How does peer-led teaching presence promote the development of cognitive presence? Evidence based on behavioural sequence analysis

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Cognitive presence is essential for deep and meaningful learning, yet developing it poses challenges. Theoretically, peer-led teaching presence can enhance cognitive presence, but research on this facilitation is limited. This study used behavioural sequence analysis to investigate how peer-led teaching presence promotes cognitive presence development. First, the study found that peer-led teaching presence promotes overall cognitive presence development by facilitating transitions from the triggering event to the resolution stage via multiple pathways. It also facilitates transitions from lower-order learning (including the triggering event to exploration, exploration back to the triggering event, and the self-reinforcing cycle of exploration) to higher-order learning in the integration stage. Additionally, it breaks the cycle of triggering new events or self-circulation from the integration stage, ensuring a smooth transition to the resolution stage. In the exploration phase, peer-led teaching presence significantly increases exploratory behavioural sequences and promotes bidirectional transitions between these behaviours. Notably, it also increases a significant bidirectional triggering of divergence in the exploration stage and connecting ideas, synthesis in the integration stage. Within the integration phase, there is a marked increase in integrative behaviour sequences, enabling multiple routes from the integration to the resolution stage. Based on these findings, we propose practical implications are.

Implications for practice or policy:

- Educators and trainers should consider designing activities that encourage peer interaction and collaborative problem-solving to facilitate transitions from initial triggering events to deeper stages of learning, such as exploration and integration.
- Institutions can invest in training programmes that equip students with the skills necessary to lead and participate effectively in peer-led learning sessions, thereby fostering a more supportive and engaging learning environment.

Keywords: peer-led teaching presence, cognitive presence, behaviour sequence analysis, online learning, student

Introduction

The community of inquiry framework is a significant topic in educational technology, with its foundational paper (Garrison et al., 1999) receiving over 9,000 citations by July 2024, according to Google Scholar (Google Academic). The framework consists of three core elements: teaching presence, social presence and cognitive presence. Cognitive presence is defined as the extent to which learners construct meaning through reflective dialogue and sustained interaction (Garrison, 2017; Wang, 2024). This process involves critical thinking, active listening and articulating ideas during discourse, emphasising higher-order thinking through metacognition (Maranna et al., 2022; Nungu et al., 2023). Cognitive presence unfolds in four stages: triggering events, exploration, integration and resolution. Triggering events refer to problems or tasks that capture students' attention; exploration involves the search for relevant information; integration entails consolidating and reconciling different insights about the problem at hand; and resolution involves applying newly acquired knowledge in novel contexts (Garrison et al., 2001).

Cognitive presence is a key indicator of students' cognitive development (Kaczkó & Ostendorf, 2023). Successfully progressing through its four stages – triggering events, exploration, integration and resolution – is crucial for deep and meaningful learning (Garrison, 2022; Garrison & Arbaugh, 2007). However, research shows that students often struggle to advance from lower-order stages (triggering events and exploration) to higher-order stages (integration and resolution) (Vaughan & Garrison, 2005). Additionally, some studies reveal that cognitive presence frequently remains at a low level (B. Liu et al., 2022; Moore & Miller, 2022). For example, Guo et al. (2021) revealed that 95% of student contributions were at the exploration stage, with only 2.5% reaching integration and another 2.5% addressing triggering events. Consequently, there is a growing call for research on how to enhance cognitive presence (Moore & Miller, 2022; Sadaf, Martin & Wu, 2021).

Teaching presence is defined as "the design, facilitation, and direction of cognitive and social processes to achieve personally meaningful and educationally valuable learning outcomes" (Anderson et al., 2001, p. 5). It directly influences the establishment and maintenance of cognitive presence (Garrison, 2023). Alharbi (2022) revealed that insufficient teaching presence hindered students' cognitive development, as cognitive presence does not naturally progress or mature over time without it. Moreover, advancing cognitive presence into the integration and resolution stages heavily relies on teaching presence (Ba et al., 2023). Studies have shown that teaching presence can enhance cognitive presence both directly and indirectly (Wang, 2022).

Teaching presence is often linked to teachers; it can also encompass any member of the learning community, reflecting the collaborative nature of knowledge construction shaped by collective contributions and interactions. Thus, teaching presence is preferred over "teacher presence". Students can contribute to facilitating learning and creating a supportive environment through inquiries, reflections and interactions (Shea et al., 2022). Consequently, establishing and maintaining teaching presence should involve shared responsibility between teachers and students (Garrison, 2022). Teachers foster teaching presence through course design and active instruction, while students develop it via engaged discussions, peer reviews and leading discussions (Shea et al., 2022). Wertz (2022) introduced a third dimension representing peer facilitation, grounded in the idea that teaching responsibilities are shared among all participants, including peer-to-peer interactions.

Recently, there has been growing interest in understanding the mechanisms and efficacy of peer feedback in fostering productive learning. Shin et al. (2020) revealed that the perceived usefulness of peer scaffolding significantly predicts group performance. W. Chen and Gao (2022) demonstrated that engaging with peer feedback enhances positive perceptions of feedback, promotes deep learning and improves critical thinking. Compared to instructor-led facilitation, student-led discussions increase peer interaction and deepen comprehension (Oh et al., 2018). Additionally, research has explored how peer facilitation contributes to cognitive presence. Gašević et al. (2015) showed that role assignment effectively enhances high-level cognitive presence. Kim et al. (2020) revealed that learning leaders post messages indicative of higher cognitive presence more frequently than non-leaders. Choo et al. (2020) proposed that assessments designed for peer support can facilitate students' demonstration of cognitive presence. Despite ongoing research into advancing cognitive presence (Al Mamun & Lawrie, 2024; Z. Liu et al., 2023), no study has yet examined the impact of peer-led teaching presence on cognitive presence. Therefore, the present study aimed to investigate whether and how peer-led teaching presence can promote cognitive presence. Specifically, we investigated the following research questions:

(1) Does peer-led teaching presence facilitate the overall advancement of students' cognitive presence? If so, in what ways can this be achieved?
(2) Does peer-led teaching presence facilitate students' cognitive development in the exploration and integration stages? If so, in what ways might this be achieved?

Literature review

Cognitive presence

Cognitive presence suggests that learning is initiated by defining problems or tasks, with solutions determined through analysing, integrating and understanding diverse perspectives based on the exploration of relevant information or knowledge (Garrison et al., 2001). As a dynamic process, the four stages of cognitive presence occur recursively rather than linearly (B. Liu et al., 2022). However, studies have highlighted challenges in transitioning to the final resolution stage (Moore & Miller, 2022), as students frequently struggle to progress from exploration to integration and from integration to resolution (Vaughan & Garrison, 2005).

Recent studies have revealed that cognitive presence is predominantly concentrated in the earlier stages. For example, Chen and Cheng (2019) found that exploration accounted for 53.5% of activities, followed by integration (28.9%), triggering events (11.2%) and resolution (1.1%). Similarly, B. Liu et al. (2022) reported that triggering events, exploration, integration and resolution accounted for 13%, 40%, 24% and 6%, respectively. These findings underscore the importance of fostering progression to higher-order stages (Y. Chen & Cheng, 2019; Olesova & Sadaf, 2024), which has made research on cognitive presence facilitation strategies a focus of recent studies. For instance, Al Mamun and Lawrie (2024) examined how scaffolding support enhances cognitive presence during learner interactions with content in online environments, while Z. Liu et al. (2023) investigated the effects of computer-based mind mapping on students' cognitive presence.

Teaching presence and cognitive presence

Teaching presence comprises three subcategories: instructional design and organisation, facilitating discourse and direct instruction. Instructional design and organisation involve planning the structure, process, interactions and evaluation of learning, including designing schedules, setting time parameters and managing collaborative reflection activities (Anderson et al., 2001). Facilitating discourse refers to strategies that support independent or collaborative learning, such as identifying areas of agreement and disagreement, encouraging student contributions and seeking consensus. Direct instruction encompasses the intellectual and academic leadership role of teachers or other participants in sharing subject knowledge, including presenting content, guiding discussions, providing explanatory feedback and diagnosing misconceptions (Garrison et al., 2001).

Teaching presence fosters cognitive presence by structuring an effective learning environment, facilitating meaningful discourse and providing direct instruction and feedback. The progression of cognitive presence from the triggering event stage to the resolution stage depends heavily on teaching presence (Garrison et al., 2001). Research has demonstrated a significant relationship between teaching presence and cognitive presence, with teaching presence being a strong predictor of cognitive presence (Ma et al., 2017). For example, Wang (2022) revealed that the three subcategories of teaching presence account for 53.4% of cognitive presence, while Ba et al. (2023) found that the advanced stages (integration and resolution) of cognitive presence are closely related to high-level teaching presence.

However, excessive teaching presence can reduce students' interactive discourse and, in extreme cases, lead to the complete cessation of student interaction. Studies show that when teacher discourse is limited, students feel more comfortable expressing their opinions (Y. Chen et al., 2019). Conversely, the presence of teachers may cause students to feel anxious about sharing their ideas, leading to reduced participation in discussions (Hew et al., 2010). Furthermore, students may perceive teaching presence as an implicit form of assessment, discouraging them from openly expressing their perspectives (Y. Chen et al., 2019). Additionally, students often view teachers' opinions as definitive and authoritative, which impedes the development of critical thinking and the advancement of cognitive presence to higher levels. Garrison (2022) emphasised that educators must carefully balance their teaching presence to support students' cognitive presence effectively. Finally, promoting active student participation and advancing cognitive presence to higher levels require substantial time and effort (Hew, 2015), yet teachers face significant workload challenges, particularly in larger classes (Sharma et al., 2023).

Peer-led teaching presence and cognitive presence

Peer facilitation has emerged as a promising strategy for advancing cognitive presence (Y. Chen, 2018; Garrison & Akyol, 2013). Garrison et al. (2001) emphasised that teaching presence is not limited to instructors but can be enacted by any member of a community of inquiry. Expanding on this, Garrison and Akyol (2013) noted that each participant shares the responsibility for constructing personal meaning while also facilitating and directing this process individually and collaboratively. Subsequent research confirmed that in instructor-less environments, students demonstrate increased self-regulation of their cognitive presence, highlighting the value of student leadership in discussions (Garrison & Akyol, 2015). Conversely, the absence of peer facilitation poses challenges for maintaining cognitive presence during online learning (Al Mamun & Lawrie, 2024). According to research, peer facilitation enhances cognitive presence by promoting constructive feedback, reflective thinking (Al Mamun & Lawrie, 2024; Farrokhnia et al., 2025) and collaborative meaning-making through peer help-giving (Jeng et al., 2023).

Cognitive presence is achieved through the integration of individual reflections with collaborative discourse, facilitated by self- and co-regulation within the learning community (Garrison, 2023). This process involves the dynamic regulation of purposeful inquiry, emphasising shared responsibility for monitoring and managing the inquiry process (Garrison, 2023). The depth and meaningfulness of learning within the community depend on members' capacity to effectively oversee and adjust this process (Garrison, 2022). This shared regulatory approach requires learners to collaboratively direct, monitor and adapt their cognitive, affective and behavioural processes to achieve collective learning goals (Garrison, 2022). Establishing and maintaining teaching presence thus necessitates a collective effort, with both teachers and students contributing to fostering an environment conducive to deep and meaningful learning. Exploring how learners regulate their cognitive processes is crucial (Sadaf et al., 2022), and focusing on peer-led teaching presence may enhance our understanding of its role in guiding cognitive presence progression.

Recent research has underscored the critical role of community members in fostering cognitive presence (Garrison, 2022). Choo et al. (2020) have suggested that assessments designed for peer support learning can enable students to demonstrate cognitive presence more effectively. Kim et al. (2020) found that learning leaders posted messages reflecting higher levels of cognitive presence more frequently than non-leaders. Furthermore, cognitive presence is closely linked to critical thinking and deep learning. W. Chen and Gao (2022) demonstrated that peer feedback enhances deep learning and improves learners' critical thinking. Xia and Xu (2024) have argued that peer facilitation in online discussions strengthens students' cognitive presence by encouraging mutual scaffolding in knowledge exchange and co-construction, thereby promoting critical thinking. However, no study has investigated the effect of peer-led teaching presence on cognitive presence. Therefore, the present study aims to explore the enhancing effects and underlying mechanisms through which peer-led teaching presence impacts cognitive presence.

Method

Ethical approval for data collection and reporting has been obtained. All participants signed informed consent forms. This study is supported by the Youth Fund of Humanities and Social Science Research of the Ministry of Education: Mining and Enhancement Strategies of Cognitive Presence Process Models Supported by Learning Analytics (23YJC880002).

Research context and research design

This study was conducted at an urban primary school in western China, part of the China Internet + Education Demonstration Zone Programme. Under the guidance of a university educational technology team, teachers implemented blended online-offline learning using Moodle. Specifically, before each new lesson, students independently learned basic knowledge through teacher-provided digital resources (e.g., character cards, micro-lessons, gamified quizzes) and created individual mind maps. They then collaborated in real-time online group discussions via the mobile Moodle chat room to develop group mind maps. The next day in class, teachers adjusted their instruction based on pre-class discussions, and groups presented their online learning outcomes, receiving feedback from both teachers and peers. Data for this study were collected from students' online group discussions during the fall semester of 2022. The research design is illustrated in Figure 1.

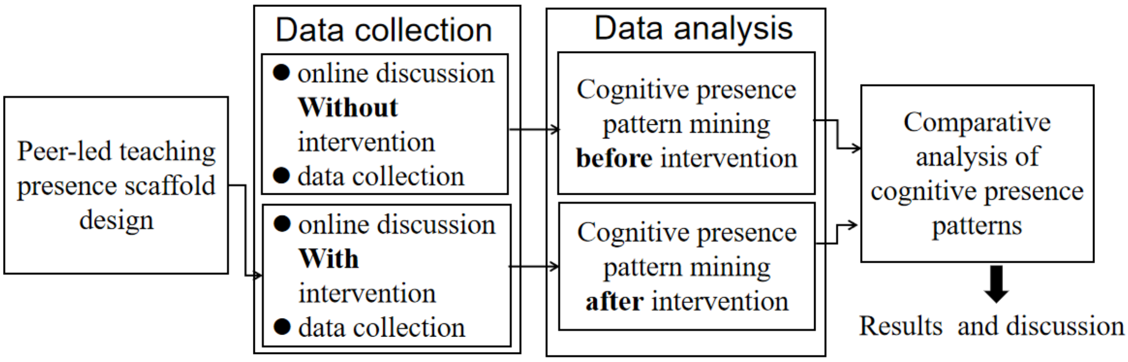

Figure 1. A summary of the research design

Peer-led teaching presence scaffold design

In accordance with the original teaching presence framework (Anderson et al., 2001), the peer-led teaching presence scaffold was designed as illustrated in Table 1. Initially, the original evaluation indices were contextualised without altering their meanings. Specifically, the specific indicators under the three subdimensions of teaching presence remained unchanged, though some examples were slightly modified to fit the specific teaching context. For instance, "This week we will be discussing ..." was changed to "Today we will be discussing ...".

Table 1
Peer-led teaching presence scaffold

Subdimensions	Indicators	Example
Instructional design and organisation	Setting curriculum	"Today we will be discussing ..."
	Designing methods	"I am going to divide you into groups, and you will debate ..."
	Establishing time parameters	"Please post a message as soon as possible"
	Utilising medium effectively	"Try to address issues that others have raised when you post"
	Establishing netiquette	"Keep your messages short"
Facilitating discourse	Identifying areas of agreement or disagreement	"Joe, Mary has provided a compelling counter example to your hypothesis. Would you care to respond?"
	Seeking to reach consensus or understanding	"I think Joe and Mary are saying essentially the same thing"
	Encouraging, acknowledging, or reinforcing student contributions	"Thank you for your insightful comments"
	Setting the climate for learning	"Don't feel self-conscious about thinking out loud ...This is a place to try out ideas after all."
	Drawing in participants and prompting discussion	"Any thoughts on this issue?" "Anyone care to comment?"
	Assess the efficacy of the process	"I think we're getting a little off track here"

Direct instruction	Present content or questions	"Bates says … what do you think"
	Focus the discussion on specific issues	"I think that's a dead end. I would ask you to consider …"
	Summarise the discussion	"The original question was … Joe said … Mary said … we concluded that …We still haven't addressed …"
	Confirming understanding through assessment and explanatory feedback	"You're close, but you didn't account for … this is important because …"
	Diagnose misconceptions	"Remember, Bates is speaking from an administrative perspective, so be careful when you say … "
	Injecting knowledge from diverse sources, such as textbooks, articles, the Internet and personal experiences	"The teacher in the micro-video said … You can find that from …."
	Responding to technical concerns	"If you want to include a hyperlink in your message, you have to …"

The experimental procedure and data collection

This study employed a quasi-experimental one-group pretest-post-test design, chosen for its suitability in natural educational settings. The research process consisted of five stages: (a) Constructing learning tasks, organising group online discussions, engaging students in group knowledge construction activities, and collecting conversation data; (b) Implementing an intervention by providing students with a peer-led teaching presence scaffold (see Table 1), along with a detailed explanation of its use and significance to ensure proper understanding; (c) Organising students for group online discussions, conducting the second group knowledge construction activity under peer teaching presence guidance and collecting conversation data. (d) Using the cognitive presence theoretical framework to explore the process model before and after the intervention through behavioural sequence analysis; (e) Comparing and analysing differences in cognitive presence process patterns pre- and post-intervention.

To ensure internal validity, multiple safeguards were implemented: First, strategic participant grouping to balance intra-group heterogeneity and inter-group homogeneity, minimising selection bias; Second, parallel task design to control for variability in difficulty and complexity; Third, standardised one-hour discussion sessions to control time-related confounds; Fourth, a homogeneous sample from the same course cohort to control for instructional variables; and finally,a robust coding protocol with multiple coders and inter-rater reliability (Cohen's Kappa > 0.80), supplemented by statistical validation of transition probabilities to strengthen the behavioural sequence analysis. Regarding external validity, the peer-led teaching presence scaffold was designed based on existing frameworks, ensuring its generalisability and applicability across various educational settings. Utilising the Moodle chat room not only ensured transparency of the learning environment but also provided a solid foundation for external validity.

Data analysis

Behavioural sequence analysis is a method in behavioural analytics that examines the sequential occurrence of actions to identify how frequently one behaviour follows another (Bakeman & Gottman, 1997, Chapter 8). Commonly used for analysing individual behaviours, peer interactions, dialogue and engagement patterns, behavioural sequence analysis helps understand what students do, why they engage in certain learning behaviours and which behaviours enhance learning outcomes, thereby deepening comprehension of the learning process.

The analysis assesses statistically significant associations between behaviours using z scores from residual tables. Z scores measure the significance of connections between actions through probabilistic statistics, with a binomial test applied to describe the dataset. A z score exceeding 1.96 indicates a statistically significant relationship, suggesting the observed sequence reflects a meaningful pattern rather than occurring by chance.

Firstly, the behavioural indicators for the three stages of cognitive presence – triggering event, exploration and integration – were strictly adhered to as defined in the original coding framework. Secondly, drawing on prior research (Akyol & Garrison, 2011; Olesova et al., 2016; Sadaf & Olesova, 2017), this study contextualised the resolution phase within the specific pedagogical practices of the research setting. Although the original framework emphasises applying constructed knowledge to solve real-world problems, resolution was redefined in this study as "successfully addressing queries posed by team leaders and group members". The cognitive presence coding framework is presented in Table 2.

Table 2
The coding framework of cognitive presence

Descriptor	Coding	Indicators	Socio-cognitive processes
Triggering events	Te-Q	Recognising the problem	Presenting background information that culminates in a question
	Te-T	Sense of puzzlement	Asking questions Messages that take discussion in new direction
Exploration	Ex-N	Information exchange	Personal narratives, descriptions or facts (not used as evidence to support a conclusion)
	Ex-S	Suggestions for consideration	Explicitly characterises message as exploration – e.g., “Does that seem about right?” or “Am I way off the mark?”
	Ex-D	Divergence – within a single message	Many different ideas or themes presented in one message
	Ex-B	Brainstorming	Adds to established points but does not systematically defend, justify or develop addition
	Ex-C	Leaps to conclusions	Offers unsupported opinions
Integration	In-Ca	Convergence – among group members	Reference to previous message followed by substantiated agreement, e.g., “I agree because …” Building on, adding to others’ ideas
	In-Cw	Convergence – within a single message	Justified, developed, defensible, yet tentative hypotheses
	In-Cs	Connecting ideas, synthesis	Integrating information from various sources – textbook, articles, personal experience
Resolution	Res	Creating solutions	Explicit characterisation of message as a solution

Discussion data extracted from the Moodle platform were cleaned to remove irrelevant content. Two trained coders independently analysed and coded the utterances based on pre-defined categories. Inter-rater agreement was assessed using Cohen’s Kappa, yielding a value of 0.85, indicating high consistency between coders.

Results

Cognitive presence patterns before intervention

The study collected 1,230 student utterances during the group knowledge construction process prior to the intervention. These were coded for cognitive presence levels using the framework in Table 2, yielding

1,012 instances of cognitive presence behaviours. Analysis in Generalized Sequential Querier software calculated behaviour frequencies and residuals (Table 3), and a graph of the adjusted residuals was generated to illustrate the pre-intervention sequence of cognitive presence behaviours (Figure 2).

Table 3
Residual values of cognitive presence behaviour sequence analysis before the intervention

	A	B	C	E	F	G	H	I	J	K	L
Residual	Te-Q	Te-T	Ex-N	Ex-S	Ex-C	Ex-B	Ex-D	In-Ca	In-Cw	In-Cs	Re
Te-Q	-0.72	-0.19	6.86	-1.29	-0.42	-0.49	-1.79	-3.37	-2.17	-1.19	-1.13
Te-T	19.70	-3.35	1.78	-3.21	-0.56	-0.65	-2.39	-4.49	-2.89	-1.58	-0.01
Ex-N	-5.14	-5.55	5.45	2.60	-0.06	0.63	3.35	-2.19	0.61	-2.68	-3.40
Ex-S	-2.75	-3.46	2.60	-0.95	2.32	-0.90	-1.35	3.53	-0.71	0.09	-0.89
Ex-C	2.08	1.41	-1.28	0.77	-0.09	-0.11	-0.40	-0.75	-0.48	-0.26	-0.25
Ex-B	-0.49	-0.65	-1.47	-0.90	-0.11	15.84	-0.46	1.88	-0.56	-0.31	-0.29
Ex-D	-1.79	-0.41	-4.48	0.19	-0.40	-0.46	0.94	-1.60	7.40	7.56	-0.06
In-Ca	-2.98	8.82	-8.10	-1.29	-0.75	-0.87	-0.79	5.89	-0.16	-1.51	5.88
In-Cw	-1.64	2.10	-2.96	2.54	-0.48	-0.56	0.73	-0.51	0.34	1.09	0.41
In-Cs	-1.19	-0.85	-2.24	0.66	-0.26	-0.31	0.81	1.37	-0.54	4.92	0.77
Res	-1.13	9.79	-3.40	0.29	-0.25	-0.29	-1.07	-0.80	-1.29	-0.71	-0.67

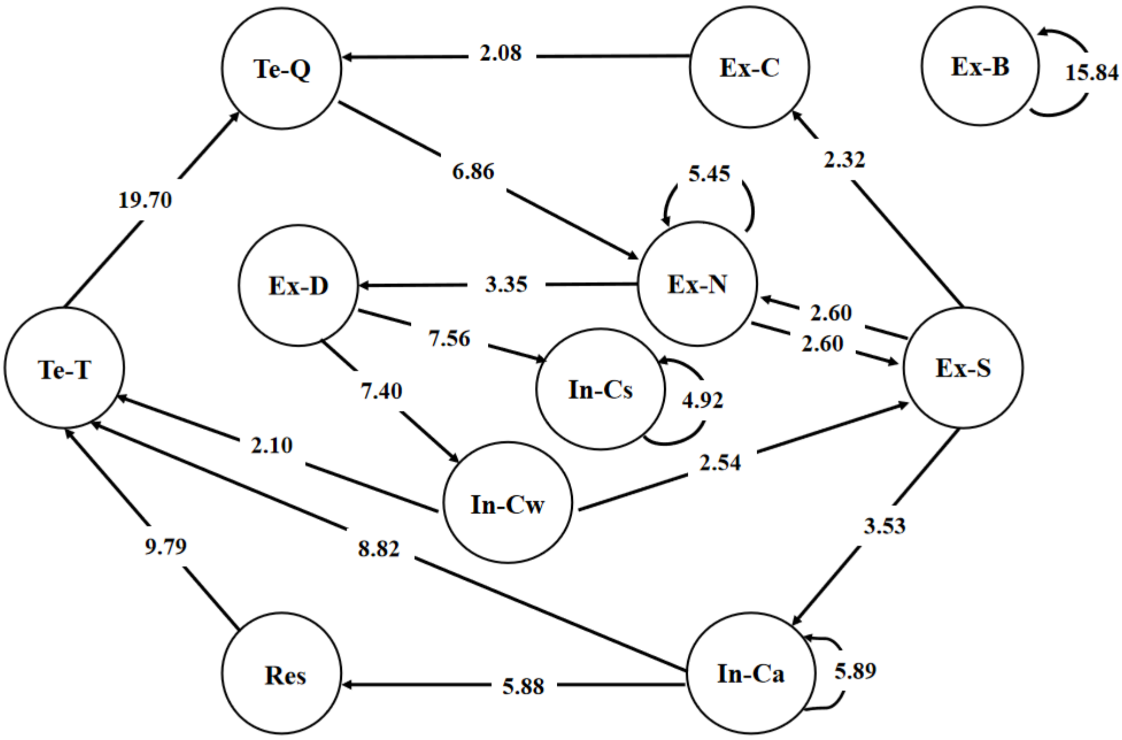

Figure 2. The cognitive presence sequence before the intervention

Cognitive presence patterns after intervention

The study collected 1,230 student utterances during group knowledge construction after the intervention. Using the framework in Table 2, these were coded for cognitive presence levels, yielding 1,129 instances of cognitive presence behaviours. These instances were analysed in Generalized Sequential Querier software to calculate behaviour frequencies and residuals (see Table 4). A graph based on the adjusted residuals was generated to illustrate the post-intervention sequence of cognitive presence behaviours (Figure 3).

Table 4
Residual values of cognitive presence behaviour sequence analysis after the intervention

	A	B	C	E	F	G	H	I	J	K	L
Residual	Te-Q	Te-T	Ex-N	Ex-S	Ex-C	Ex-B	Ex-D	In-Ca	In-Cw	In-Cs	Re
Te-Q	-1.72	-2.21	9.46	-2.54	-0.39	-0.51	-1.34	-2.32	-1.08	-1.72	-2.68
Te-T	24.97	-2.03	0.00	-3.36	-0.51	-0.66	-1.73	-3.39	-2.22	-2.22	-3.47
Ex-N	-5.28	-5.59	8.05	2.40	2.50	3.23	2.21	0.61	-2.33	-2.33	-6.20
Ex-S	-3.30	-2.42	2.55	-0.08	-0.75	-0.97	-0.19	3.56	-1.79	-0.65	-1.25
Ex-C	-0.39	-0.50	2.49	-0.75	-0.09	-0.12	-0.31	-0.71	-0.39	-0.39	-0.61
Ex-B	-0.51	-0.65	3.22	-0.97	-0.12	-0.15	-0.39	-0.92	-0.51	-0.51	-0.79
Ex-D	-1.34	-1.72	-3.75	0.29	-0.31	-0.39	-1.04	-0.93	8.37	7.56	-1.53
In-Ca	-3.11	-2.10	-7.57	-0.62	-0.71	-0.92	0.06	2.60	3.20	-1.53	12.19
In-Cw	-1.08	-1.70	-3.52	0.86	-0.39	-0.51	-0.53	1.62	0.21	2.13	3.49
In-Cs	-1.72	-2.21	-2.93	0.48	-0.39	-0.51	2.70	0.83	-0.44	7.91	-0.48
Res	-2.24	20.61	-7.64	1.09	-0.61	-0.79	-1.53	-4.31	0.40	-1.80	0.96

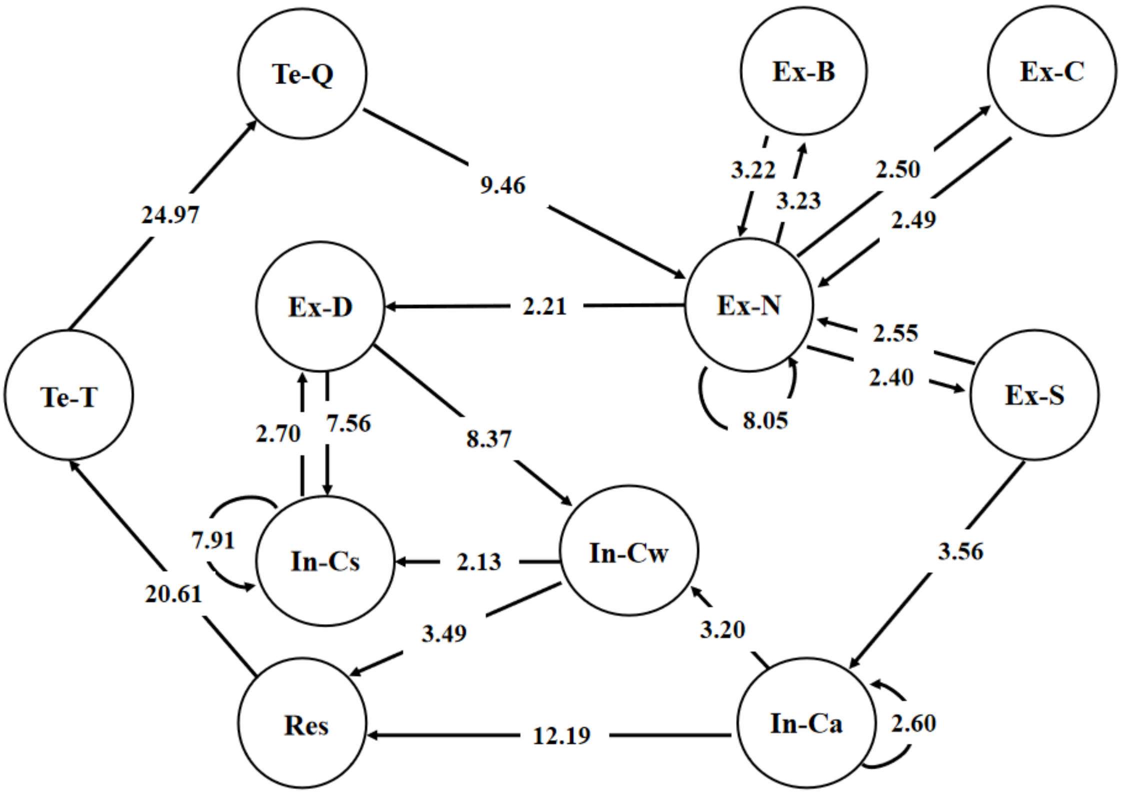

Figure 3. The cognitive presence sequence after intervention

The difference in cognitive presence patterns before and after the intervention

The difference in overall cognitive presence patterns before and after the intervention

Firstly, prior to the intervention, cognitive presence followed two distinct paths from the triggering event through exploration and integration to resolution (Figure 4, left). Post-intervention, cognitive presence exhibited four distinct pathways along the same stages (Figure 4, right).

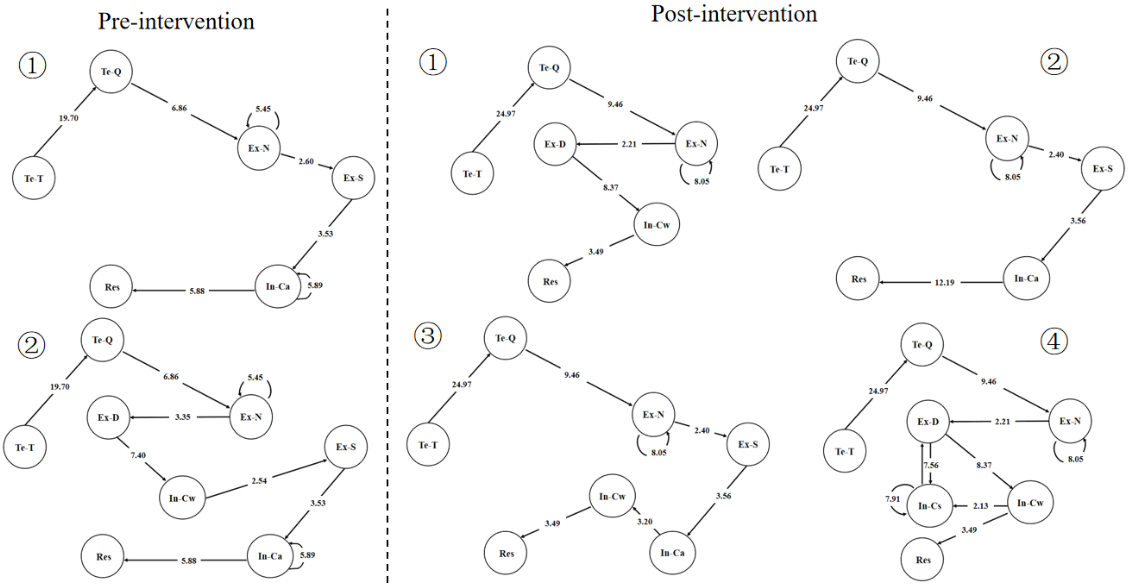

Figure 4. The overall differences in cognitive presence patterns before and after the intervention

Secondly, pre-intervention analysis revealed a cyclical pattern (Te-T → Te-Q → Ex-N → Ex-S → Ex-C → Te-Q; Figure 5, top) indicating that cognitive presence was confined to lower-order learning, oscillating between triggering events and exploration stages without progression. Furthermore, it was often trapped in self-reinforcing exploration loops involving brainstorming (Ex-B) and information exchange (Ex-N) (Figure 5, top). Post-intervention data demonstrated significant progression, with cognitive presence consistently advancing from triggering events through exploration to integration, as evidenced by sequences Te-T → Te-Q → Ex-N → Ex-D → In-Cw, Te-T → Te-Q → Ex-N → Ex-D → In-Cs, and Te-T → Te-Q → Ex-N → Ex-S → In-Ca (Figure 5, bottom). Notably, pre-intervention leaps to conclusions frequently triggered new events (Ex-C → Te-Q), while post-intervention cognitive cycles predominantly originated from the resolution stage.

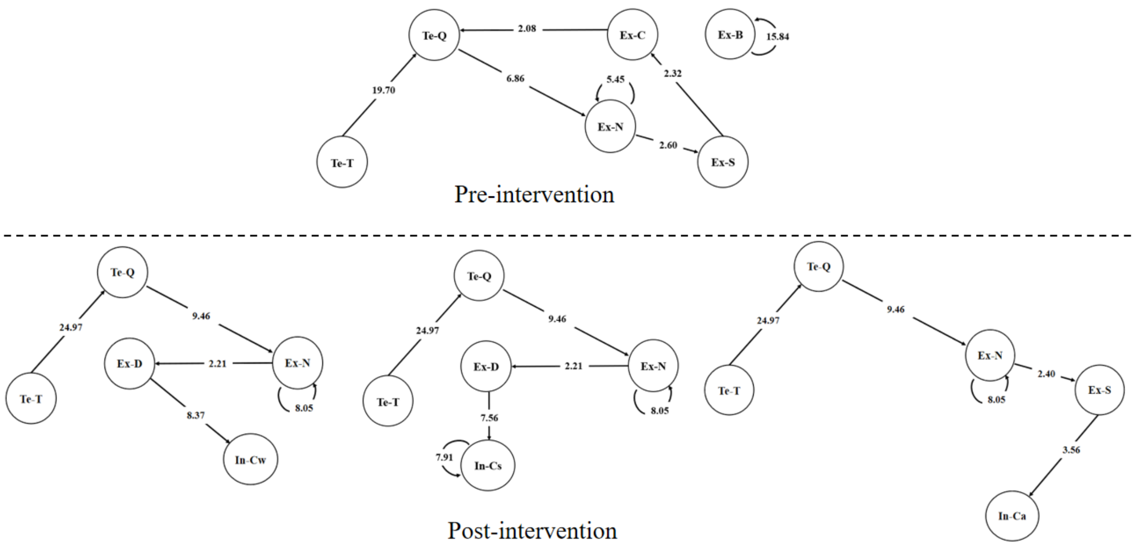

Figure 5. The overall differences in cognitive presence patterns before and after the intervention

Thirdly, pre-intervention, sequences such as Te-T → Te-Q → Ex-N → Ex-S → In-Ca → Te-T and Te-T → Te-Q → Ex-N → Ex-D → In-Cw → Te-T (Figure 6, top) show cognitive presence progressing from triggering events to exploration and then to integration (Ex-S → In-Ca and Ex-D → In-Cw) but failing to reach resolution, instead cycling back to triggering events (In-Ca → Te-T and In-Cw → Te-T). In addition, the sequence Te-T → Te-Q → Ex-N → Ex-D → In-Cs (self-loop) indicates that cognitive presence progressed from triggering events to exploration (Te-Q → Ex-N) and then to integration (Ex-D → In-Cs) but became trapped in a self-cycle of connecting ideas and synthesis (In-Cs). Additionally, cognitive presence often fell into a self-cycle loop of group convergence among group members (In-Ca) during integration. Conversely, post-intervention (Figure 6, bottom), none of the three integration-stage indicators significantly initiated new triggering events. Instead, cognitive presence successfully transitioned from integration to resolution through either group member convergence (In-Ca) or intra-message convergence (In-Cw). Notably, the persistent group convergence loop (In-Ca) observed pre-intervention was eliminated. Furthermore, although self-cycles of idea synthesis (In-Cs) persisted, cognitive presence could escape these loops through the pathway of divergence to convergence to resolution (In-Cs → Ex-D → In-Cw → Res).

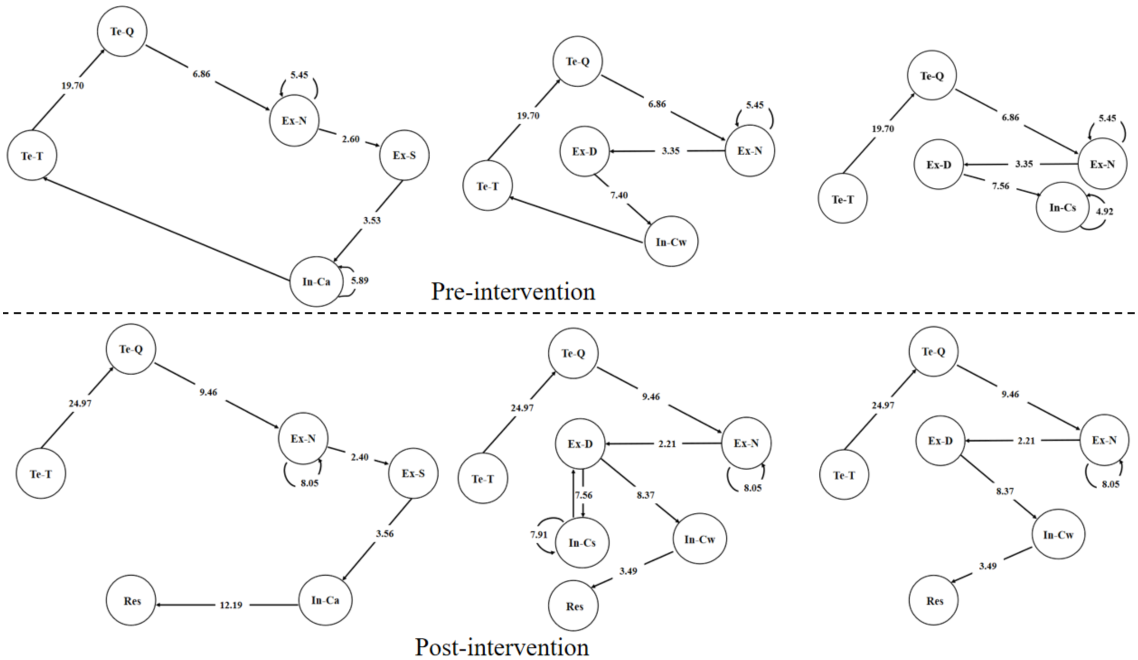

Figure 6. The overall differences in cognitive presence patterns before and after the intervention

The difference in cognitive presence in the exploration and integration stages before and after intervention

In the exploration stage, information exchange serves as the foundation for smooth cognitive presence development. Firstly, pre-intervention (Figure 7, left), information exchange significantly initiates divergence (Ex-N → Ex-D) and suggestions for consideration (Ex-N → Ex-S). Post-intervention (Figure 7, right), it continues to initiate these actions while also leading to leaps to conclusions (Ex-N → Ex-C) and brainstorming (Ex-N → Ex-B). Secondly, pre-intervention, information exchange and suggestions for consideration (Ex-S) reinforced each other. Post-intervention, information exchange significantly initiates suggestions for consideration (Ex-N → Ex-S), leaps to conclusions (Ex-N → Ex-C) and brainstorming (Ex-N → Ex-B), which in turn significantly trigger further information exchange (Ex-S → Ex-N, Ex-C → Ex-N, Ex-B → Ex-N). Thirdly, pre-intervention, divergence in the exploration stage significantly initiates connecting ideas and synthesis in the integration stage (Ex-D → In-Cs). Post-intervention, divergence and connecting ideas and synthesis develop a significant mutual triggering relationship (Ex-D → In-Cs, In-Cs → Ex-D), effectively bridging exploration and integration.

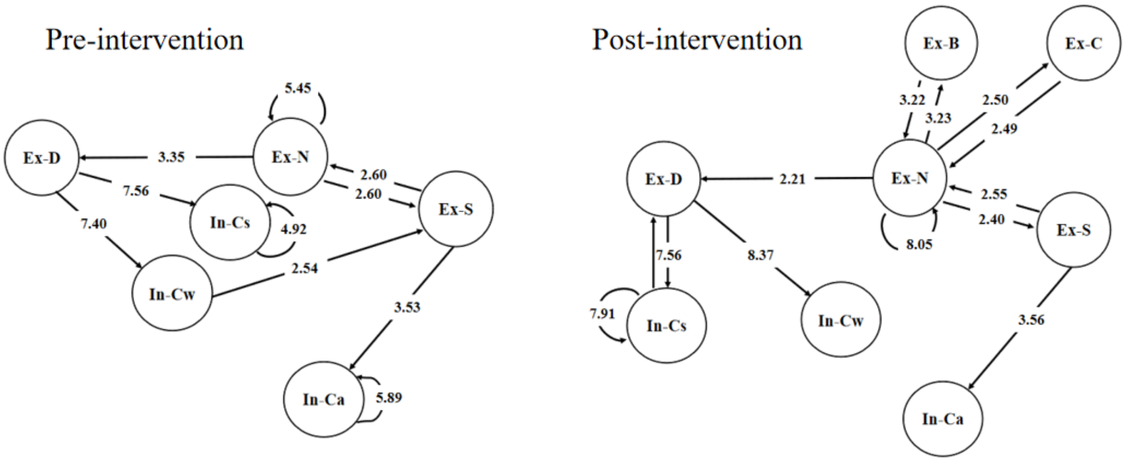

Figure 7. The differences in cognitive presence patterns in the exploration stage

Regarding the integration stage, initially (Figure 8, left), no direct links existed between the three behavioural indicators. Following the intervention (Figure 8, right), convergence among group members significantly initiated convergence within a single message (In-Ca → In-Cw), which then significantly triggered connecting ideas and synthesis (In-Cw → In-Cs). This indicates that behaviours within the integration stage developed reciprocal triggering patterns, resulting in a significant increase in phase-specific cognitive activities. Additionally, prior to the intervention, cognitive presence reached resolution only via convergence among group members (In-Ca → Res). Post-intervention, resolution can be achieved through multiple pathways: convergence within a single message (In-Cw → Res), group convergence (In-Ca → Res) or connecting ideas and synthesis leading to divergence, followed by convergence within a single message, and finally resolution (In-Cs → Ex-D → In-Cw → Res).

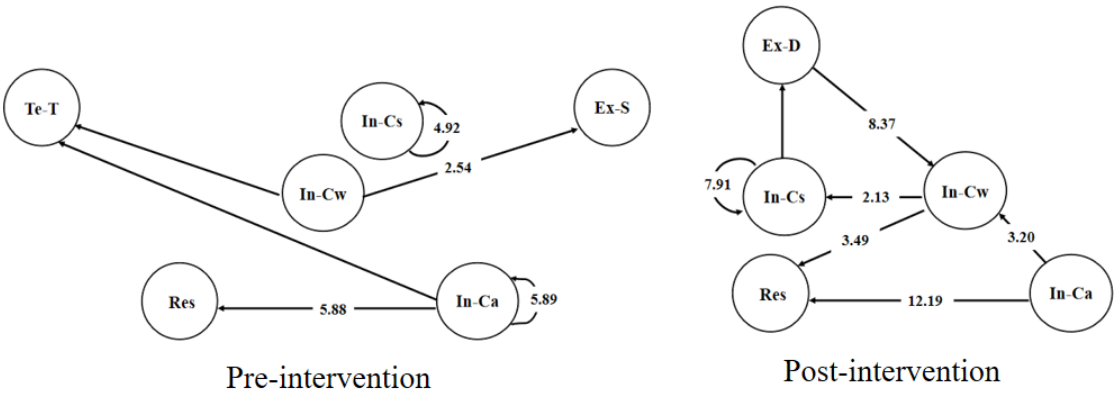

Figure 8. The differences in cognitive presence patterns in the integration stage

Discussion

First, this study revealed that peer-led teaching presence enhances students' cognitive presence by increasing the number of transition paths from triggering events to the resolution stage. Initially, divergence in the exploration phase significantly initiated convergence among group members (Ex-D → In-Ca) and within individual messages (Ex-D → In-Cw) in the integration stage. Following the intervention, these pathways were strengthened, and a significant reciprocal link emerged between divergence and the connecting of ideas or synthesis in the integration stage (Ex-D → In-Cs, In-Cs → Ex-D). As individuals possess unique understandings due to varying prior experiences (Boogert et al., 2018), disagreements in collective knowledge construction are inevitable. However, the key lies in establishing connections among these divergent viewpoints. Peer-led teaching presence facilitates this by identifying erroneous or incomplete perspectives, resolving conflicts and addressing misconceptions explicitly among group members (Y. Chen, 2018). This aligns with the notion that teaching presence engages students in reflection, cognitive conflicts and deeper cognitive engagement (Wang & Stein, 2021).

Another critical factor in enhancing cognitive presence from initial triggering events to the resolution phase is the role of group member convergence. This convergence not only initiates resolution (In-Ca→Res) but also fosters convergence within individual messages (In-Ca→In-Cw), which subsequently promotes resolution (In-Cw→Res). Peer feedback facilitates this process through evaluative and reflective activities (Faridah et al., 2020), prompting critical assessment of peer understanding and articulation of individual perspectives (Lin et al., 2001). At the group level, feedback fosters shared understanding and solution development as students integrate multiple perspectives. Simultaneously, within individual messages, synthesising feedback leads to more comprehensive responses, deepening discussions and driving resolution. This dual convergence mechanism enhances both collective and individual understanding, ultimately contributing to problem resolution.

Second, the study revealed that, prior to the intervention, cognitive presence oscillated between triggering events and exploration, as well as within the exploration phase itself. This finding aligns with research indicating that cognitive presence in discussions lacking guidance tends to remain in lower-order phases (Kanuka, 2011; Pawan et al., 2003), resulting in superficial interactions without meaningful progression (Gašević et al., 2015). The intervention effectively disrupted these patterns, enabling consistent progression from exploration to integration. The observed shift towards advanced learning can be attributed to the peer teaching presence, which fostered an environment conducive to knowledge construction through active engagement and critical thinking (Kara, 2018). This setting facilitated deeper comprehension and integration of information by promoting the sharing of diverse perspectives and encouraging deeper content engagement. Consequently, students were able to integrate new knowledge with existing understandings, thus enhancing higher-order cognitive presence.

Moreover, while pre-intervention leaps to conclusions often triggered new cycles, post-intervention cognitive cycles predominantly originated from the resolution stage. This finding aligns with the theoretical proposition that cognitive presence triggers new cycles at the resolution stage (Garrison et al., 2001; Kovanović et al., 2015). One possible explanation is that peer-led teaching presence helped identify and correct misunderstandings or incomplete thinking when hasty conclusions were drawn, thereby preventing the recurrence of triggering events. Additionally, the development of critical thinking skills through peer feedback and guidance (W. Chen & Gao, 2022; Oh et al., 2018) may have enabled students to more objectively assess the validity of their conclusions, further reducing the recurrence of triggering events.

Third, the study revealed that, pre-intervention, cognitive presence in the integration phase either became entrapped in repetitive integration sequences or prematurely instigated new discussion topics. Ideally, the integration phase requires dynamic teaching presence to identify misconceptions, pose probing questions and provide insights, fostering the continuous development of cognitive presence (Fiock, 2020). However, the absence of teaching presence prior to the intervention left students without timely support, resulting in a self-reinforcing cycle within the integration stage and premature initiation of new topics before resolving current discussions. Following the intervention, a pivotal change emerged: as cognitive presence transitions to the integration phase, peer-led teaching presence facilitates progression towards the resolution phase, preventing both perpetuation within the integration stage and premature triggering of new topics. This transformation can be attributed to enhanced metacognitive awareness facilitated by real-time peer feedback (Zheng et al., 2018), which enables students to better monitor and regulate their learning process. By adjusting their strategies, students avoid repetitive loops and maintain focus on resolving current discussions before progressing to new topics. Furthermore, Pham et al. (2020) showed that online peer feedback enhances reflective thinking skills. As a form of timely and structured online peer feedback, peer teaching presence likely encourages deeper reflection, active synthesis of diverse perspectives and critical evaluation of conclusions, ensuring meaningful progression towards resolution.

Fourth, regarding the exploration phase, post-intervention observations reveal that information exchange not only significantly triggers divergence and suggestions for consideration but also stimulates brainstorming and leaps to conclusions. This indicates a significant expansion in the range of exploratory behavioural patterns, suggesting that peer-led teaching presence promotes a thorough examination of relevant information during the exploration phase. This finding reinforces the earlier assertion that peers' contributions significantly inspire a broader range of perspectives on the discussed topics (Alharbi, 2022). Peer-led teaching presence provides learners with structured, timely and relevant feedback, helping clarify misunderstandings, highlight gaps in reasoning and suggest new directions for exploration, thereby encouraging more inquiry behaviours.

Additionally, the intervention facilitates a bidirectional flow of exploratory actions. Specifically, information exchange stimulates the generation of suggestions for consideration, leaps to conclusions, and brainstorming, while these activities, in turn, reciprocally ignite further information exchange. This dynamic aligns with the theoretical construct that learners oscillate between individual contemplation and collective exploration, toggling between introspective critique and collaborative discourse (Garrison et al., 2001; Gašević et al., 2015). Peer-led teaching presence is crucial in this navigation by providing structured feedback and guiding students to reflect on their own ideas while engaging with others' perspectives (Xia & Xu, 2024), fostering a richer exchange of ideas. The bidirectional flow of exploratory actions highlights the importance of facilitating discourse (the second subdimension of teaching presence) in creating a balanced and dynamic learning environment. By encouraging both contributions and responses to ideas (Wang & Stein, 2021), peer leaders help maintain discussion momentum and prevent stagnation.

Furthermore, the intervention achieves a significant bidirectional triggering of divergence and connecting ideas or synthesis, indicating a bidirectional synergy between idea generation and synthesis. This demonstrates the efficacy of peer-led teaching presence in bridging the exploration and integration stages in cognitive processes, validating the theoretical premise of non-linear cognitive progression (B. Liu et al., 2022). Peer-led teaching presence encourages a dynamic interplay between divergent thinking and idea connection within group discourse, enhancing critical examination of the subject matter through reciprocal transitions. This approach goes beyond linear disagreement-to-agreement sequences, promoting iterative discourse that enriches understanding.

Fifth, concerning the integration phase, it can be observed that post-intervention, there is a marked increase in behaviours indicative of this phase. This finding aligns with Akyol and Garrison (2011), who reported that integration was the most frequently observed level in students' online peer-facilitated discussions, and with Kim et al. (2020), who revealed messages at the integration level from learning leaders were twice as frequent compared to non-learning leaders. On the one hand, the objective of the integration phase is to evaluate the applicability of information gathered during exploration by weaving connections between different perspectives (Garrison et al., 2001; Olesova et al., 2016). Central to this process is the identification and understanding of diagnostic errors. Diagnosing misconceptions is a pivotal aspect of direct instruction (the third subdimension of teaching presence), which helps students attain accurate comprehension (Fiock, 2020). Direct instruction also confirms peer understanding through assessment and explanatory feedback, facilitating the evaluation of information applicability by integrating knowledge from diverse sources (Anderson et al., 2001; Garrison & Arbaugh, 2007). On the other hand, the timeliness of peer feedback encourages deeper engagement with discussion topics (Alharbi, 2022), thereby invigorating the integration phase.

Furthermore, the present study revealed that the intervention transformed cognitive presence progression from a singular group convergence pathway to resolution pre-intervention into multiple, distinct resolution pathways post-intervention. One possible explanation is that the integration phase, as delineated by Garrison et al. (2001), revolves around comprehending and synthesising exploratory findings, with a focus on the convergence of different ideas (Olesova et al., 2016). Students must engage in peer collaboration, moving beyond their initial comprehension to levels requiring critical analysis of the problem, formulation of solutions and validation of the proposed resolutions (Sadaf & Olesova, 2017).

During this phase, learners frequently encounter cognitive conflicts that impede the constructive exchange of ideas. Peer-led teaching presence manages these disagreements, helping to untangle conflicting ideas. This ensures that learners maintain a correct course in their cognitive journey and ultimately reach the resolution stage. However, this requires further research.

Conclusion and implications

Cognitive presence is the foundation of deep learning and critical thinking; thus, facilitating its smooth progression is of utmost importance. This study employed behavioural sequence analysis to investigate the effect of peer-led teaching presence on cognitive presence. The findings indicate that peer-led teaching presence enhances the overall developmental level of cognitive presence, also the developmental levels in both the exploration and integration phases. These findings highlight the critical role of peer-led teaching presence in enhancing cognitive presence. To effectively foster peer-led teaching presence, several practical implications are presented below.

First, institutions should develop and validate a robust teaching presence assessment rubric to systematically identify potential expert learners. This instrument should evaluate essential competencies based on the three dimensions of teaching presence: instructional design and organisation, facilitating discourse and direct instruction. Subsequently, a structured training programme should be implemented, focusing on developing these core teaching presence skills through simulated scenarios and guided practice sessions. This approach ensures that expert learners are well-equipped to foster an effective learning environment by mastering the essential components of instructional design, discourse facilitation and direct instruction.

Second, we recommend establishing clear protocols for expert learner roles across different cognitive phases. For example, during the exploration phase, expert learners should guide information exchange and perspective generation; in the integration phase, they should introduce alternative viewpoints and challenge misconceptions; and at the resolution phase, they should facilitate consensus-building and solution validation. Furthermore, to maximise skill development, a rotation system should be implemented, allowing multiple students to assume expert learner roles throughout the course.

Third, we recommend that teachers provide expert learners with regular monitoring and feedback sessions, supplemented by opportunities to share best practices. Additionally, institutions should establish periodic evaluation mechanisms to assess the overall effectiveness of the peer teaching. Concurrently, ongoing professional development opportunities should be provided for teachers to enhance their capacity in mentoring expert learners.

Limitations and future research

Although the findings of this study provide valuable insights, the generalisability of the results is limited by the specific sample of students from a single course. Future research should explore diverse educational contexts and learner demographics to strengthen external validity. Additionally, although methodological safeguards were implemented, potential internal validity concerns remain. Incorporating control groups in future studies could further address these limitations.

Author contributions

Xuemei Bai: Conceptualisation, Investigation, Writing – original draft, Writing – review and editing; **Xiaoqing Gu:** Writing – review and editing.

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