purpose of discovering and solving problems in the process of classroom embodiment participation. The CoI framework is a self-consistent theory framework with teaching experience as its core, but the ultimate goal of education and teaching lies in learners' acquisition of knowledge and abilities. How to transform the teaching experience into learners' learning effectiveness is worthy of attention from the academic field. The learning effectiveness includes cognitive dimensions (learners' objective cognitive gains) and non-cognitive dimensions (learners' subjective feelings) [25]. The cognitive level can be examined from the perspective of students' perceptual learning [26], while the non-cognitive level can be evaluated from the perspective of satisfaction [27]. Sung et al. explored the learning effectiveness of mobile devices in education through meta-analysis [28]. Zhong et al. integrated the design of cooperation and competition in robot education practice to improve learners' learning effectiveness [29]. Both studies suggest that learners can effectively improve their learning effectiveness through collaborative learning by building groups in social media. However, further explanation is needed for the relationship between the teaching organization and guidance, as well as learners' specific emotions and perception, and the learning effectiveness in the process of group learning. In summary, it can be inferred that the teaching presence, social presence, and cognitive presence in the CoI framework have a direct or indirect positive impact on learners' learning effectiveness. However, the specific way this impact occurs needs further exploration. Based on this, the present study proposes the following hypothesis:

H4: Teaching presence has a positive effect on learning effectiveness.

H5: Social presence has a positive effect on learning effectiveness.

H6: Cognitive presence has a positive effect on learning effectiveness.

2.2.3. The mediating effect of social presence and cognitive presence

Teaching presence is the core of the CoI framework, representing learners' in-depth perception of classroom teaching experiences. As the starting point of the entire framework, teaching presence has a crucial impact on learning effectiveness. Learning effectiveness refers to the benefits that learners obtain through livestream teaching, which is an important indicator for measuring individual learner engagement and the quality of livestream teaching. It is the goal of livestream teaching and manifests as learners' gains in knowledge, skills, and emotions. Social presence and cognitive presence are two factors that mediate between teaching presence and learner learning effectiveness. It is not clear what role they play in the process of teaching presence influencing learning effectiveness.

Social presence reflects the learners' participation in livestream teaching activities, which needs to be enhanced through the construction of teaching presence [22]. It aims at the realization of learners' cognitive presence and the improvement of learning effectiveness [21], playing the role of a mediating bridge between teaching presence, cognitive presence, and learning effectiveness. High participation in livestream teaching activities by learners can effectively alleviate the negative emotions caused by cross-field learning, enabling learners to fully immerse themselves in classroom learning, increasing the impact of teaching presence on cognitive presence, and thus promoting the improvement of learning effectiveness. Cognitive presence is directly related to the acquisition of

deep and meaningful learning. When learners encounter specific tasks or real-world problems, they feel perplexed and enter a state of learning. On this basis, they actively explore relevant information, integrate different viewpoints and ideas, and formulate solutions to solve the problem. Finally, after application and testing, learners can solve the problem and obtain satisfactory results [25]. Cognitive presence is acquired through practical exploration guided by teachers' design and instruction, which is directly related to learners' deep learning and critical thinking. It reflects the process of acquiring and applying higher-order knowledge [30]. The former relies on the design, organization, promotion of dialogue, and direct teaching in teaching presence, while the latter points to the perceived learning and satisfaction in learning effectiveness. Based on this, this study proposes the following hypothesis:

H7a: Teaching presence affects learning effectiveness through social presence.

H7b: Teaching presence affects learning effectiveness through cognitive presence.

H7c: Teaching presence affects learning effectiveness through social presence and cognitive presence in turn.

2.3. The relationship hypothesis model

Based on the CoI framework and the above analysis, this study explores the description of the three types of presence by the CoI theory. According to the relevance and importance of each type of presence to this study, we selected and designed variables for teaching presence, social presence, cognitive presence, and learning effectiveness. Teaching presence was grouped into design and organization, facilitating discourse, and direct instruction. Social presence was grouped into open communication, group cohesion, and effective expression. Cognitive presence was grouped into triggering event, exploration, integration, and resolution. Learning effectiveness was grouped into satisfaction and perpetual learning. We then constructed a relationship hypothesis model between the four variables as shown in Figure 2 and proposed the following hypothesis:

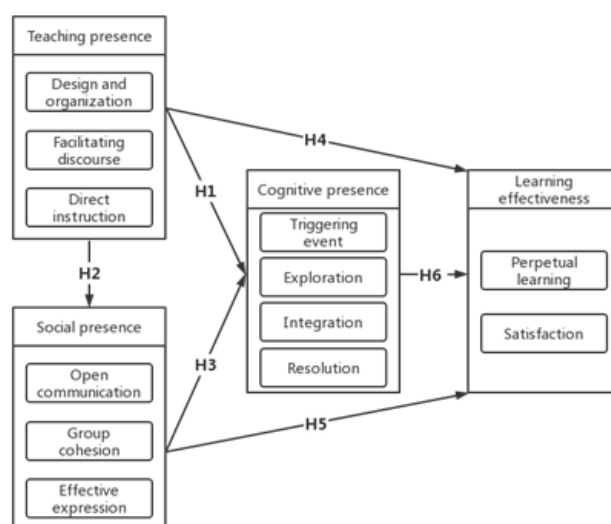


Figure 2. Relationship hypothesis model.

3. Research design

3.1. Development of survey questionnaires

The Community of Inquiry Survey (CoIS) was developed by Garrison [31] and is a proponent of the Community of Inquiry (CoI) theory. This survey has undergone empirical testing both in China and internationally [32]. The study employed the Chinese version of the Community of Inquiry (CoI) measurement instrument, revised and developed by Lan Guoshuai et al. [32], to obtain the observed data on teaching presence, social presence, and cognitive presence in the model. This measurement instrument has been partially adapted from the original English version to better fit the online learning environment in China.

For assessing learning effectiveness, the variables of perpetual learning and course satisfaction were designed with reference to the satisfaction measurement instrument developed by Aldhahi et al. in an online learning environment [33] and the perpetual learning measurement instrument developed by Thomas et al. for smart learning environments [34]. The survey consists of four questionnaires outlined below:

- 1) The teaching presence questionnaire comprises three categories: design and organization, direct instruction, and facilitating discourse, with a total of 13 items.
- 2) The social presence questionnaire consists of three dimensions: group cohesion, open communication, and effective expression, with a total of 5 items.
- 3) The cognitive presence questionnaire involves four aspects: triggering event, exploration, integration, and resolution, with a total of 9 items.
- 4) The learning effectiveness questionnaire with two components: perpetual learning and satisfaction, with a total of 8 items.

Table 1. Survey reliability and validity test results.

Variables	Factors	Factor load	Cronbach's α	CR value	AVE
Teaching presence	Design and organization	0.84	0.947	0.93	0.81
	Direct instruction	0.94			
	Facilitating discourse	0.93			
Social presence	Group cohesion	0.94	0.929	0.91	0.82
	Open communication	0.87			
	Effective expression	0.88			
Cognitive presence	Triggering event	0.88	0.961	0.95	0.84
	Exploration	0.91			
	Integration	0.92			
	Resolution	0.95			
Learning effectiveness	Perceptual learning	0.95	0.959	0.95	0.90
	satisfaction	0.95			

Table 1 displays the test results for the survey's convergence validity. Each group displays factor loads above 0.8, all variables boast Cronbach's α coefficients surpassing 0.9, the combined reliability (CR) value is over 0.9, and the Average Variance Extracted (AVE) value exceeds 0.8. These

outcomes validate the survey's robust reliability and validity, aligning with the criteria for explanatory variables.

3.2. Research subjects

The research subjects of this study are college students who participate in livestream courses, mostly including undergraduate students from L University and Z University. L University and Z University are located in the eastern and western regions of China, respectively, and are typical representatives of Chinese universities. These students have experienced livestream courses as typical participants of livestream teaching. From May to July 2022, the research team randomly distributed questionnaires through Wenjuanxing (an online crowdsourcing platform in mainland China), and a total of 395 questionnaires were distributed and collected, of which 357 were valid questionnaires with a validity rate of 90.37%.

Among the valid samples, 164 participants were male (45.9%) and 192 were female (54.1%). Additionally, the participants were distributed across different academic years, with 104 freshmen (29.1%), 80 sophomores (22.4%), 94 juniors (26.3%), and 79 seniors (22.1%). Furthermore, all 13 major categories were distributed in terms of majors.

3.3. Research methods

The collected questionnaires underwent reliability and validity testing, and the relevant data were analyzed using Amos 23.0 for structural equation analysis, SPSS 24.0 for multi-layer regression analysis of valid data, and the Process V3.3 plug-in to test the mediating effect. Structural equation modeling (SEM) is a method for establishing, estimating, and testing causal relationship models, which can clearly analyze the effects of individual indicators on the overall effect and the mutual relationship between individual indicators. Therefore, structural equation modeling can be used to study the impact of presence on college students' learning effectiveness in livestream teaching. However, structural equation modeling alone cannot exclude the possibility of masking effects. To avoid the first type of statistical error, this study refers to the research of Wen and Ye [35] and Li, Luo, and Ge [36], and decides to use hierarchical regression and the Bootstrap Method for additional verification, so as to make the results more reliable.

4. Analysis of research results

4.1. Confirmatory factor analysis

Initially, Amos was used to conduct confirmatory factor analysis for each variable. The results, presented in Table 2, reveal that the 4-factor model exhibited the following fit statistics: $\chi^2 = 159.944$, $df = 46$, $RMSEA = 0.083$, $RMR = 0.015$, $CFI = 0.979$, and $NFI = 0.971$. Notably, all indicators met the statistical standards. In addition, five alternative models were formulated based on the variable correlations, and their respective fitting indices proved to be less favourable compared to those of the 4-factor model. This underscores that the 4-factor model demonstrated superior discrimination validity.

Table 2. Confirmatory factor analysis results.

Model	χ^2	df	χ^2/df	RMSEA	RMR	CFI	NFI
4-factor model	159.944	46	3.477	0.083	0.015	0.979	0.971
3-factor model 1	328.408	51	7.498	0.138	0.019	0.939	0.930
3-factor model 2	490.609	51	9.620	0.156	0.021	0.919	0.911
3-factor model 3	484.019	51	9.491	0.154	0.023	0.920	0.912
2-factor model	634.103	53	11.964	0.175	0.023	0.893	0.885
1-factor model	828.466	54	15.342	0.201	0.027	0.857	0.849

Note: The 4-factor model includes teaching presence, social presence, cognitive presence, and learning effectiveness. The 3-factor models are as follows: 3-factor model 1 incorporates teaching presence, social presence, cognitive presence, and learning effectiveness; 3-factor model 2 integrates teaching presence, cognitive presence, social presence, and learning effectiveness; and 3-factor model 3 combines teaching presence, social presence, cognitive presence, and learning effectiveness. The 2-factor model consists of teaching presence, social presence, cognitive presence, and learning effectiveness. The 1-factor model includes all four factors together.

4.2. Descriptive statistics

Descriptive statistics and correlation analyses were conducted for each variable. The results of these analyses are shown in Table 3. Teaching presence displays noteworthy and favourable correlations with social presence ($r = 0.844$, $p < 0.01$), cognitive presence ($r = 0.838$, $p < 0.01$), and learning effectiveness ($r = 0.758$, $p < 0.01$). Social presence similarly showcases substantial and positive correlations with cognitive presence ($r = 0.822$, $p < 0.01$) and learning effectiveness ($r = 0.784$, $p < 0.01$). Moreover, cognitive presence indicates a significant and positive correlation with learning effectiveness ($r = 0.847$, $p < 0.01$). These findings serve as the foundation for subsequent hypothesis testing.

Table 3. Results of descriptive statistics and correlation analysis.

Variables	Mean	Standard deviation	Teaching presence	Social presence	Cognitive presence
Teaching presence	4.35	0.63			
Social presence	4.27	0.75	0.844**		
Cognitive presence	4.30	0.69	0.838**	0.822**	
Learning effectiveness	4.24	0.77	0.758**	0.784**	0.847**

Note: ** indicates significance at the 0.01 level (two-tailed), confirming a significant correlation.

4.3. Hypothesis testing

4.3.1. Structural equations for hypothesis testing

In this study, Amos was utilized for the purpose of hypothesis testing to validate the effects of teaching presence, social presence, and cognitive presence on learning effectiveness in livestream teaching. The analysis results in the optimal model (see Figure 3) with the following model-related fit data: $\chi^2 = 176.987$, $DF = 47$, $RMSEA = 0.088$, $CFI = 0.976$, $NFI = 0.968$, $IFI = 0.976$, and $GFI = 0.923$. Notably, all of these indices satisfy the established statistical criteria.

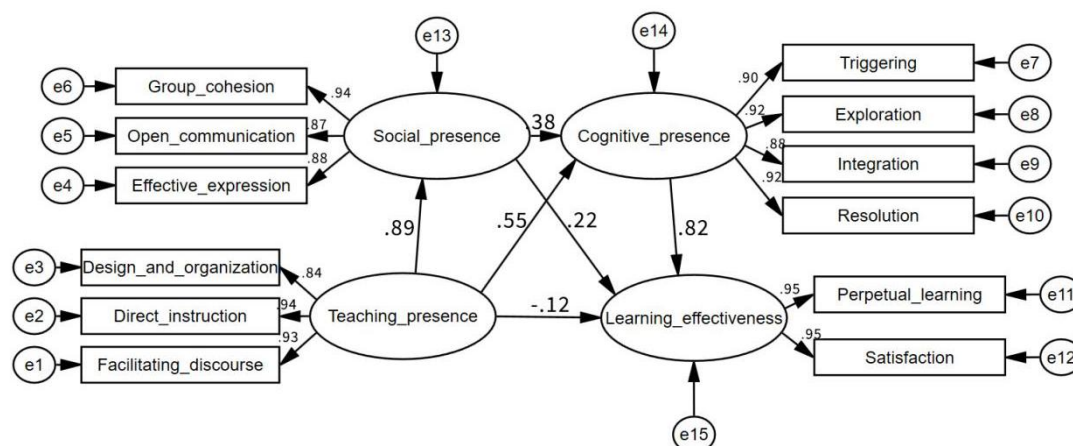


Figure 3. Hypothesis testing results – Structural equations.

Table 4 presents the tested values of the model parameters. Teaching presence significantly contributes to the social presence ($\beta = 0.891$, $p < 0.001$) and positively impacts cognitive presence ($\beta = 0.551$, $p < 0.001$), confirming the validation of H1 and H2. Additionally, it is observed that social presence significantly and favourably affects cognitive presence ($\beta = 0.383$, $p < 0.001$), thus affirming the verification of H3. Conversely, the effect of teaching presence on learning effectiveness is not statistically significant ($p = 0.183$), indicating that H4 is not validated. Furthermore, it is noteworthy that social presence significantly and positively contributes to learning effectiveness ($\beta = 0.218$, $p < 0.010$), while cognitive presence similarly exerts a positive impact on learning effectiveness ($\beta = 0.821$, $p < 0.001$). These findings further support the validation of H5 and H6.

Table 4. Test values of structural equation model parameters and validation of research hypotheses.

Hypothesis	Model path	Standard path estimate	S.E.	C.R.	P	Research hypothesis
H1	Social presence ← Teaching presence	0.891	0.183	8.203	***	accept
H2	Cognitive presence ← Teaching presence	0.551	0.168	8.387	***	accept
H3	Cognitive presence ← Social presence	0.383	0.095	3.198	***	accept
H4	Learning effectiveness ← Teaching presence	-0.123	0.127	3.632	0.183	reject
H5	Learning effectiveness ← Social presence	0.218	0.182	2.674	0.010	accept
H6	Learning effectiveness ← Cognitive presence	0.821	0.062	8.63	***	accept

Note: *** indicates significance at the 0.001 level, confirming a significant correlation.

Significantly, upon the completion of the structural equation model test, it becomes apparent that teaching presence does not exert a noteworthy influence on learning effectiveness. However, the correlation analysis presents a significant and positive correlation between teaching presence and learning effectiveness ($r = 0.758$, $p < 0.01$). As shown in Figure 3, teaching presence indirectly shapes learning effectiveness by positively affecting both social presence and cognitive presence, suggesting a mediating effect of teaching presence on learning effectiveness. To enhance the robustness of the findings and mitigate the potential for Type I errors, this study aligns with the

methodology outlined by Wen Zhonglin [35] and Li Shuwen [36], employing hierarchical regression and the Bootstrap Method for additional validation.

4.3.2. Hierarchical regression for hypothesis testing

The test results of hierarchical regression analysis are presented in Table 5. According to Model 1, Model 2, and Model 4, teaching presence indicates a substantial and positive impact on social presence ($\beta = 0.840$, $p < 0.001$), cognitive presence ($\beta = 0.837$, $p < 0.001$), and learning effectiveness ($\beta = 0.751$, $P < 0.001$). $p < 0.001$), confirming the validation of H1, H2 and H4.

Based on Model 3 and Model 5, social presence demonstrates a positive effect on cognitive presence ($\beta = 0.819$, $p < 0.001$) and learning effectiveness ($\beta = 0.778$, $p < 0.001$), confirming the validation of H3 and H5.

In Model 6, cognitive presence evidences a substantial and positive effect on learning effectiveness ($\beta = 0.842$, $p < 0.001$), thereby validating H6.

Furthermore, within the framework of Model 7, considering the collective influences of teaching presence, social presence, and cognitive presence, it is evident that teaching presence does not yield a significant positive impact on learning effectiveness ($\beta = 0.778$, $p = 0.750$). In contrast, social presence distinctly manifests a noteworthy and positive effect on learning effectiveness ($\beta = 0.257$, $p < 0.001$). Moreover, cognitive presence asserts a robust and markedly positive influence on learning effectiveness ($\beta = 0.618$, $p < 0.001$).

Through a comprehensive validation of Model 4, Model 5, Model 6, and Model 7, a notable trend emerges. The regression coefficient value attributed to teaching presence in relation to learning effectiveness undergoes a reduction from 0.751 to 0.018, rendering it statistically insignificant. Similarly, the regression coefficient values associated with social presence and cognitive presence concerning learning effectiveness diminish, transitioning from 0.778 and 0.842 to 0.257 and 0.618, respectively.

The outcomes collectively signify a significant insight: social presence and cognitive presence act as full mediators in the link between teaching presence and learning effectiveness. Thus, the confirmed validation of hypotheses H7a, H7b, and H7c is evident.

Table 5. Results of hierarchical regression analysis.

Variables	Social presence	Cognitive presence		Learning effectiveness			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Teaching presence	0.840***	0.837***		0.751***			0.018
Social presence			0.819***		0.778***		0.257***
Cognitive presence						0.842***	0.618***
Gender	-0.030	-0.040	-0.017	-0.003	0.024	0.039	0.034
Grade	-0.034	0.018	-0.005	-0.056	-0.042	-0.051	-0.039
Major	0.009	0.006	0.022	-0.007	-0.003	-0.013	-0.017
R2	0.714	0.705	0.676	0.577	0.618	0.722	0.740
F	219.598***	209.867** *	183.350** *	120.175** *	142.103** *	228.295** *	170.085** *

Note: *** indicates significance at the 0.001 level, confirming a significant correlation.

4.3.3. The Bootstrap method for the mediating effect test

Drawing from the abovementioned tests and analyses, the Bootstrap method is further used to examine the mediating effect of social presence and cognitive presence between teaching presence and learning effectiveness. The test results are shown in Table 6, where "Direct effect" appraises the influence of teaching presence on learning effectiveness before incorporating mediating variables, and "Total mediating effect" evaluates the impact after the inclusion of mediating variables. "Path 1" tests the mediating effect of social presence on teaching presence and learning effectiveness, while "Path 2" examines the mediating effect of cognitive presence on teaching presence and learning effectiveness. Additionally, "Path 3" explores the chain mediating effect of social presence and cognitive presence on teaching presence and learning effectiveness. Furthermore, the "Difference test" evaluates the presence of significant distinctions between two distinct pathways.

As illustrated in Table 6, the Bootstrap method test reveals an effect value of 0.9206 for the total mediating effect. The associated 95% confidence interval is [0.8358, 1.0054]. Notably, the confidence interval does not encompass the value 0. This finding holds significant implications, indicating a pronounced positive impact of teaching presence on learning effectiveness, even in the absence of mediating variables. This suggests that the relationship between teaching presence and learning effectiveness is robust and remains statistically significant without considering potential intermediary factors. In contrast, the direct effect analysis shows that the effect value is 0.0225, and the associated 95% confidence interval is [-0.1159, 0.1609]. Importantly, the confidence interval encompasses the value 0. This observation suggests that, with the inclusion of mediating variables, there is no statistically significant effect of teaching presence on learning effectiveness.

Taken together, these outcomes point towards a complete mediation effect between teaching presence and learning effectiveness. This aligns consistently with the results obtained through hierarchical regression analysis.

We examined the mediating effects of social presence and cognitive presence in the relationship between teaching presence and learning effectiveness. In line with Path 1, the mediating effect of teaching presence on learning effectiveness via social presence is quantified at 0.2698, with a 95% confidence interval of [0.1311, 0.4085]. Notably, the confidence interval excludes the value 0, underscoring the significance of social presence as a mediator between teaching presence and learning effectiveness. As a result, H7a is validated.

Continuing to path 2, the mediation analysis reveals a mediating effect of 0.3938 for teaching presence on learning effectiveness through cognitive presence. The associated 95% confidence interval of [0.2598, 0.5277] further supports the notion of a distinct effect. This outcome emphasizes cognitive presence's role as a substantive mediator between teaching presence and learning effectiveness, confirming the validation of H7b.

Finally, path 3 delves into the combined mediating effects of social presence and cognitive presence. The analysis establishes a mediating effect value of 0.2542, with a 95% confidence interval of [0.1637, 0.3446]. As with the previous paths, the confidence interval's exclusion of 0 underscores the consequential role of the intertwined social presence and cognitive presence as a chain mediator between teaching presence and learning effectiveness. Consequently, H7c is verified.

Through a comparative analysis of the various mediating paths, it becomes evident from the first distinction that path 2 displays a notably stronger mediating effect when contrasted with path 1. Furthermore, upon examining the second distinction, no substantial distinction emerges between path

1 and path 3. However, the third distinction highlights a significant difference between path 2 and path 3, showcasing path 2's more pronounced mediating impact compared to path 3.

Collectively, these findings highlight that the path wherein teaching presence influences learning effectiveness via cognitive presence emerges as the optimal pathway. The conclusion is drawn from the discernible differences in mediating effects observed between the different paths.

Table 6. Test results of the mediating effect, using the Bootstrap method.

Mediating path	Point estimate	95% confidence interval	
		Lower limit	Upper limit
Direct effect	0.0225	-0.1159	0.1609
Total mediating effect	0.9206	0.8358	1.0054
Path 1 = JX → SH → XG	0.2698	0.1311	0.4085
Path 2 = JX → RZ → XG	0.3938	0.2598	0.5277
Path 3 = JX → SH → RZ → XG	0.2542	0.1637	0.3446
Difference 1 = path 1 - path 2	-0.6636	-0.3909	-0.9362
Difference 2 = path 1 - path 3	0.0157	-0.0326	0.0639
Difference 3 = path 2 - path 3	0.1396	0.0961	0.1831

5. Theoretical implications and practical implications

5.1. Theoretical implications

Based on the community of inquiry framework, we have developed a comprehensive research model aimed at investigating the impact of teaching presence, social presence, and cognitive presence on learning effectiveness. The research hypotheses were rigorously assessed through the application of a structural equation model, hierarchical regression analysis, and the Bootstrap method. The theoretical implications of this study include the following three aspects:

5.1.1. *Fostering learning effectiveness through the enhancement of three types of presence*

The findings underscore substantial and positive impacts exerted by teaching presence, social presence, and cognitive presence on the improvement of learning effectiveness. Previous research has pointed out the significance of teaching presence, as evidenced by instructors' skillful utilization of nonverbal cues [37] and immersive technology [38] in the context of livestream instruction. Likewise, the nurturing of social presence through collaborative online learning or joint construction of knowledge [39], coupled with the development of cognitive presence encompassing the stages of triggering, exploration, integration, and resolution [40], have all been substantiated in prior research as significant contributors that collectively improve learners' overall learning effectiveness. Drawing upon teaching practice as a foundation, this study validates the favorable impacts of teaching presence, social presence, and cognitive presence on learning effectiveness using the structural equation, hierarchical regression, and Bootstrap Method approaches. These findings are consistent with the perspectives put forth in prior research.

Contemporary learning theories, encompassing behaviorism, cognitivism, constructivism, and humanism, all converge on the core principle that experience forms the bedrock for acquiring

knowledge and skills. According to these theories, learners learn best through hands-on experiences. In consonance with this perspective, the teaching presence, social presence, and cognitive presence advocated by the Community of Inquiry (CoI) framework revolve around enriching learners' experiences, while learning effectiveness reflects the advancement of learners' knowledge and skills gained through livestream teaching. The shift from the community of inquiry framework to learning effectiveness signifies the evolution from experiential learning to the acquisition of knowledge and abilities.

5.1.2. Unveiling mediation: Teaching presence's impact on learning effectiveness

Leveraging the framework underpinning this study, the impact of teaching presence on learning effectiveness exhibits complete mediation. Moreover, the influence on learning effectiveness unfolds via three distinct intermediary channels: the first orchestrated by social presence, the second navigated through cognitive presence, and a third avenue characterized by the combined mediation of both social and cognitive presence. Initially, teaching presence indicates a significant and positive influence on learning effectiveness, independently of social presence and cognitive presence. However, this effect loses significance upon the introduction of mediating variables. According to Wen Zhonglin et al. [35], this outcome exemplifies a full mediation effect, signifying that teaching presence entirely shapes learning effectiveness through mediating mechanisms. This intricate process involves three pathways of mediation: one through social presence, another through cognitive presence, and a sequential chain of mediation involving both.

Within the context of the learning environment, the process of learning is characterized as a series of orchestrated steps, engaging learners peripherally in a particular area of expertise [40]. The transformation of teaching presence into learning effectiveness hinges on active social engagement, evident through study groups and collaborative discussions, which underscores the pivotal role of social presence as a mediator. Pertaining to the subject matter of learning, it involves the constructive assimilation of knowledge by the learners themselves. Guided and mentored by educators, learners meticulously construct meaning to attain mastery over knowledge, thus substantiating the role of cognitive presence as a mediator. In terms of the embodied nature of learning, it involves a cognitive construction process that is intrinsically intertwined with bodily perception. This includes both the autonomous self-learning construction process based on self-bodily perception and the interactive learning construction among peers. This setup establishes another route from teaching presence to learning effectiveness, validating the presence of a chain mediation between social presence and cognitive presence.

5.1.3. Optimal path of mediation: Teaching presence's impact on learning effectiveness through cognitive presence

Among the pathways that mediate the impact of teaching presence on learning effectiveness, the path where teaching presence exerts its effect through cognitive presence emerges as the most effective. Livestream teaching, as a cross-field online mode, faces unique challenges in nurturing social presence due to constraints imposed by platform selection and network connectivity. These limitations impede the augmentation of social presence. Conversely, cognitive presence remains unaffected by these challenges. Hence, educators can proactively enhance learners' cognitive

engagement by attentively addressing their needs, linking new knowledge to their prior experiences, and fostering a sense of relevance.

Extant research highlights the importance of addressing learners' needs and optimizing the design of online courses as pivotal strategies to improve the quality of open online courses [41]. Irrespective of whether education is delivered through online, offline, or blended approaches, the goal is to refine the teaching process and improve learning effectiveness, while maintaining a central focus on fostering comprehensive student development.

Within this transition journey from teaching to learning effectiveness, learners' perception assumes a pivotal role. It serves as a bridging element, harmoniously weaving together the dimensions of presence and learning effectiveness. This synthesis reaches a dynamic unity, driving multi-dimensional enhancement and advancing the overall learning experience.

5.2. Practical implications

The practical implications of the research results of this study for the effective implementation and further promotion of livestream teaching are as follows:

5.2.1. *Unveiling mediation: Teaching presence's impact on learning effectiveness*

The derived conclusions highlight the substantial impact of enhancing three essential forms of presence - teaching, social, and cognitive - in effectively advancing learning effectiveness. Consequently, the foremost aim lies in fostering the sense of presence during livestream teaching sessions. In the context of cross-field pedagogy, livestream teaching necessitates the shift from a passive teaching approach, marked by fragmented subject boundaries, to a dynamic mode of active learning rooted in contextual connection. This transition resonates with the situational cognition theory, which emphasizes the context-dependent nature of learners' cognitive processes, intricately woven with the functional interplay between the individual and the specific situational context [42].

Cultivating an open, interconnected, observable, and truth-oriented livestream teaching environment aligns seamlessly with the primary objective of enhancing teaching presence. This proactive strategy facilitates the establishment of a robust sense of presence, effectively reinforcing the three key dimensions: Teaching presence, social presence, and cognitive presence. Enhancing the authenticity of learning situations and enriching the sense of presence in livestream teaching can be obtained through two distinct approaches. The first approach consists of capitalizing the inherent features of the live platform, such as portrait displays, roll call queries, and interactive chat discussions, so that the sense of presence can be enhanced. The second approach involves a deliberate emphasis on innovation within the livestream teaching context, facilitated by the integration of intelligent technology. This involves using intelligent teaching tools like Rain Classroom¹, Learning Pass², and others, to facilitate activities such as offline classroom responses, in-class exercises, role-playing, and various interactive activities. The incorporation of such tools enables learners to immerse themselves in an environment similar to on-site teaching, thereby fostering a deep sense of involvement and active interaction.

1 Rain Classroom. Welcome to use Rain Classroom! [EB/OL]. [2023-07-28]. <https://www.yuketang.cn/>.

2 Chaoxing. Learning Pass [EB/OL]. [2023-07-28]. <https://app.chaoxing.com/>.

The integration of cutting-edge technologies like virtual reality (VR), augmented reality (AR), and metaverse can further elevate the teaching experience. By creating dynamic real-time interactive environments that seamlessly blend virtual and real elements, along with multi-scene transformative setups, both educators and students can fully engage in an immersive classroom experience. Through the utilization of big data, cloud computing, and other technologies, we can collect students' learning data throughout the whole process and conduct real-time online analysis considering different feedback from learning activities. This helps us in achieving comprehensive wisdom diagnosis and adaptive improvisation in livestream teaching.

Additionally, creating authentic situations as described above enables learners to actively participate in the teaching content and classroom discussions set up by teachers. This enhances the teaching presence, which in turn boosts learners' social presence and cognitive presence. Ultimately, all these elements come together to enhance the overall effectiveness of learning.

5.2.2. Guidance

The research findings indicate that the impact of teaching presence on learning effectiveness is influenced by both social presence and cognitive presence, as well as their interconnected mediation. Notably, the pathway in which teaching presence affects learning effectiveness through cognitive presence emerges as the most efficient route. Within the context of livestream teaching, social presence reflects learners' active engagement in learning activities, and a robust level of learner engagement proves effective in counteracting potential negative emotions often associated with cross-field learning [43]. Furthermore, complete engagement in classroom learning further enhances the extent to which teaching presence influences cognitive presence [31].

As mentioned earlier, cognitive presence focuses on the concept of the learner's embodied cognition, involving the process of knowledge acquisition through the interplay of the body, mind, and external experiences. Embodied learning emphasizes the integration of learners' knowledge, feelings, and intentions, viewing it as a holistic endeavor that unfolds during the interaction between the individual and their environment. Encouraging learners to explore their inherent psychological resources and external situational conditions fosters novel insights through in-depth analysis and positive cognitive processes, emphasizing the importance of achieving a dynamic balance among mind, body, and environment [44].

Therefore, beyond creating a dynamic livestream teaching environment, teachers must take additional measures to facilitate active learner engagement, encourage embodiment, and ensure meaningful participation. These efforts collectively contribute to overall course effectiveness within the framework of the community of inquiry. Regarding teachers' roles, they ought to assume a guiding position in livestream teaching, taking the initiative to steer learners towards group discussions, collaborative learning, and similar undertakings that cultivate social presence, all while nurturing learners' autonomy in addressing challenges. Learners should consider themselves as the core participants in the class and actively engage in livestream teaching, integrating these experiences into their learning journey. By engaging in collaborative exploration through group cooperation and practical exercises grounded in real-life scenarios, learners can internalize classroom challenges and essential knowledge components, leading to an elevated understanding and proficient utilization of information. This process culminates in the optimization of their learning achievements.

5.2.3. *Enhancing*

Teaching activities entail two-way interactions involving teachers' instructions and learners' learning processes [45]. The primary purpose of teaching activities is to stimulate the development of learning activities and ensure authentic knowledge assimilation. Carefully designed and implemented live learning activities possess the potential to promote emotional communication between teachers and learners, bridge geographical divides inherent in livestream teaching, and facilitate the shift from knowledge transmission to dynamic knowledge creation. This progression significantly augments the overall effectiveness of learners' educational experiences. Notably, research has demonstrated that the arrangement of learning activities shapes the teaching paradigm [45]. Therefore, the deliberate design and strategic sequencing of live learning activities contribute to the evolution of the livestream teaching model, nurturing innovation in pedagogical approaches.

Livestream learning activities encompass several key categories, including comprehension and creation exercises, interactive sharing sessions, and evaluation and reflection tasks [46]. Within these categories, comprehension and creation activities involve learners engaging with livestream lectures and actively participating in activities such as role-playing, case analysis, and problem-solving. Interactive sharing activities include real-time discussions and Q&A sessions between teachers and learners, peer interactions, collaborative group work, debates, presentations, and the utilization of course materials, handouts, educational games, virtual experiments, and other resources. Evaluation and reflection activities involve quizzes, self-assessment, peer assessment, voting, and reflective writing.

Given their pivotal role, teachers must not only select and design learning activities that align with the content of the taught knowledge but also thoughtfully arrange the sequence of these activities to innovate the livestream teaching approach. Additionally, technology integration is essential for live learning activities, incorporating interactive features of the livestream teaching platform, intelligent technology-supported tools, and the comprehensive application of multiple platform resources. Continuous attention to the appropriateness of technology and the effectiveness of interaction remains crucial.

In summary, meticulously crafted live learning activities foster heightened interaction among the four key components: Teachers, students, resources, and environment. This interaction seamlessly blends teaching, social, and cognitive presence within the activity. Such fusion facilitates discourse facilitation and direct instruction within teaching presence, fosters open communication, strengthens group cohesion, and encourages effective expression in the context of social presence. Additionally, it prompts the phases of triggering, exploration, integration, and resolution within cognitive presence. This collective synergy significantly contributes to a noteworthy enhancement in learners' overall learning effectiveness.

6. **Limitations**

The limitations of this study mainly lie in the representativeness and scale of the research sample. The subjects of this study are limited to students from L University and Z University who participate in livestream teaching. Although these two universities are representatives of universities in China's eastern and western regions, there are a large number of universities in China, and it is difficult to represent the entire picture of Chinese college students by only surveying students from two

universities who participate in livestreaming teaching. In this study, a total of 357 valid questionnaires were collected, which is a relatively small sample size compared to the total number of Chinese college students participating in livestream teaching. The collected data may not be representative of the entire group, and the analysis results may be biased. In future studies, it is necessary to address the issues of insufficient sample representativeness and size to improve the reliability and validity of the research.

Our focus of this study is on the impact relationship between three types of presence (cognitive presence, teaching presence, and social presence) in livestream teaching and learning effectiveness. In the future, we can start from a single type of presence and explore its impact on learning effectiveness in livestream teaching, thereby obtaining more accurate research conclusions. In addition, future research can also conduct continuous follow-up surveys on the same sample group to explore the long-term dynamic impact mechanism of the same sample group in different semesters or different livestream courses.

Use of AI tools declaration

The authors declare that they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declare that there are no conflicts of interest in this article.

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