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Research Article

The mediating role of digital skills between teaching presence and cognitive presence: A structural equation modeling analysis

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With the rapid advancement and widespread use of information and communication technologies, computer-supported collaborative learning has become an important pedagogical method in higher education. To enhance the effectiveness of computer-supported collaborative learning, educators must understand the factors influencing cognitive presence in this learning environment. This study investigated the associations among teaching presence, digital skills, and cognitive presence in computer-supported collaborative learning, and tested the mediating effect of digital skills on the association between teaching presence and cognitive presence among undergraduate students in China. This study adopted a quantitative, cross-sectional research design. A multistage stratified random sampling was used to select 608 undergraduate students from a college in China. Data were collected via online structured questionnaires and analyzed using structural equation modeling in IBM SPSS Amos. The research results indicated that teaching presence is positively associated with digital skills and cognitive presence within the hypothesized model. Meanwhile, digital skills demonstrated a positive association with cognitive presence. The findings provide cross-sectional evidence consistent with digital skills functioning as an important intermediary mechanism linking perceived teaching presence with cognitive presence in CSCL among the sampled Chinese undergraduates. The findings provide higher education educators with a novel perspective for implementing more effective computer-supported collaborative learning practices. Specifically, this study integrates three interrelated dimensions, including teaching presence, digital skills, and cognitive presence, and underscores that digital skills serve as a crucial correlational mediating factor that links teaching presence and cognitive presence in the computer-supported collaborative learning context. Future longitudinal or experimental research is warranted to verify the causal associations among the three variables.

Keywords: Cognitive presence; Computer-supported collaborative learning; Digital skills; Higher education; Structural equation modeling; Teaching presence

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1. Introduction

The rapid advancement and widespread use of information and communication technologies (ICTs) have driven adaptive changes in both workplace and academic settings. The challenges facing academia and industry are becoming increasingly complex and interdisciplinary, making

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them difficult to address through isolated efforts (Chai et al., 2024; Fiore et al., 2018). These changes require higher education students to develop collaborative problem-solving (CPS) skills for both academic and future professional challenges. Computer-supported collaborative learning (CSCL) has enabled students to engage collaboratively in solving complex academic tasks (Kaliisa et al., 2025; Luengo-Aravena et al., 2024; Ouyang et al., 2021). In addition, this pedagogical approach has considerable potential to enhance learning experiences, facilitate student engagement, and improve academic outcomes (Li et al., 2024; Lin et al., 2022; Zabolotna et al., 2023). However, a large-scale study by the Organisation for Economic Co-operation and Development (OECD) shows that most students still have relatively low CPS proficiency in most countries (OECD, 2017). To enhance graduates' employment competitiveness and career prospects, higher education institutions and educators must equip students with strong CPS skills through effective CSCL practices.

CSCL integrates various ICTs into collaborative learning activities, enabling two or more students to actively engage in either synchronous or asynchronous collaboration to achieve common learning goals (Kaliisa et al., 2025; Ouyang & Zhang, 2024). Effective CSCL environments could significantly enhance students' interaction, collaboration, and engagement during their CPS process, thereby promoting their cognitive development and knowledge co-construction (Kaliisa et al., 2025; Zabolotna et al., 2023). However, simply providing students with the opportunity to participate in CSCL activities does not guarantee active learning engagement, high-quality social interaction, meaningful team collaboration, or valuable cognitive outcomes (Chen et al., 2024; Fathali, 2024; Zabolotna et al., 2023). Integrating ICTs into CSCL has broadened the diversity of the learning environment while concurrently increasing its complexity. This complexity may pose difficulties for many teachers lacking the requisite expertise and experience to effectively conduct CSCL practices, and for many students who lack the necessary skills and experience.

The Community of Inquiry (CoI) framework proposed by Garrison et al. (2000) is widely acknowledged by scholars and identifies three interrelated elements in CSCL environments, including teaching presence, social presence, and cognitive presence (Fathali, 2024; Mutezo & Mare, 2023; Shea et al., 2022). The CoI framework underscores the necessity for teachers to strengthen students' social presence through effective teaching presence, thereby ultimately facilitating their cognitive presence in CSCL environments (Arbaugh et al., 2008; Garrison et al., 2000; Garrison & Arbaugh, 2007; Shea et al., 2022). The CoI framework aims to improve students' cognitive presence in learning environments to support meaningful knowledge construction (Garrison et al., 2000). However, effective teaching presence does not necessarily guarantee higher levels of cognitive presence among students (Fathali, 2024; Mutezo & Mare, 2023). After over two decades of technological advancement and educational reform, factors beyond social presence may also influence students' cognitive presence in CSCL environments. Thus, it is necessary to examine additional potential influencing factors, thereby better supporting higher education educators in designing and implementing effective CSCL environments that improve students' CPS performance.

Garrison et al.'s (2000) CoI framework is grounded in Vygotsky's (1978) sociocultural theory. Vygotsky (1978) posited that learners can attain higher-order cognitive development through social interactions with more knowledgeable others within a cultural context, facilitated by teaching scaffolding. Existing research mainly examines associations among cognitive, social, and teaching presence, but pays relatively little attention to the skills learners need for effective digital-mediated learning. Digital skills may constitute this critical, yet underexplored, learner-level mechanism in CSCL. In CSCL environments that integrate ICTs, learners' digital skills may play a pivotal role in their CPS processes. According to Vygotsky's (1978) theory, learners' higher-order cognitive development is mediated by cultural tools. These cultural tools include books, media, ICTs, languages, concepts, or symbols. The impact of ICTs on learning depends not only on teachers' pedagogical choices and instructional design, but also on students' digital skills. Students' digital skills are likely to shape their learning experience and academic outcomes in CSCL

environments (Bond, 2020; Bond et al., 2020). The effect of extrinsic CSCL practices is influenced by students' intrinsic digital skills, which could affect students' ability to internalize educational content into their own knowledge and skills.

Due to the integration of ICTs in CSCL environments, digital skills are expected to influence students' CPS performance. Effective integration of ICTs holds significant potential to enhance teaching effectiveness, foster greater student engagement, enrich learning experiences, and improve learning outcomes in collaborative learning environments (Bond, 2020; Bond et al., 2020). The extent of such digital enhancement depends not only on educators' strategic planning and digital integration, but also on their digital skills and practical experience (Aldahdouh & Nokelainen, 2026; Hazzam & Wilkins, 2023; Rubach & Lazarides, 2021). However, most current research primarily focuses on how teachers' digital skills, attitudes, or beliefs shape their teaching practices (Rubach & Lazarides, 2021), overlooking students' digital skills and their impact on learning performance in CSCL environments.

In CSCL environments, teachers strategically integrate various ICTs to design and implement teaching practices for enriching students' learning experiences and performances (Aldahdouh & Nokelainen, 2026; Luengo-Aravena et al., 2024). Compared with traditional offline collaborative learning, CSCL may be more dependent on students' digital skills, due to the integration of ICTs. Different levels of digital skills among students will impact their perception of teaching presence. Luengo-Aravena et al. (2024) reported that students with lower digital skills showed lower satisfaction with CSCL practices compared to their peers with higher digital skills. Meanwhile, digital skills can be taught (Rubach & Lazarides, 2021), and thus may be influenced by the teaching presence. By offering teaching opportunities, scaffolding support, and digitally mediated learning activities, students may be able to more effectively use digital technologies for information management, communication, collaboration, content creation, and reflection.

With the continuous development of ICTs, digital skills have become increasingly indispensable in the CSCL. In the 21st century, digital skills have evolved beyond purely technical level and reached the cognitive level (Van Laar et al., 2017, 2020). Digital skills enable individuals to search, analyze, reflect on, and evaluate digital information to solve complex problems (Aldahdouh & Nokelainen, 2026; Aesaert et al., 2014; Rubach & Lazarides, 2021). Therefore, digital skills may influence students' cognitive presence, or they may be affected by their cognitive capabilities. But the influences among teaching presence, digital skills, and cognitive presence in the CSCL environment remain insufficiently understood. Investigating the specific relationships among teaching presence, digital skills, and cognitive presence could empower higher education professionals to design and implement more effective CSCL practices tailored to students' characteristics.

The CoI framework elucidates how teaching presence fosters cognitive presence through teaching design, support, and instruction (Garrison et al., 2000). But this framework does not account for how students' digital skills enable them to effectively translate these pedagogical opportunities into tangible cognitive development, especially in technology-driven CSCL environments. Despite providing well-designed teaching presence to promote social presence in CSCL, many students' cognitive presence remains a low levels (Fathali, 2024). This may stem from students' inadequate digital skills. Given potential mutual influences among teaching presence, digital skills, and cognitive presence, digital skills may be a key mechanism for transforming the teaching presence into meaningful cognitive presence. Although the relationships among teaching presence, social presence, and cognitive presence have been well studied (Arbaugh et al., 2008; Garrison et al., 2000; Garrison & Arbaugh, 2007; Shea et al., 2022), the effect of digital skills in CSCL environments still requires further investigation. Previous studies have examined the mediating role of social presence in teaching presence and cognitive presence (Mutezo & Mare, 2023). However, no study has yet investigated the mediating role of digital skills between teaching presence and cognitive presence. Except for social presence, digital skills may mediate the association between teaching presence and cognitive presence. There may be a gap in the existing

literature regarding the mediating effect of digital skills on the association between teaching presence and cognitive presence. Studying the mediating role of digital skills elucidates how students translate their perception of teaching presence in CSCL environments into actual cognitive presence.

This study aims to address the existing research gap concerning the mediating role of digital skills in the association between teaching presence and cognitive presence in higher education in China. Thus, this study aims to understand how digital skills mediate the association between teaching presence and cognitive presence within CSCL environments. To better support higher education teachers in implementing CSCL practices, improve students' CPS performance, and address the existing gap, the research purpose of this study is to examine the association between teaching presence, digital skills, and cognitive presence within the CSCL environment in higher education, and to investigate the mediating role of digital skills in the relationship between teaching presence and cognitive presence. Based on the research purpose, the research questions (RQ) of this study were as follows: (1) What are the associations between teaching presence, digital skills, and cognitive presence? (2) Do digital skills mediate the association between teaching presence and cognitive presence in higher education? By examining the relationships among teaching presence, digital skills, and cognitive presence, this study offers theoretical and practical insights for higher education practitioners in implementing CSCL activities.

2. Literature Review

2.1. Cognitive Presence

Garrison et al. (2000) proposed the concept of cognitive presence. Cognitive presence is defined as the extent to which learners are capable of constructing meaning through sustained communication within a specific learning environment (Garrison et al., 2000). Developing cognitive presence is widely regarded as a pivotal objective in higher education. Cognitive presence throughout the learning process consists of four sequential stages, namely triggering event, exploration, integration, and resolution (Garrison et al., 2000). At these stages, learners must apply different levels of cognitive ability to solve learning problems, thereby creating meaning and constructing knowledge (Mutezo & Mare, 2023; Sadaf et al., 2021; Shea et al., 2022). Garrison et al. (2000) highlighted that critical thinking and cognitive engagement are essential for achieving high-level cognitive presence. More than 20 years later, the cognitive presence is still generally recognized to include the four stages proposed by the CoI framework, and primarily assessed through self-reporting tools (Ba et al., 2023). But the effectiveness of self-reporting tools may be affected by the subjective tendencies of the respondents.

During CSCL activities, when students encounter cognitive dissonance triggered by a specific event, they enter the exploration stage to actively seek relevant information and to deep their understanding of the problem. Then, students form their own perspectives and possible hypotheses through critical thinking and collaborative dialogue during the integration stage, and they ultimately develop solutions to solve the identified problems and construct new knowledge in the resolution stage (Fathali, 2024; Garrison et al., 2000; Sadaf et al., 2021). However, many researchers have found that students' cognitive presence in learning activities frequently stagnates at the initial exploration stage and seldom progresses to the integration or even resolution stages (Fathali, 2024; Garrison & Arbaugh, 2007; Mutezo & Mare, 2023). While prior research indicates that teaching presence and social presence can impact cognitive presence (Arbaugh et al., 2008; Mutezo & Mare, 2023; Shea et al., 2022), additional environmental factors may also significantly influence cognitive presence in CSCL environments. The factors that could influence students' cognitive presence in CSCL environments are likely multidimensional and highly complex. Therefore, a detailed investigation of factors related to students' cognitive presence in CSCL is essential to help educators foster it more effectively.

2.2. Teaching Presence

Garrison et al. (2000) define teaching presence as instructors' deliberate design, support, and direction of learning activities. The primary purpose of teaching presence is to facilitate meaningful and educationally valuable learning achievements for learners (Garrison et al., 2000). Many studies indicate that inadequate teaching presence can hinder learners' progression from lower-order to higher-order cognitive presence during the problem-solving process (Arbaugh et al., 2008; Garrison & Arbaugh, 2007; Mutezo & Mare, 2023). Teaching presence quality plays a pivotal role in shaping the degree of social and cognitive presence within CSCL environments (Li & Wang, 2024; Pham & Nguyen, 2025). High-quality social interaction and advanced cognitive development both depend on the effectiveness of teaching presence. Teaching can directly influence cognitive presence or indirectly affect cognitive presence through the mediating role of social presence (Mutezo & Mare, 2023).

Garrison et al. (2000) identified three core dimensions of teaching presence through empirical research, including instructional management, building understanding, and direct instruction. Instructional management refers to the pedagogically deliberate design of learning activities, curriculum plans, curricular structures, and teaching strategies (Garrison & Arbaugh, 2007). Building understanding means teachers actively support students' learning, social interaction, collaboration, understanding, and individual contributions (Arbaugh et al., 2008). Direct instruction refers to that teachers directly guide students' learning, reflection, and collaboration through purposeful teaching behaviors and strategies (Garrison et al., 2000). Offering effective teaching presence requires teachers to possess substantial professional knowledge and practical experience (Li & Wang, 2024; Pham & Nguyen, 2025). CSCL practices integrated with a variety of ICTs has enhanced its flexibility, complexity, and diversity (Kaliisa et al., 2025). Greater complexity of the CSCL environment demands teachers to possess higher professional competence, instructional experience, and relevant skills. Additionally, teachers must recognize various elements of the learning environment that influence students' cognitive presence, thereby enabling them to offer effective teaching presence that enhance students' learning performance.

2.3. Digital Skills

Technological evolution and societal development have increased the demand for individuals' digital skills in evolution academic and professional contexts. In the 21st century, individuals must possess essential digital skills to effectively handle various challenges in social, professional, and educational contexts (Aldahdouh & Nokelainen, 2026; Van Laar et al., 2020). The conceptual evolution of digital skills has advanced through three phases: mastery phase, application phase, and reflection phase (Aesaert et al., 2014). The mastery phase focuses on acquiring and mastering theoretical knowledge of ICTs. The application phase emphasizes the practical application of digital technologies across diverse digital environments. But, merely mastering and applying digital technologies is no longer sufficient to effectively solve the academic and workplace challenges posed by the increasing complexity of contemporary issues (Vuorikari et al., 2026). In today's reflection phase, digital skills are no longer confined to the technical dimension of mastery and application, but have also expanded to related cognitive and social-emotional dimensions (Aldahdouh & Nokelainen, 2026; Van Laar et al., 2017, 2020). The digital skills of both teachers and students are crucial for improving learning performance in CSCL environments (Aldahdouh & Nokelainen, 2026; Luengo-Aravena et al., 2024; Rubach & Lazarides, 2021). Luengo-Aravena et al. (2024) found that students with lower digital skills performed significantly worse on CPS tasks in CSCL environments than those with higher digital skills.

Nowadays, digital skills should encompass the mastery and application of digital technologies for effective communication and collaboration, as well as the critical and creative resolution of cognitive problems encountered (Aldahdouh & Nokelainen, 2026; Van Laar et al., 2020; Vuorikari et al., 2026). Van Laar et al. (2017) emphasized that the 21st-century digital skills should involve multiple dimensions, including technical, information management, communication,

collaboration, creativity, critical thinking, and problem solving, through a systematic literature review. However, Van Laar et al. (2017) did not investigate how to effectively assess multidimensional digital skills. Traditional digital skills assessment is limited to operational skills and knowledge, whereas other multidimensional assessments are often overly lengthy and complex (Vuorikari et al., 2026). Rubach and Lazarides (2021) developed a multidimensional digital skills framework that could be utilized to evaluate the digital skills of both educators and learners. Rubach and Lazarides's (2021) framework includes six factors: information and data literacy, communication and collaboration, digital content creation, safety and security, problem solving, and analyzing and reflecting. This study employs Rubach and Lazarides's (2021) framework and adapts it to align with the specific research objectives and the characteristics of targeted students.

The safety and security dimension was excluded in this study, because its components mainly focused on the privacy issues, security settings, and potential risks involved when users apply digital tools. In CSCL environments, the responsibility for selecting appropriate tools, ensuring digital safety, and assessing digital risk rests with teachers and institutions, not with students. Therefore, students are not required to use digital skills related to safety management and risk assessment during CSCL activities. This exclusion reflects the contextual scope of the study, not an assumption that digital safety and security are not important. In this study, problem solving was integrated into analyzing and reflecting as a collective dimension. The problem-solving dimension and analyzing and reflecting dimension of Rubach and Lazarides's (2021) digital skills framework are deeply interrelated within CSCL environments. Analyzing and reflecting involve systematically examining and critically evaluating digital information, tools, and contexts, while problem solving applies these cognitive processes purposefully to identify needs and develop solutions (Rubach & Lazarides, 2021). Within CSCL environments, these two typically unfold not in isolation but as an integrated and iterative sequence of cognitive activities. Integrating them into a unified construct thus yields a more parsimonious and theoretically coherent representation of students' cognitive digital skills, while fully preserving the core dimensions articulated in the original framework. Similarly, Vuorikari et al. (2026) argue that digital skills assessments should be concise and integrated, and combine thinking, reflecting, and problem-solving into a single dimension for efficient evaluation.

2.4. Relationships among Variables

Teachers can enhance students' learning performance via intentional design, support, and guidance of learning activities. Empirical studies indicate that teaching presence significantly influences students' cognitive presence in CSCL environments (Li & Wang, 2024; Mutezo & Mare, 2023; Pham & Nguyen, 2025). Teaching presence and cognitive presence are interdependent in CSCL environments. When teaching presence is appropriate and effective, students are more likely to engage in the exploration, integration, and resolution processes during CSCL activities. However, limited research has examined the relationship between teaching presence and cognitive presence within the context of higher education in China. Based on these findings, this study tested the following hypothesis 1 (H1) within the context of Chinese higher education:

H1: Teaching presence is positively associated with cognitive presence.

In a technology-driven learning environment, teaching practices encompass the design, delivery, and facilitation of learning activities enabled by digital technologies. Digital skills are inherently teachable and can be improved through effective practices (Aesaert et al., 2014). Teachers could foster students' digital skills by thoughtfully integrating digital technologies into the learning environment and providing explicit guidance. CSCL environments that integrate ICTs can enhance teaching effectiveness and improve learning outcomes (Aldahdouh & Nokelainen, 2026; Kaliisa et al., 2025; Zabolotna et al., 2023). When students perceive a stronger teaching presence, they are more likely to have enhanced opportunities to develop information and data literacy, digital communication abilities, digital collaboration competencies, digital content

creation capabilities, and the capacity for critical reflection on their use of digital tools. Based on these findings, this study proposed the following hypothesis 2 (H2):

H2: Teaching presence is positively associated with digital skills.

In technology-driven learning environments, students may increasingly rely on digital technologies to access information, communicate and collaborate with peers, create learning content, critically evaluate information, and solve learning problems. Today's digital skills have evolved beyond purely technical proficiency to involve higher-order cognitive capability (Aesaert et al., 2014; Van Laar et al., 2017, 2020). Students with stronger digital skills tend to use digital resources more effectively in CSCL environments to tackle complex learning tasks, leading to deeper and more active cognitive activities. Based on this, this study proposed the following hypothesis 3 (H3):

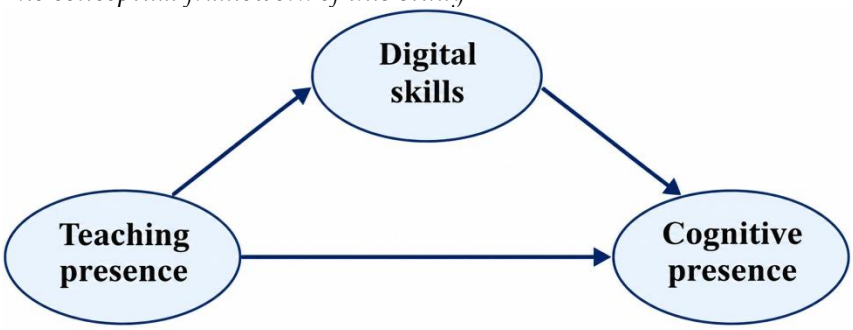
H3: Digital skills is positively associated with cognitive presence.

Based on the potential direct relationships among teaching presence, digital skills, and cognitive presence, digital skills may serve as a mechanistic bridge linking teaching presence to cognitive presence. Vygotsky's (1978) sociocultural theory indicates that learners' higher-order cognitive development during the learning process is mediated by cultural tools. Students' use of digital technologies in CSCL environments may depend on their digital proficiency. When teachers provide purposeful activities, promote learning understanding, and offer direct guidance, they create meaningful opportunities for students to enhance their digital skills. Enhanced digital skills, in turn, empower students to leverage digital technologies more effectively for learning and to engage in higher-order cognitive processes. Based on this theoretical mechanism, the following hypothesis 4 (H4) is proposed:

H4: Digital skills mediate the relationship between teaching presence and cognitive presence.

The conceptual framework presented in Figure 1 illustrates the research hypotheses tested in this study. By testing this conceptual framework, higher education educators could deeply understand the relationships among teaching presence, digital skills, and cognitive presence in CSCL environments.

Figure 1
The conceptual framework of this study



3. Method

3.1. Research Design

The main objective of this study is to examine the associations among teaching presence, digital skills, and cognitive presence, and to test the mediating effect of digital skills in the association between teaching presence and cognitive presence. To achieve this objective, this study employed a quantitative research methodology. Quantitative research can identify associations among variables by analyzing quantifiable data from a representative sample and testing proposed hypotheses (Creswell & Creswell, 2018). This study employed a cross-sectional survey design, and collect data through an online questionnaire.

3.2. Participants

The target population for this study is students enrolled in a higher education institution in China. Due to the impact of the COVID-19 pandemic and the widespread adoption of online courses, all higher education students in China have experienced at least two years of CSCL courses before entering universities or colleges. This study employed a multistage stratified random sampling technique, which was a probability-based sampling method. China's higher education institutions can be broadly categorized into four geographical regions: northwest, southwest, northeast, and southeast China. Firstly, two regions were randomly selected from China's four geographical regions using stratified sampling. The southwestern region was chosen. Secondly, one province was randomly selected from each chosen region using simple random sampling. The Yunnan province was chosen. Thirdly, the colleges served as the cluster sampling units. One college was randomly selected from each of the selected provinces. Fourthly, grade level served as the sampling type for cluster sampling, with one grade randomly selected from each participating university. The sophomore year was selected. Finally, students were randomly selected from each of the selected grade levels using simple random sampling.

The minimum required sample size for the proposed structural model was estimated via using G*Power 3.1. The priori power analysis was conducted for a linear multiple regression fixed model with an R^2 increase, assuming an anticipated effect size ($f^2 = .15$), a significance level ($\alpha = .05$), a statistical power ($1-\beta = .80$), one tested predictor, and two total predictors. This analysis results indicated that a minimum total sample size of 55 participants is required. However, given the number of registered students at the selected college is approximately 20000, a substantially larger sample size may be required to ensure adequate statistical power and stable estimation of the proposed structural models.

The Raosoft Sample Size Calculator was employed to calculate the required sample size, based on a 95% confidence level, a 5% margin of error, and a 50% response distribution. This results indicated that a required sample size of 385 was required for a population of 20000. Additionally, Wolf et al. (2013) demonstrated that reliable structural equation modeling (SEM) analyses of complex models with multiple indicators require a valid sample size exceeding 460 (for the two-factor model with three indicators and loading at .50). Since the structural model proposed in this study comprises three variables, eleven latent factors, and 41 observed indicators, the minimum required sample size in this study needs to exceed 460. Accounting for the effects of response rate and attrition rate in online questionnaire surveys, the actual sample size must be larger than the minimum sample size (Wu et al., 2022). Holtom et al. (2022) reported that the average response rate for surveys used in social science research has been approximately 60% in recent years. To achieve a target sample size of 460 with an anticipated response rate of 60%, a minimum sample of 767 participants is required. Therefore, the sample size for this study was determined to be 767. A total of 767 undergraduate students from a college in China were invited to participate in this online questionnaire survey. 657 completed questionnaires were collected, with a response rate of 85.7% (657/767).

3.3. Instruments

This study's research instrument was an online self-report questionnaire, and developed through adapting established questionnaires. The research instrument comprised three distinct scales: teaching presence, cognitive presence, and digital skills. First, the teaching presence and cognitive presence scales were adapted from the CoI self-report questionnaire developed by Arbaugh et al. (2008). The teaching presence scale includes instructional management, building understanding, and direct instruction. Cognitive presence encompasses four factors: triggering event, exploration, integration, and resolution. Then, the digital skills scale is based on the evaluation questionnaire for basic ICTs digital competence beliefs developed by Rubach and Lazarides (2021). After minor refinements to ensure alignment with research objectives, the digital skills scale employed herein comprises four After minor refinements for alignment with research objectives, the digital skills

scale comprises four dimensions: information and data literacy, communication and collaboration, digital content creation, and analyzing and reflecting.

Minor modifications were made to the existing questionnaires to enhance their suitability for the specific context of this study. The modified online questionnaire was administered to gather Chinese higher education students' perspectives on and experiences with CPS activities in CSCL environments. A 5-point Likert scale was used for all variables, with the following options: 5 (strongly agree), 4 (agree), 3 (neutral), 2 (disagree), and 1 (strongly disagree). The online questionnaire used in this study was translated from English into Chinese, which is the participants' native language. This native language translation is aimed at enhancing the accuracy of the responses and minimizing possible comprehension errors due to differences in the proficiency of the second language. During this translation process, this study used three translation methods: forward-translation, back-translation, and bilingual reconciliation. Firstly, the original English questionnaire was forward-translated into Chinese by two bilingual translators with expertise in the relevant research domain. Secondly, an independent bilingual translator, who was uninvolved in the forward-translation process, performed a back-translation of the Chinese version of the questionnaire into English. Thirdly, the original questionnaire and its back-translated version were compared by the participating editors to identify discrepancies in wording and conceptual meaning. Subsequently, these differences were discussed and corrected through coordination efforts.

To ensure the validity and reliability of the modified questionnaire, this study conducted an expert review, internal consistency analysis, and confirmatory factor analysis (CFA). First, the revised online questionnaire were distributed to four experts in Chinese higher education for conducting an expert review. Expert review is a widely adopted method in academic research for assessing the face and content validity of a questionnaire (Taherdoost, 2016). To safeguard their anonymity, their names and institutions were not reported. All Chinese experts hold doctoral degrees or equivalent advanced academic qualifications and have dedicated over fifteen years to higher education in China, thereby accumulating extensive professional knowledge and substantial practical experience in CSCL.

The experts independently evaluated the relevance of each item and provided constructive recommendations for those deemed inappropriate. They further assessed the questionnaire's overall clarity, linguistic precision, response redundancy, conceptual equivalence, and terminology usage. All evaluations were conducted using a four-point rating scale (1=not, 2=somewhat, 3=quite,4=highly). The relevance scores were used to compute the content validity index (CVI), that was a widely adopted metric for evaluating the content validity of measurement instruments (Yusoff, 2019). Yusoff (2019) indicated that for three to five experts, the acceptable item-level content validity index (I-CVI) value was 1. Therefore, items with an I-CVI value of 1 were included, whereas those with an I-CVI value below 1.0 were excluded. As a result, 3 items with an I-CVI value less than 1 were deleted, one each from the digital content creation, triggering event, and resolution factors. Online questionnaires were distributed to participants only after expert review.

Following expert review, the online questionnaire was published as a WeChat QR code and subsequently distributed to participants for completion. The researchers contacted the four selected higher education institutions and their respective teachers. Through coordinated communication, the participating teachers randomly selected students from the student list of the selected grade and subsequently distributed WeChat QR codes to the selected students. To uphold participants' right to informed consent, all students were briefed on the research purpose, voluntary nature, procedural details, and potential applications before completing the online questionnaire. Participants voluntarily consented to take part in this study, and the questionnaire contained no sensitive or personally identifiable information. Of the 657 original questionnaire responses collected, 608 were retained as valid data following data cleaning. Next, the reliability of the research instrument was assessed using internal consistency analysis.

Internal consistency analysis is a widely used method for assessing the reliability of measurement instruments, particularly for questionnaire surveys (George & Mallery, 2016). This study used Cronbach's alpha coefficient (α) to assess internal consistency, which is a widely accepted metric for research reliability (George & Mallery, 2016). The internal consistency analysis results of the research instrument were presented in Table 1. The Cronbach's alpha (α) coefficient for the entire online questionnaire was high at .975. The α value for each scale also exceeded .9, as follows: teaching presence (α = .954), digital skills (α = .946), and cognitive presence (α = .955). An α value above .7 is generally considered acceptable, whereas an α value exceeding .9 is widely regarded as excellent, according to George and Mallery's (2016) explanation. Furthermore, Cronbach's alpha coefficients for all factors across each scale of the online questionnaire exceeded .8, ranging from .868 to .911. Typically, a Cronbach's alpha coefficient greater than .8 indicates that the research instrument exhibits high reliability and demonstrates a good level of internal consistency (George & Mallery, 2016). Therefore, the internal consistency analysis indicates that the research instrument has good reliability. In addition, the reliability and validity of the research instrument were further assessed using CFA.

Table 1
The internal consistency analysis results

Scales and factors	*Items*	*Cronbach's Alpha*	
Teaching Presence			.954
Instructional Management	4	.898	
Building Understanding	4	.904	
Direct Instruction	4	.900	
Digital Skills			.946
Information and Data Literacy	4	.886	
Communication and Collaboration	4	.888	
Digital Content Creation	3	.911	
Analyzing and Reflecting	4	.888	
Cognitive Presence			.955
Triggering Event	3	.884	
Exploration	4	.901	
Integration	4	.882	
Resolution	3	.868	
Overall			.975

3.4. Data Analysis

The collected data were analyzed mainly using SEM to examine the relationships among variables and to test research hypotheses. During the data analysis phase, descriptive statistical analysis was first conducted in IBM SPSS Statistics to characterize the data collected via the online questionnaire survey. Descriptive statistics are commonly employed to analyze the fundamental characteristics and distributional patterns of research data (Creswell & Creswell, 2018). The descriptive statistical analysis performed by IBM SPSS Statistics software was summarized in Table 2, including mean, standard deviation, variance, skewness, and kurtosis. The mean values of all variables ranged from 3.5 to 3.9, with corresponding standard deviations and variances falling within ±1. The observed standard deviation and variance indicated that the results were both consistent and moderately dispersed.

Skewness and kurtosis were used to assess whether the research data approximately follow a normal distribution. The analysis results indicated that the skewness and kurtosis values for all first-order and second-order factors were within the acceptable thresholds for approximate normality, suggesting no significant deviation from normality (see Table 2). The results indicated that the skewness values ranged from –.806 to –.426, while the kurtosis values ranged from –.089 to. 753. In empirical research, kurtosis and skewness values falling within the range of ±2.0 are

generally regarded as acceptable (George & Mallery, 2016). All observed indicators are within the acceptable range for approximate univariate normality.

Table 2
The results of descriptive statistical analysis

Factors	*Mean*	*Standard Deviation*	*Variance*	*Skewness*	*Kurtosis*
Instructional Management	3.87	.840	.705	–.806	.551
Building Understanding	3.79	.862	.743	–.667	.237
Direct Instruction	3.79	.860	.739	–.780	.454
Information and Data Literacy	3.77	.778	.605	–.527	.440
Communication and Collaboration	3.75	.783	.613	–.533	.144
Digital Content Creation	3.66	.868	.754	–.451	.113
Analyzing and Reflecting	3.66	.797	.636	–.426	–.089
Triggering Event	3.80	.857	.735	–.726	.580
Exploration	3.75	.813	.661	–.637	.481
Integration	3.79	.787	.620	–.649	.419
Resolution	3.68	.787	.620	–.738	.720
Variables					
Cognitive Presence	3.76	.730	.534	–.768	.753
Teaching Presence	3.82	.792	.627	–.769	.423
Digital Skills	3.71	.693	.480	–.563	.195

Subsequently, correlation analysis was performed to assess the associations among the study variables. Furthermore, collinearity diagnosis was performed to assess potential multicollinearity issues. Multicollinearity issues could undermine the validity and stability of the research findings (George & Mallery, 2016). Then, CFA was used to further evaluate the validity and reliability of the research instrument. CFA is widely employed in empirical research to evaluate the construct validity and the reliability of measurement instruments, and serves as a prerequisite for SEM (Abu-Bader & Jones, 2025; Cheung et al., 2024). Following the CFA, the SEM was conducted to examine the hypothesized structural model, assess the associations among the research variables, and evaluate the mediating effect. Path analysis and Bootstrapping were used in SEM to test whether the mediating effect is significant. The Bootstrapping method is widely regarded as highly effective for testing mediating effects and remains the most commonly used approach in mediation analysis (MacKinnon et al., 2007).

4. Results

4.1. Correlation Analysis and Collinearity Diagnostics

In this study, the Pearson correlation coefficients (r) obtained from the correlation analysis were presented in Table 3 below. Consistent with prior literature and the proposed hypotheses, all variables exhibited significant positive interrelationships, with all p-values less than .001. The r value between the second-order factor and its corresponding first-order factor was significantly greater than that between any other first-order factors. There was also a significant positive correlation among the three second-order factors (teaching presence, digital skills, and cognitive presence), ranging from .589 to .859. The correlation coefficients among certain variables were relatively high, exceeding .8. It was necessary to assess whether there were potential multicollinearity problems. In the collinearity diagnostics, the variance inflation factor (VIF) values ranged from 1.59 to 3.958, and the corresponding tolerance values ranged from .253 to .629. The collinearity diagnostics results revealed that the VIF and tolerance values for both first-order and second-order factors remained within acceptable thresholds, indicating the absence of substantial multicollinearity. A VIF value less than 10 and a tolerance value greater than .1 generally indicate that there is no multicollinearity issue (George & Mallery, 2016; Mason & Perreault, 1991). Therefore, multicollinearity was not a concern in this study.

Table 3
The results of correlation analysis and collinearity diagnostics

Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1 (Instructional Management)	–													
2 (Building Understanding)	.775***	–												
3 (Direct Instruction)	.766***	.827***	–											
4 (Information and Data Literacy)	.558***	.497***	.508***	–										
5 (Communication and Collaboration)	.565***	.530***	.497***	.708***	–									
6 (Digital Content Creation)	.439***	.410***	.402***	.609***	.618***	–								
7 (Analyzing and Reflecting)	.503***	.463***	.450***	.684***	.671***	.648***	–							
8 (Triggering Event)	.650***	.660***	.660***	.633***	.634***	.508***	.591***	–						
9 (Exploration)	.624***	.613***	.634***	.673***	.673***	.555***	.633***	.787***	–					
10 (Integration)	.596***	.601***	.612***	.729***	.694***	.537***	.622***	.742***	.798***	–				
11 (Resolution)	.561***	.529***	.548***	.704***	.648***	.531***	.677***	.679***	.718***	.745***	–			
12 (Teaching Presence)	.912***	.936***	.933***	.561***	.572***	.449***	.509***	.708***	.673***	.650***	.589***	–		
13 (Digital Skills)	.602***	.554***	.540***	.876***	.874***	.818***	.877***	.689***	.738***	.753***	.747***	.609***	–	
14 (Cognitive Presence)	.675***	.668***	.683***	.760***	.737***	.592***	.698***	.887***	.928***	.920***	.859***	.728***	.812***	–

Note. ***= p <.001.

4.2. Confirmatory Factor Analysis

Based on the foregoing fundamental analyses, subsequent SEM testing of the proposed research hypotheses and model structure can be conducted using IBM SPSS Amos. The normality of the observed indicators was again evaluated in Amos. The evaluation results indicated that skewness values ranged from –.813 to -.280, and kurtosis values ranged from –.393 to .453. All skewness and kurtosis values fell within the widely accepted ±2 threshold, indicating that there were no substantial univariate departures from normality (George & Mallery, 2016). Additionally, in this study, five-point Likert-scale items were treated as approximately continuous variables and analyzed using maximum likelihood estimation in Amos. The use of this estimation approach was based on the five-category response format, the acceptable univariate skewness and kurtosis values, and the relatively large sample size. Although the results indicated that the observed indicators demonstrated acceptable univariate distribution properties, the data did not fully satisfy the assumption of multivariate normality. Given evidence of multivariate non-normality, the bootstrapping method was additionally employed to mitigate reliance on the assumption of multivariate normality in assessing the stability and statistical significance of the parameter estimates.

CFA is typically conducted first in SEM to assess the fit of the measurement model (Abu-Bader & Jones, 2025; Cheung et al., 2024). This study employed several of the most widely used fit indices in SEM, based on the recommended criteria established in prior authoritative literature summarized by Abu-Bader and Jones (2025). The acceptance criteria for the model fit indices and corresponding analytical results were shown in Table 4. The CFA results of the hypothesized second-order factor model indicated that all fit indices met the acceptable thresholds and demonstrated good model fit (χ^2 = 1598.518, p < .001, χ^2/df = 2.09, SRMR = .0401, RMSEA = .042, CFI = .96, TLI = .957, IFI = .96, NFI = .926). Although the chi-square statistic was significant (χ^2 = 1598.518, p <.001), it was still regarded as acceptable in practical studies within the context of a complex model with a large sample size (Abu-Bader & Jones, 2025). The CFA fit statistics were generally strong. No correlated error terms were incorporated into the final CFA model, and no items were excluded solely based on modification indices.

Table 4
The acceptance criteria and results of model fit

Model Fit	*Acceptable Criteria*	*Second-order factor model*	*First-order factor model*
χ^2	-	1598.518 (p < .001)	3672.267 (p < .001)
χ^2/df	<3	2.09	4.732
SRMR	<.08	.0401	.0475
RMSEA	<.08	.042	.078
CFI	>.9	.960	.861
TLI	>.9	.957	.853
IFI	>.9	.960	.861
NFI	>.9	.926	.830

In addition, to further examine the appropriateness of the hypothesized second-order factor model, an alternative first-order factor model was tested. In the alternative first-order factor model, all items measuring each variable construct were specified to load directly onto a single first-order factor, without differentiating among the theoretically proposed dimensions. For example, all items about teaching presence were specified as indicators of a single teaching presence factor, rather than being divided into the dimensions of instructional management, building understanding, and direct instruction. Similarly, the items measuring digital skills and cognitive presence were specified as indicators of their respective overarching first-order factors, without separating them into their proposed dimensions. The results showed that the hypothesized second-order factor model (χ^2 = 1598.518, p < .001, χ^2/df = 2.09, SRMR = .0401, RMSEA = .042, CFI = .96, TLI =.957, IFI = .96, NFI = .926) provided a substantially better fit to the

data than the alternative first-order factor model (χ^2 = 3672.267, p < .001, χ^2/df = 4.732, SRMR = .0475, RMSEA = .078, CFI = .861, TLI = .853, IFI = .861, NFI = .830). The alternative first-order model exhibited higher values for χ^2/df, SRMR, and RMSEA compared with the hypothesized second-order model. The first-order model produced lower values for CFI, TLI, IFI, and NFI, each falling below the recommended threshold of .90, than the second-order model. These results indicated that representing the constructs through their theoretically specified dimensions and corresponding second-order factors provided a substantially better representation of the data than treating all items within each construct as indicators of a first-order factor.

Due to the fact that teaching presence, digital skills, and cognitive presence were all assessed using the same self-report questionnaire and collected from the same respondents at a single time point, the potential influence of common-method variance was evaluated using the common latent factor (CLF) approach. A CLF was incorporated into the CFA measurement model in this study. Although the model fit improved slightly upon incorporation into the CLF (χ^2/df = 2.006, SRMR = .0337, RMSEA = .041, CFI = .963, TLI = .960, IFI = .964, and NFI = .930), compared to the CFA model (χ^2/df = 2.090, SRMR = .0401, RMSEA = .042, CFI = .960, TLI = .957, IFI = .960, and NFI = .926), the improvement in model fit was relatively smaller. In addition, standardized factor loadings were compared across the original CFA model and the CFA model incorporating the CLF. After adding the CLF, the standardized loadings of all factors changed very little, with differences ranging from .00 to .03. The improvement in model fit was small, and the changes in factor loadings were minimal. These results indicated that common method variance was unlikely to meaningfully bias the measurement associations (Afthanorhan et al., 2021).

The reliability of the research instrument was further assessed using CFA. CFA is a widely employed method for evaluating the construct validity and the reliability of instruments in academic research (Abu-Bader & Jones, 2025; Cheung et al., 2024). In CFA, the composite reliability (CR) value exceeding .7 indicated a good reliability (Cheung et al., 2024; Nasrabadi et al., 2025). Additionally, the average variance extracted (AVE) should exceed .5 to indicate acceptable convergent validity, and the square root of the AVE for each latent variable must be greater than its correlations with all other latent variables for acceptable discriminant validity (Cheung et al., 2024; Nasrabadi et al., 2025). The CR values for all factors ranged from .871 to .915, exceeding the recommended threshold of .7 (see Table 5). The CR values for all factors ranged from .871 to .915, all exceeding the recommended threshold of .7. Similarly, the CR values for all variables ranged from .909 to .955, likewise surpassing the threshold of .7. This indicated a good internal consistency of the instrument. The analytical results indicated that the AVE for all variables and their respective factors exceeded the accepted threshold of .5. Furthermore, all the standardized factor loadings in the measurement model were statistically significant (p < .001), and all of them exceeded .7, ranging from .729 to .954. These results indicated that the observed indicators adequately represented their respective latent constructs, supporting adequate convergent validity. Furthermore, the square root of the AVE for each factor exceeded all corresponding inter-factor correlation coefficients, and the square root of the AVE for each variable exceeded all corresponding inter-variable correlation coefficients. This analytical result confirmed the discriminant validity of the instrument.

The path diagram of the measurement model derived from CFA was presented in Figure 2. The path analysis results for the measurement model were presented in Table 6. The pathways connecting each first-order factor to its corresponding second-order factor were all statistically significant (p < .001), supporting the validity of the hypothesized measurement structure. The standardized coefficient estimates (beta) of all paths were relatively high, ranging from .729 to .954. These analysis results further confirm the construct validity of the proposed measurement model in this study. The measurement model proposed in this study demonstrates adequate validity and is therefore suitable for subsequent structural equation modeling (SEM) analysis.

Table 5
The results regarding the convergent validity and reliability in the confirmatory factor analysis

Variables and Factors	*CR*	*AVE*	*The square root of the AVE*	*CR*	*AVE*	*The square root of the AVE*
Teaching Presence				.952	.870	.933
Instructional Management	.900	.694	.833			
Building Understanding	.904	.703	.838			
Direct Instruction	.901	.694	.833			
Digital Skills				.909	.717	.847
Information and Data Literacy	.886	.661	.813			
Communication and Collaboration	.888	.665	.815			
Digital Content Creation	.915	.783	.884			
Analyzing and Reflecting	.889	.668	.817			
Cognitive Presence				.955	.841	.917
Triggering Event	.885	.720	.848			
Exploration	.902	.697	.834			
Integration	.882	.651	.806			
Resolution	.871	.693	.832			

Figure 2
The path diagram for the measurement model

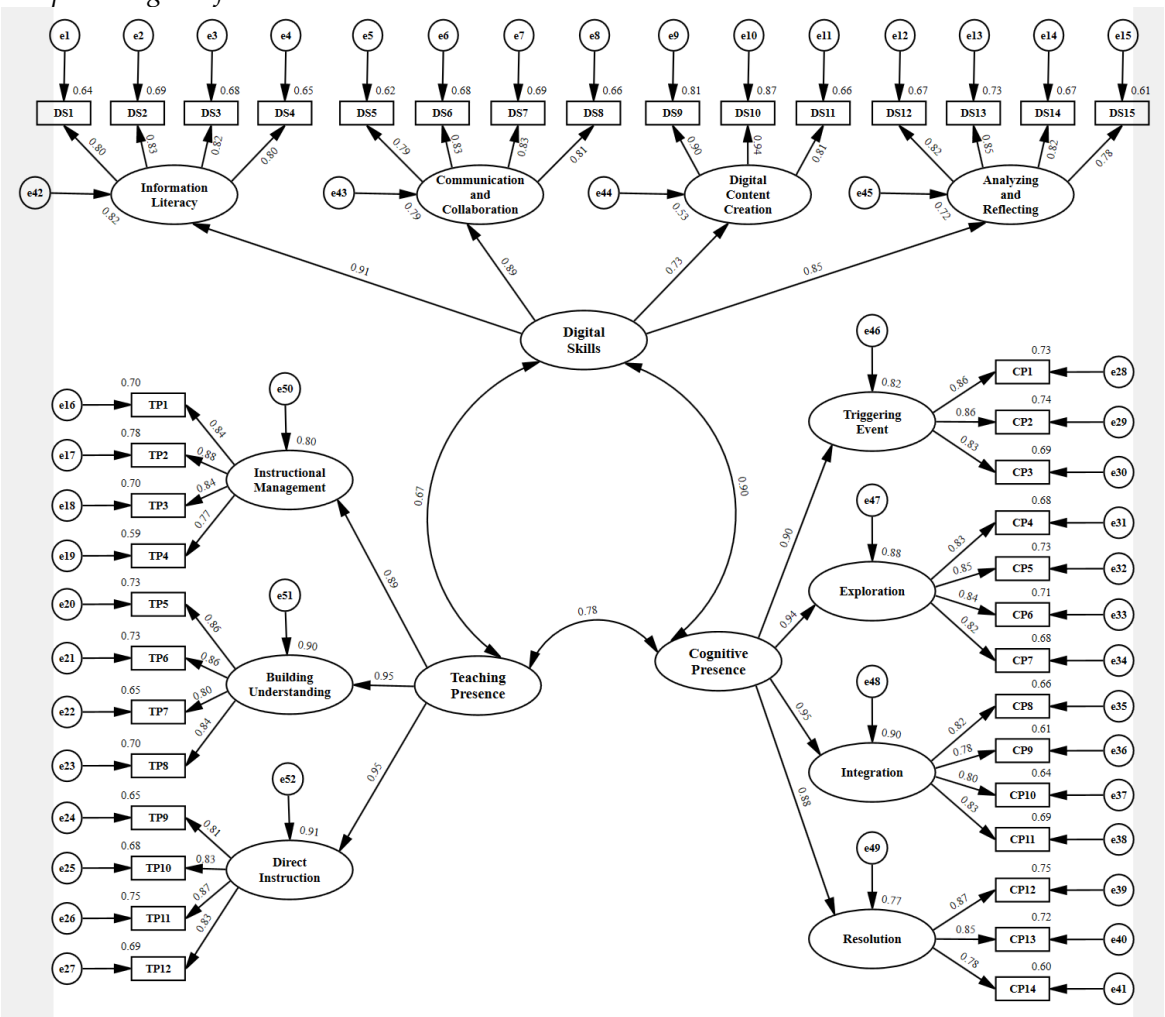


Table 6
The path analysis results of the measurement model

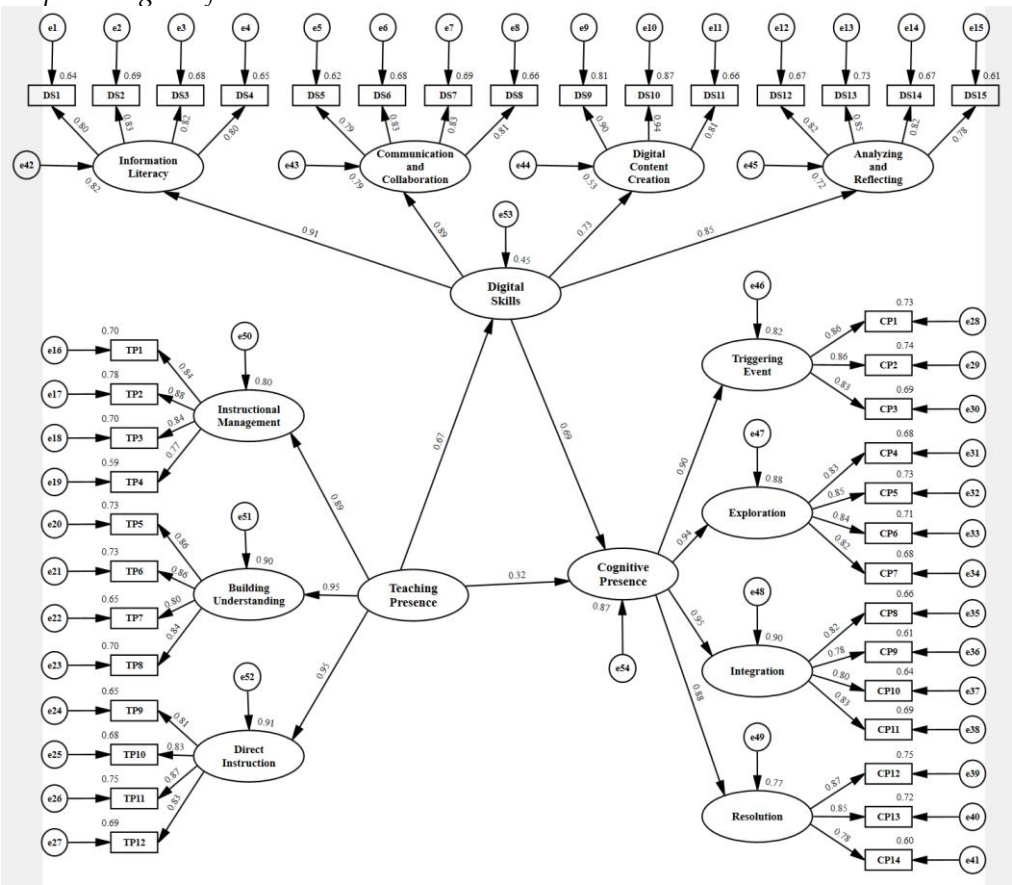
Pathway	*Estimate (β)*	*Standardized Estimate (beta)*	*S.E.*	*C.R.*	*p*
Teaching Presence→Instructional Management	1	.893			
Teaching Presence→Building Understanding	1.259	.950	.067	18.708	***
Teaching Presence→Direct Instruction	1.220	.954	.065	18.667	***
Digital Skills→Information and Data Literacy	1	.908			
Digital Skills→Communication and Collaboration	1.034	.889	.059	17.521	***
Digital Skills→Digital Content Creation	.955	.729	.058	16.353	***
Digital Skills→Analyzing and Reflecting	.972	.850	.056	17.454	***
Cognitive Presence→Triggering Event	1	.904			
Cognitive Presence→Exploration	.968	.938	.046	20.987	***
Cognitive Presence→Integration	.954	.948	.046	20.855	***
Cognitive Presence→Resolution	.924	.877	.045	20.511	***

Note. ***: $p < .001$.

4.3. Structural Equation Modeling

After validating the measurement model, the hypothesized structural model was tested using SEM to achieve the research objectives and test the proposed hypotheses. During this process, path analysis and the Bootstrapping method were employed to examine the direction of associations among the three second-order factor variables (teaching presence, digital skills, and cognitive presence) and to assess the mediating effect of digital skills on the association between teaching presence and cognitive presence. Figure 3 shows the path diagram of the mediation structural model, visually illustrating the path associations, standardized path coefficients (beta), and measurement error terms.

Figure 3
The path diagram for the mediation structural model



Path analysis and bootstrapping results from Amos were shown in Table 7. The mediating effect of digital skills was tested using the bootstrapping method with 5,000 resamples and a 95% confidence interval. The standardized estimate was the standardized path coefficient (beta) in Table 7. The 95% confidence intervals for all pathways, spanning from the lower limit to the upper limit, exclude zero, indicating statistical significance (MacKinnon et al., 2007). Based on the structural equation model, teaching presence was positively associated with cognitive presence (beta=.323, 95%CI [.243, .402], $p < .001$) and digital skills (beta=.672, 95%CI [.595, .736], $p < .001$). Meanwhile, digital skills demonstrated a significant positive association with cognitive presence (beta=.687, 95%CI [.604, .762], $p < .001$).

Table 7
The results of path analysis and bootstrapping method

H	*Path*	*Standardized Estimate (beta)*	*95% Confidence Interval (CI)*		*p*	*Effect Proportion*
			Lower Limit	*Upper Limit*		
H1	Teaching Presence→Cognitive Presence	.323	.243	.402	***	41.1%
H2	Teaching Presence→Digital Skills	.672	.595	.736	***	/
H3	Digital Skills→Cognitive Presence	.687	.604	.762	***	/
H4	Teaching Presence→Digital Skills→Cognitive Presence	.462	.396	.537	***	58.9%
/	Total effect	.785	.73	.83	***	

Note. H: Hypothesis; ***: $p < .001$.

Furthermore, the hypothesized indirect association in the mediation model (Teaching Presence→Digital Skills→Cognitive Presence) was statistically significant (beta = .462, 95%CI [.396, .537], $p < .001$). The 95% bootstrapping confidence interval for the standardized indirect effect excluded zero, which supported a mediating association of digital skills in the relationship between teaching presence and cognitive presence within the proposed model. The standardized estimates of both the direct effect (Teaching Presence→Cognitive Presence) and the indirect effect (Teaching Presence→Digital Skills→Cognitive Presence) were positive, which is consistent with the partial mediation. These statistical findings were consistent with the proposed research hypotheses H1, H2, H3, and H4. The total effect of teaching presence on cognitive presence in the hypothesized model was .785, with an indirect effect of .462. This indirect pathway accounts for approximately 58.9% of the total effect. These results strictly describe the mediation model and do not constitute empirical evidence of causal mediation.

5. Discussion

This study identified statistically significant associations among teaching presence, digital literacy, and cognitive presence, and the association directions conform to the hypothesized model. Although the CoI framework proposed by Garrison et al. (2000) clearly articulates the interrelationships among cognitive, social, and teaching presence, empirical research specifically examining higher education students in the Chinese context remains limited. This study further confirms that teaching presence is positively associated with cognitive presence in CSCL environments within the context of higher education in China through using SEM. In this study, the correlation between teaching presence and cognitive presence was .728, which was higher than the value of .66 reported by Mutezo and Mare (2023). This suggests that the effect of teaching presence on students' cognitive presence depends differently on their educational background. Therefore, when designing teaching practices to enhance students' cognitive development, higher education educators must comprehensively consider students' prior educational experiences, cultural contexts, and individual characteristics. Leveraging students' individual traits and academic backgrounds, educators should design tailored activities, offer constructive support, and apply purposeful strategies to more effectively foster cognitive development, meaning-making,

and knowledge construction in CSCL.

This study finds that the teaching presence is positively associated with higher education students' digital skills. Moreover, this finding provides indirect empirical support for the theoretical proposition that students' perceived effectiveness of teaching practices is statistically correlated with their level of digital skills. With the rapid advancement and widespread adoption of ICTs, digital skills have assumed an increasingly pivotal role in contemporary education (Van Laar et al., 2017, 2020). Higher education educators could integrate various digital technologies into teaching practices in varied and purposeful ways to enrich students' learning experiences (Cattaneo et al., 2022; Hollister et al., 2022; Lai & Jin, 2021). However, most prior studies in higher education have focused on teachers' digital skills, while neglecting students' digital skills (Lai & Jin, 2021; Rubach & Lazarides, 2021). Based on prior literature, teacher-designed teaching practices may reciprocally influence students' digital skills. Teaching presence not only shapes students' digital skills development, but students' digital skills may also affect the effectiveness of well-designed CSCL practices. But the causal relationship between teaching presence and digital skills still warrants further empirical investigation.

Although this study does not empirically confirm a causal relationship between teaching presence and digital skills, their positive association remains meaningfully relevant for higher education practitioners. Today's advanced, widespread ICTs give teachers more digital tools for CSCL and greater flexibility in designing digital learning content. When implementing CSCL practices, educators need to consider the different levels of digital skills of students, carefully select appropriate digital tools, design media-rich instructional content, and intentionally integrate instructional strategies that foster the development of students' digital skills. For students with advanced digital skills, overly simplistic digital learning designs may fail to meaningfully enhance their digital skills development. Conversely, for students with weaker digital proficiency, appropriately complex digital content can facilitate deeper engagement with and effective internalization of CSCL practices. However, excessively complex content may impede their digital skills development and undermine the effectiveness of well-designed CSCL practices. These possible impacts require further longitudinal investigation to be conclusively established.

Another key finding indicates that digital skills is is positively associated with cognitive presence in Chinese higher education. With the widespread popularity of ICTs, students' digital skills has become an increasingly critical role in higher education. Prior research has demonstrated that students' digital skill levels significantly impact both the effectiveness of learning activities and their academic performances (Aesaert et al., 2014; Luengo-Aravena et al., 2024). However, there has been limited research to determine the relationship between digital skills and cognitive presence in CSCL environments. This study identified a positive correlation between digital skills and cognitive engagement, but a causal relationship could not be determined due to the limitations of the cross-sectional study. Future research can determine the specific causal relationship between these two constructs through longitudinal studies. Future research also could further examine the extent of cognitive presence differences among students with varying levels of digital skills within the same CSCL context.

Identifying a positive correlation between digital skills and cognitive presence has significant practical importance for higher education. This positive association means that students with higher digital skills tend to show greater cognitive process, leading to stronger learning, deeper critical thinking, stronger problem-solving, and ultimately greater cognitive gains, during CSCL activities. Thus, when designing CSCL practices, higher education educators should focus not only on improving students' cognitive presence but also on improving their digital skills, for achieving better teaching effects. In the CSCL activities, by clearly assessing digital skills, providing structured digital literacy education, carefully integrating appropriate digital tools, continuously monitoring digital collaboration, promoting reflection on digital use, and instructing digital problem-solving strategies, these measures could collectively scaffold students' cognitive process from lower-level exploration to higher-level resolution.

Although the empirical results support the proposed hypotheses, other factors may partially account for the associations among teaching presence, digital skills, and cognitive presence. A possible confounding factor is students' generally positive tendency toward the learning environment. Students who exhibit a generally positive tendency toward CSCL environments may perceive teacher presence as strong, evaluate their own digital skills favorably, and report high levels of cognitive presence. Additionally, students with higher digital proficiency or stronger cognitive ability may perceive teaching presence more positively, potentially because they find it easier to navigate CSCL activities. In contrast, students with lower levels of digital proficiency or cognitive ability may assign lower ratings to their teaching practices. Similarly, Luengo-Aravena et al. (2024) reported that students with lower digital proficiency prefer to show lower satisfaction with CSCL activities. Since this study employed a cross-sectional design, it cannot establish a definitive temporal sequence or causal inference, nor can it fully address confounding arising from students' tendency biases.

Prior research has empirically validated social presence as a mediator linking teaching presence and cognitive presence (Mutezo & Mare, 2023). This study's findings further confirm a partial mediating effect of digital skills in the association between teaching presence and cognitive presence. This confirmed mediating effect extends current understanding of relational dynamics CSCL environments, highlighting the theoretical and practical importance of digital skills for higher education. This partial mediating effect suggests that digital skills may partially mediate the observed association between teaching presence and cognitive presence in CSCL environments, but it does not establish a causal relationship. Prior research shows that, even with carefully designed instruction, many students' cognitive presence fails to advance from lower-order stages to higher-order stages (Fathali, 2024; Garrison & Arbaugh, 2007; Mutezo & Mare, 2023). Digital skills' partial mediating role offers a explanatory perspective for this learning phenomenon, revealing a potential internal pathway underlying the inconsistent relationship between teaching and cognitive presence across student groups.

Due to the partial mediating role of digital skills, the correlation between teaching and cognitive presence may vary across students depending on their digital skill levels. Teaching presence may be more strongly linked to cognitive presence when students possess adequate digital skills required to engage effectively in technology-mediated CSCL activities. The research findings encourage higher education educators to prioritize the systematic integration of digital skill development into the design and implementation of CSCL. By scaffolding students' digital skills, teachers could optimize the effectiveness of teaching practices, strengthen the link between teaching and cognitive presence, and promote comprehensive cognitive development in CSCL environments. In this way, the cognitive presence of higher education students in CSCL activities may more actively progress to the higher-order integration and resolution stages.

Recently, some scholars have turned their attention to the mediating role of digital skills in educational contexts. Ibrahim et al. (2024) found that university students' digital skills mediate the relationship between emotional intelligence and academic stress, and Ofem (2026) revealed that digital skills play a mediating role between institutional policies and students' use of social media for academic research. These studies examined the mediating role of digital skills in the social dimension of learning. However, these studies neither focused on the cognitive dimensions of learning nor established a connection between teaching practice and digital skills. Previous literature has not examined the specific role of digital skills in the relationship between teaching presence and cognitive presence within CSCL environments. This study may fill this gap to some extent.

When designing and implementing CSCL activities to promote students' cognitive development, teachers should fully account for the mediating effect of digital skills. Effective teaching presence not only directly enhances students' cognitive presence in CSCL environments, but this effect also becomes more pronounced when students possess high-level digital skills. Thus, higher education teachers should not overlook the mediating effect of digital skills when

designing CSCL environments. On the one hand, individual differences in students' digital skills are likely to significantly influence the effect of CSCL activities. On the other hand, beyond directly fostering students' cognitive presence by providing teaching support, teachers could indirectly enhance cognitive presence by improving students' digital skills. Students' information and data literacy, digital communication and collaboration skills, digital content creation ability, and critical analysis and reflection on digital tool use may affect how efficiently they internalize perceived CSCL teaching practices as cognitive competencies. By studying the specific impacts of digital skills, higher education practitioners can implement more effective CSCL practices to enhance students' cognitive development and to fully realize the pedagogical potential of CSCL environments.

Notably, this study employed a cross-sectional design with questionnaire data collected at a single time point. This cannot establish temporal sequencing or rigorous causal relationships. Consequently, all statistically significant path coefficients and mediating effects reflect only associations consistent with the hypothesized structural model, rather than definitive causal effects. In the proposed mediation model, both the direct association (Teaching Presence→Cognitive Presence) and indirect association (Teaching Presence→Digital Skills→Cognitive Presence) were positive and statistically significant, verifying a partial mediating association in the model. Substantively, this partial mediation pattern indicated that teaching presence is associated with cognitive presence both directly and indirectly through digital skills within the specified structural model. However, given the inherent limitations of cross-sectional design, this finding cannot confirm a causal mediating mechanism.

6. Limitations

Similar to other academic studies, this one has certain limitations. Firstly, it focused solely on teaching presence, digital skills, and cognitive presence, omitting another core component-social presence of the CoI framework. Teaching presence, social presence, cognitive presence, and digital skills may dynamically interrelate to form a more intricate structural model. Therefore, future research could attempt to integrate these four factors into a unified theoretical model. The factors influencing students' learning performance are multifaceted and complex within CSCL environments. In addition to teaching presence, social presence, digital skills, and cognitive presence, other environmental factors may also influence students' learning outcomes in CSCL environments. Secondly, this study only adopted a cross-sectional design. Due to the inherent limitations of a cross-sectional design, this study cannot establish temporal sequencing or infer causal relationships. Future research could determine the causal relationships among teaching presence, digital skills, and cognitive presence through longitudinal or experimental study designs. Using only one cross-sectional design may lead to common method variance and self-biased tendencies, thereby affecting the validity and reliability of the research findings to some extent.

Thirdly, this study employed quantitative methods exclusively, relying on self-reported questionnaire surveys for data collection. Drawing on the principle of methodological triangulation, integrating qualitative approaches or supplementing the research data with additional forms of empirical evidence would substantially enhance the rigor, accuracy, reliability, and validity of the findings. Such evidence may include video recordings, worksheets, assessment tests, teacher reports, behavioral learning analytics, performance assessments, discussion transcripts, or observational measures. Adopting more empirical methods could help mitigate the influence of students' self-biased tendencies and common-method variance on research findings. Fourthly, this study is confined exclusively to students within China's higher education system. Consequently, the generalizability of its findings to other cultural contexts may be limited. Although this study adopted a multistage stratified sampling approach, the final sample comprising 608 students from a institution across a province remains relatively limited in scope when considered against the vast population of higher education students in China. The personal

characteristics, educational experiences, and sociocultural backgrounds of higher education students in China are exceptionally complex and diverse. Thus, the findings of this study may not be fully generalizable to the broader population of higher education students in China.

7. Conclusions

The findings of this study indicate that teaching presence is positively associated with cognitive presence both directly and indirectly, and that this association is partially mediated by digital skills. The research findings provide cross-sectional SEM evidence consistent with digital skills functioning as an important intermediary mechanism linking perceived teaching presence with cognitive presence in CSCL environments among the sampled Chinese undergraduates. The research findings further highlight the complexity and multidimensionality of the CSCL environment. When designing CSCL activities to enhance students' cognitive presence, educators must attend to both the quality of teaching presence and the levels of students' digital skills. Furthermore, the results in this study have both theoretical and practical significance for higher education educators in designing and implementing more effective learning activities to enhance student learning outcomes. This study only adopted a cross-sectional research design, which has certain limitations. Future research would benefit from adopting longitudinal or experimental designs to investigate causal inference.

Author contributions: Qu Binqin: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. Marlissa Omar: Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review & editing. Fathiyah Kamaruzaman: Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review & editing. All authors have made substantial contributions to the study, reviewed and approved the final version of the manuscript, and agreed to be accountable for their contributions.

Declaration of interest: The authors declared that there were no potential conflicts of interest.

Data availability: Data availability can be obtained by contacting the corresponding author directly.

Ethical statement: The author stated that this study has been approved by the Ethics Committee for Biomedical Research, Yunnan Normal University on February, 9, 2026, with the approval number No.: ynnuethic2026-019. All participants provided written informed consent, and their privacy and anonymity were strictly safeguarded. Data collection was conducted in accordance with ethical guidelines. All participants provided voluntary consent and retained the right to withdraw from the study at any time.

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