Revisiting the Interrelationships Between Social and Cognitive Presences in Asynchronous Online Courses: Insights from Epistemic Network Analysis

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Abstract

Asynchronous online discussions (AODs) are a critical component of online learning, enabling students to exchange ideas and interact with peers in a flexible manner. To explore the interrelationships between social presence and cognitive presence, and how these two presences are connected across various instructional strategies used in AODs, this study involved twenty-two students from two fully online courses participating in AODs, and students' posts were coded and analyzed based on the Community of Inquiry framework. Utilizing the Epistemic Network Analysis (ENA) approach, this study uncovered the intricate connections and meanings behind students' interactions and engagements in AODs. Results indicated that the exploration phase of cognitive presence exhibited the strongest connections with social presence indicators, particularly affective and interactive categories. These findings highlight the importance of emotional and interactive engagement in fostering cognitive presence in AODs. Having compared the high-active and low-active classes, we concluded that learners in the high-active class reported higher social presence compared to those in the low-active class. Furthermore, a detailed week-by-week analysis showed that certain instructional strategies in AODs, such as debate, personalized tasks, and compare and contrast strategies, led to variations in student engagement and active participation. This study offers practical implications for instructional designers and educators in developing more engaging online courses and facilitating AODs. Additionally, it highlights the effectiveness of ENA as a valuable method for analyzing the relationships among CoI presences.

Keywords: Community of inquiry, asynchronous online discussions, social presence, cognitive presence, epistemic network analysis

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Online education has become increasingly popular in the last two decades, evolving into an integral part of higher education due in large part to its accessibility and flexibility (Castro & Tumibay, 2021; Kebritchi et al., 2017). To enhance the effectiveness of online courses, asynchronous online discussions (AODs) are widely adopted (e.g., Cheng & Chau, 2016; Dumford & Miller, 2018; Rivera-Vargas et al., 2021). Analyzing the content of AODs may provide educators with information on how knowledge is constructed and how social interaction occurs in collaborative online learning environments (Anderson & Dron, 2011; Fehrman & Watson, 2021; Ferreira et al., 2018). One of the most widely validated frameworks for studying AODs is the Community of Inquiry (CoI) framework, which provides valuable methodological insights to examine meaningful learning experiences through the interplay of social presence, cognitive presence, and teaching presence (Garrison et al., 2000, 2001). Social presence refers to the extent to which participants in computer-mediated communication feel emotionally connected to one another; cognitive presence is the degree to which learners construct and confirm meaning through ongoing reflection and discussion; and teaching presence involves designing, facilitating, and guiding cognitive and social processes to support learning (Anderson et al., 2001; Garrison et al., 2000; Rourke et al., 1999). These elements work together to support deep and meaningful online learning.

Numerous studies have investigated the interrelationships among the three presences in CoI studies. However, most CoI studies examining relationships primarily rely on self-report CoI surveys and quantitative content analysis of discussion posts (e.g., Garrison et al., 2010; Kozan & Richardson, 2014; Shea et al., 2010), making it challenging to capture detailed information related to the dynamic interrelationships and the variations in group-level interaction patterns (Csanadi et al., 2018; Kapur, 2011). Moreover, studies showed that various instructional strategies used in AODs may impact students' social, cognitive, and teaching presences (e.g., Kilis & Yıldırım, 2019; Olesova et al., 2016). However, little attention was given to how various instructional strategies influence the dynamic relationships among CoI presences. Addressing this gap is essential for designing more effective AODs that promote deeper engagement and learning, as well as for advancing our understanding of how specific instructional strategies shape the dynamics of presences (Fiock, 2020). The purpose of this study is to apply Epistemic Network Analysis (ENA) to investigate the dynamic interrelationships among CoI presences, especially social and cognitive presences, in AODs across classes with varying levels of activity and different instructional strategies. By leveraging ENA's ability to offer statistical modeling and comparable network representations for understanding the relationships and co-occurrences among coded data (Chesler et al., 2015; Shaffer et al., 2016), this study aims to contribute to the growing body of CoI research that employs advanced learning analytics and offers practical insights for enhancing the design and facilitation of online discussions.

Literature Review

The Community of Inquiry Framework

The CoI framework is a widely used theoretical framework for understanding and analyzing learning experiences rather than learning outcomes in online and blended environments (Akyol et al., 2009; Caskurlu et al., 2021; Choo et al., 2020). Developed by Garrison et al. (2000), the CoI framework conceptualizes creating a deep and meaningful (collaborative-constructivist) learning experience by developing three interdependent elements: social, cognitive, and teaching presence.

Social presence can be defined as "the ability of participants to identify with the community (e.g., course of study), communicate purposefully in a trusting environment, and develop interpersonal relationships by way of projecting their individual personalities" (Garrison, 2009, p. 352). Also, social presence facilitates learning by fostering a relaxed atmosphere where students feel free to share their thoughts and participate in insightful conversations (Lee, 2014; Martin et al., 2022), so it is widely discussed by researchers because of its importance for learning outcomes (Chen et al., 2018; Kim, 2011). Furthermore, social presence involves three categories: affective expression (affective), open communication (interactive), and group cohesion (cohesive), as evidenced by studies like Rourke et al. (1999). Specifically, affective expression is the ability to express emotions and attitudes, creating a sense of shared community and emotional connection. Open communication is students' willingness to engage in open, honest, and respectful dialogue, facilitating mutual understanding and trust. Group cohesion refers to the ability to build a sense of belonging and collaboration, promoting teamwork, and collective problem-solving (Rourke et al., 1999). Studies show that social presence is crucial in enhancing knowledge construction in online learning environments. It fosters a sense of connection among learners, which is essential for effective learning and collaboration (Galikyan & Admiraal, 2019; Lee, 2014).

Cognitive presence is essential for critical thinking and deep learning as it involves inquiry, reflection, and the integration of new knowledge (Akyol & Garrison, 2011; Garrison et al., 2001). Cognitive presence refers to the ability of a learner to create and evaluate meanings through essential, ongoing communication and thought (Garrison et al., 2001). Garrison et al. (2000) constructed a practical inquiry model for assessing cognitive presence in online environments, comprising four phases: triggering event, exploration, integration, and resolution. In the triggering event phase, students identify problems, while in the exploration phase, they brainstorm and exchange information. This exploration leads to the integration phase, where students construct meanings through the gathered ideas and information. Finally, in the resolution phase, the newly acquired knowledge is applied in a real-world context (Garrison et al., 2000). Overall, cognitive presence entails the identification of problems, the exploration of relevant information, the construction of new meanings, and the application of solutions to those problems, which is closely related to academic achievements (Cakiroglu, 2020; Kozan & Richardson, 2014; Sadaf et al., 2021).

Anderson et al. (2001) defined teaching presence as "the design, facilitation, and direction of cognitive and social processes to realize personally meaningful and educationally worthwhile learning outcomes" (p. 5). It has three categories: design and organization,

facilitating discourse, and direct construction (Anderson et al., 2001). Teaching presence is a key determinant of student satisfaction, perceived learning, and sense of community (Akyol & Garrison, 2008; Arbaugh, 2008). So far, many researchers have investigated the intricate relationships among social, cognitive, and teaching presences, and results showed these components are strongly and positively interrelated, collectively contributing to developing an interactive and supportive learning environment that facilitates deep understanding and critical thinking (Wilson & Berge, 2023). More specifically, social presence is a mediating factor between teaching and cognitive presence, serving as a prerequisite for developing cognitive presence within the context of collaborative inquiry (Garrison et al., 2010). Although teaching presence is critically important in shaping the learning environment, our study is grounded by student-generated discussion data alone, and instructors are minimally involved in AODs. Therefore, this exploratory study intentionally excluded teaching presence and focused on the relationships between social and cognitive presence.

The Relationship Between Social Presence and Cognitive Presence

Prior research has consistently highlighted the critical role of the interplay between social and cognitive presences in fostering effective and supportive online learning environments that enhance academic success and learning outcomes (e.g., Akyol & Garrison, 2008; Lee, 2014; Tirado Morueta et al., 2016). Additionally, understanding the interrelationships helps educators implement strategies and interventions that address both the social and cognitive needs of students, leading to more satisfying and meaningful learning experiences (Holbeck & Hartman, 2018). A prior study demonstrated that social presence was significantly correlated with cognitive presence and had a positive linear correlation between indicators of social and cognitive presence (Pellas, 2017). Moreover, social presence creates a supportive environment that encourages cognitive engagement (Armellini & De Stefani, 2016). Students who feel connected and comfortable are more likely to participate in discussions, share ideas, ask questions, challenge each other's thinking, and engage in deeper cognitive processes (Costley, 2019; Garrison & Arbaugh, 2007; Rovai, 2002). Social presence has also been found to be positively related to the quality of cognitive presence and could be regarded as a mediating variable between teaching and cognitive presence (Garrison et al., 2010; Kozan, 2016; Shea & Bidjerano, 2009). Furthermore, social presence not only facilitates higher-order thinking by providing a context for critical discourse (Lee, 2014), it also fosters open communication and a sense of belonging to a community, which are associated with higher levels of cognitive presence in learners to improve knowledge understanding and application (Akyol & Garrison, 2008; Lee, 2014). However, the dynamic nature of social and cognitive presences has not been explicitly addressed, highlighting the need to analyze their temporal progression to capture the evolving interactions and developmental trajectories throughout the learning process (Elmoazen et al., 2024; Saqr & López-Pernas, 2023).

Epistemic Network Analysis in CoI Analysis

The interrelationships among social and cognitive presences have been examined by several researchers using a variety of instruments and methodologies (e.g., Kozan & Richardson, 2014; Morueta et al., 2016). One approach is the CoI survey which was widely accepted and used to observe and assess the relationships among different indicators of these three presences in order to investigate students' learning experiences (Stenbom, 2018). The CoI survey developed by Arbaugh et al. (2008) has been widely employed to examine the interrelationships

among two or more presences, as well as their associations with other variables such as perceived learning (Rockinson-Szapkiw et al., 2016). This instrument facilitates the application of statistical analyses to ensure the reliability and validity of the data (Stenbom, 2018). However, the survey results reveal little information regarding the discussion process, making it difficult for instructors to understand what students are learning (Ba et al., 2023). Quantitative content analysis of online discussion transcripts is another frequently employed method to examine relationships among presences, frequencies of occurrence, and posting patterns (e.g., Kilis & Yıldırım, 2019; Shea et al., 2010). However, coding and counting can only provide limited information and may lose the temporal associations hidden behind three presences (Csanadi et al., 2018).

In recent years, ENA has emerged as a powerful tool for examining how social and cognitive presences are intricately related in online collaborative environments, because it allows researchers to visualize and analyze the dynamic interactions among these presences over time (Rolim et al., 2019; Shaffer et al., 2016). For instance, researchers utilized ENA to analyze AODs to investigate the associations between the individual phases of cognitive presence and the indicators of social presence, as well as their temporal progression across different contexts (Fathali, 2024; Rolim et al., 2019). ENA has also proven effective in uncovering patterns and developmental trajectories of cognitive presence at both the individual and group levels (Ba et al., 2023, 2024). Additionally, Iqbal et al. (2022) used ENA to examine the associations between cognitive presence and speech acts, emphasizing the potential of speech acts to expand the cognitive presence classification. Some researchers also adopted ENA to explore the relationships between social or cognitive presence and course topics. For example, Ferreira et al. (2018) explored the interplay between social presence and course topics using ENA. Their study found that different course topics influenced the expression and development of social presence, revealing the critical role of topic selection in fostering social interactions. This demonstrates how important it is to choose course topics carefully when designing online courses to improve social interaction and develop more dynamic learning environments.

Instructional Strategies in AODs Within CoI Framework

Online discussion prompts, shaped by various instructional strategies, play a crucial role in helping instructional designers and educators to understand how these differing strategies used in AODs impact students' levels of social and cognitive presence within online learning environments. For example, Richardson and Ice (2010) investigated students' critical thinking levels across three instructional strategies: case-based, debate, and open-ended strategy. Their findings revealed that the exploration phase occurred most frequently in open-ended discussions, followed by debate and case-based discussions. However, the integration phase appeared frequently in case-based discussions, followed by debate and open-ended discussions. Lowenthal and Dunlap (2018) examined student perceptions of various strategies for establishing and maintaining social presence and found that instructors can establish social presence by using strategies such as personal video introductions, sharing personal stories, and actively participating in discussion forums. Additionally, Kilis and Yıldırım (2019) concluded that high levels of social presence and cognitive presence are often observed when the discussion topics are based on sharing real-life experiences. In summary, various instructional strategies in online discussions would affect the levels of cognitive presence and social presence. However, existing studies have primarily focused on the types of instructional strategies and their effectiveness in

fostering cognitive presence and building social presence (e.g., Kilis & Yıldırım, 2019; Olesova et al., 2016; Richardson & Ice, 2010). Limited research explored how the relationships between social and cognitive presences were influenced by various instructional strategies. For this study, the following types of instructional strategy were explored: *compare and contrast*, where students were expected to compare and contrast different theories and discuss how they are similar or different; *debate*, where students were expected to defend their ideas; *personalized tasks*, where students were asked to select and share their own reading. Therefore, the following research questions were investigated in this study:

- What are the interrelationships between the indicators of social presence and the phases of cognitive presence?

- Do these interrelationships between social and cognitive presence differ between the high-active class and the low-active class?

- How do the interrelationships between social and cognitive presence evolve over time, as reflected in detailed weekly analyses, across various instructional strategies used in AODs?

Methodology

Context and Participants

This study was conducted in two eight-week fully online courses titled "*Foundations of Learning Design and Technology: An Introduction to the Field*" in Summer 2022. This course served as a core and required course in the first semester of an online master's degree program in *Learning Design and Technology* at a midwestern university in the U.S. It provided a historical overview and outlined the fundamental information, abilities, and attitudes required of professionals working in the fields of instructional design and educational technology. Each class consisted of 11 students, resulting in a total of 22 participants in this study. Those students were all first-year online master students, and they all have working experiences and diverse professional backgrounds.

Discussions occurred asynchronously each week. A guiding question was developed by the instructor for each week, and post prompts and objectives were provided for students. During the first five weeks, students are asked to generate an original post and respond to at least two peers each week. However, the instructor did not require students to respond to specific peers. Furthermore, students were expected to participate throughout the week in the discussions. As Week 6, 7 and 8 did not require any interactions and the formats were completely different from week 1 to week 5, therefore, we excluded Week 6, 7 and 8 from this study. Table 1 presents the weekly discussion topics, post prompts and objectives.

Table 1

Weekly Topics

Week	Discussion Topic	Instructional Strategy Types	Discussion Prompt
Week 1	Definition of LDT	Compare and contrast	Students are required to create a complete definition of LDT and compare and contrast their definitions of the field to other definitions identified in the textbook.
Week 2	Instructional Design Timeline	Debate	This debate will require students to create a history of Instructional Design Timeline and defend what they select to be the best decade.
Week 3	ID Model	Create and post	Students will create a job aid in the format of a horoscope about a specific ID model.
Week 4	Learning Theory Comparison	Compare and contrast	Students will compare and contrast two learning theories and discuss how they are similar or different.
Week 5	Bring Your Own Reading	Personalized task (select and summarize)	Students will select and summarize their own reading.
Week 6	Group Project		Students will sign up and establish groups of 2-3 individuals and each group submit a single post representing the contributions of two or three students
Week 7	Preparing the Final Course Assignment		

| Week 8 | Self-reflections | No responses required | Students will self-reflect on your final definition of the field (LDT) as well as discuss the role of ethics in instructional design practice. |

Data Collection

Data was collected through a series of asynchronous discussion posts from week 1 to week 5. All posts were securely stored in the learning management system, and measures were taken to ensure data integrity, including regular backups and encryption. As shown in Table 2, the posts from week 1 to week 5 were collected and analyzed with a total of 635 posts, and 5,358 sentences were generated. Among them, Class 1 had 360 posts with 3,169 sentences, and Class 2 had 275 posts with 2,189 sentences. Since both classes had an equal number of participants, Class 1 demonstrated a higher number of posts compared to Class 2. We used the quantity of discussion posts as an indicator of activity level in this study, as it directly reflects the frequency and volume of student contributions to AODs. Therefore, we labeled Class 1 as the "high-active" class and Class 2 as the "low-active" class in this study.

Table 2

The Number of Posts per Week

Week	High-active Class (Class 1)		Low-active Class (Class 2)	
	Posts	Sentences	Posts	Sentences
Week 1	61	521	46	487
Week 2	81	685	74	577
Week 3	65	589	57	367
Week 4	78	556	48	285
Week 5	75	818	50	473
Total	360	3,169	275	2,189

Data Processing and Coding

Social and cognitive presence coding themes were adapted from previous studies (Garrison et al., 2000, 2001; Rourke et al., 1999). The original coding themes of social presence included affective (3 indicators), interactive (6 indicators) and cohesive categories (3 indicators). In this study, we removed the indicator "continuing a thread" under the interactive category, since it refers to technical replies on discussion boards, which are not necessarily indicative of meaningful interaction (Lee, 2014). We also decided to remove "use of humor" under the

affective category, because there were no sentences indicating it, and its effects could be ignored and did not influence the results. The final coding frameworks were presented in Table 3 and 4.

The data and coding process included three main steps. Firstly, we used Excel to collect and sort the data before we coded. Secondly, we split all discussion posts into sentences to understand more detailed information in their postings, enabling deeper insight despite the small sample (e.g., Ba et al., 2023, 2024; Fahy et al., 2000). Following coding up and coding down principles (Garrison et al., 2001), when the distinction between phases was unclear, we coded the sentences as belonging to an earlier phase. Conversely, if clear evidence of multiple phases was present, we coded them as a later phase. Thirdly, using binary coding, two coders annotated 1 for presence and 0 for absence for each sentence reflecting these themes of social and cognitive presence. To ensure reliability, the coders first established an initial common understanding and coded one-week data independently first, and then met together to resolve any differences, and inter-coder reliability was assessed regularly, finally achieving a Cohen's Kappa of 0.9235, indicating high reliability (McHugh, 2012).

Table 3

Categories and Indicators of Social Presence

Categories	Indicator	Definition	Example
Affective	Expression of Emotions (AF.Emotion)	Conventional expressions of emotion, or unconventional expressions of emotion, include repetitious punctuation, conspicuous capitalization, emoticons	"I'm excited to see all the definitions that everyone came up with!"
	Self-disclosure (AF.SD)	Presents details of life outside of class, or expresses vulnerability	"I have had the same experience speaking to my friends and family and even teaching colleagues about LDT."
Interactive	Quoting from other's messages (IN.Quote)	Using software features to quote other's entire message or cutting and pasting selections of others' messages	"You made an excellent point that "[e]ven though technology has continued to advance leaps and bounds beyond this period of time, the foundational learning design publications by Bloom and Skinner are still widely valued and used in teacher education programs."

	Referring explicitly to others' messages (IN.Refer)	Direct references to the contents of others' posts	"I like that you addressed where the two aspects of LDT meet each other."
	Asking questions (IN.Question)	Students ask questions of other students or the moderator	"Can you elaborate?"
	Complimenting, expressing appreciation (IN.Appr)	Complimenting others or the contents of others' messages	"I really liked the creativity and thought you put into your timeline!"
	Expressing agreement (IN.Agree)	Expressing agreement with others or the content of others' messages	"I agree with you completely."
Cohesive	Vocatives (CO.Vocatives)	Addressing or referring to participants by name	"Hi Jeffrey"
	Addresses or refers to the group using inclusive pronouns (CO.Group)	Addresses the group as we, us, our, group	"We talk a lot about having Constructivist elements, which is a better descriptor."
	Phatics, salutations (CO.Salute)	Communication that serves a purely social function; greetings, closures	"I look forward to reading everyone's comparisons!"

Table 4

Cognitive Presence Coding Template

Phases	Definition	Example
Triggering Event (CP.TE)	Sense of Puzzlement	"What do you think about AI in LDT?"
Exploration (CP.EX)	Information Exchange	"Learning is an active process that involves engagement."
Integration (CP.IN)	Connecting Ideas	"I really like the wording of your definition because it does a good job of highlighting the intersection

		of instructional design and instructional technology."
Resolution (CP.RE)	Applying New Ideas	"I think it is very important to be able to identify what your students are supposed to learn at the end of instruction, to make sure you are including content that will enable them to reach that goal."

Epistemic Network Analysis

The ENA web tool (https://www.epistemicnetwork.org/) was used to analyze and visualize the coded results. It is a methodological approach for quantifying and identifying the relationships between elements within coded data, subsequently representing these relationships in dynamic network models (Shaffer et al., 2016). It is specifically tailored for analyzing problems that involve a limited set of concepts characterized by highly dynamic and densely interconnected interactions (Rupp et al., 2010; Shaffer et al., 2016), and it is particularly useful for comparing different networks visually and through summary statistics based on weighted connections between networks (Shaffer & Ruis, 2017).

The process of generating ENA models and performing the ENA analysis begins by making decisions based on the three basic concepts: units, conversations, and codes (Shaffer et al., 2016). Units in ENA models can refer to people, groups, concepts, or any elements of interest that are used to build networks. These units help organize sequences of stanzas into groupings that summarize the relationships between them. Conversation in ENA refers to the set of lines used to represent the relationships between concepts. Codes represent the concepts whose association patterns are modeled as nodes within the ENA network representation.

This study was analyzed according to the following settings in the ENA web tool. For Research Question 1, we selected the column "StudentName" as the unit of analysis. For Research Questions 2 and 3, we employed a hierarchical approach by selecting two columns: "Class" or "Week," further subdivided by "StudentName" as the units of analysis. Therefore, we can generate class and weekly comparison networks. "StudentName" also serves as the conversation unit, as it encompasses the collection of sentences posted by each student. The codes listed in Tables 2 and 3 were used with indicators of social presence and phases of cognitive presence set as the codes. The ENA algorithm builds a network model for every line in the data by using a moving window, illustrating the relationships between codes that occur in the current line and codes that happened in earlier lines (Ruis et al., 2019; Siebert-Evenstone et al., 2017). Therefore, we defined the moving stanza as eight (each line plus the seven previous lines), which is the average line of each post. In the ENA models, the edges between two codes indicate how frequently these codes occur together. The size of the nodes shows how important each node is for this group.

Results

The ENA method was used in this study to pinpoint the details of the interrelationships between social and cognitive presences. As previously noted, the resulting networks were aggregated for all sentences across all discussion posts for every unit of analysis based on the "StudentName" in the model. Since each student's post contained several sentences, different phases of cognitive presence could be represented within the same moving stanza. As listed in Tables 3 and 4, our ENA model finally included the following 14 codes: CP.TE, CP.EX, CP.IN, CP.RE, AF.Emotion, AF.SD, IN.Quote, IN.Refer, IN.Question, IN.Appr, IN.Agree, CO.Vocatives, CO.Group, and CO.Salute. Finally, we constructed ENA models and presented all students within the relationships between indicators of social presence and phases of cognitive presence.

RQ1: Interrelationships Between the Indicators of Social Presence and the Phases of Cognitive Presence

In Figure 1, 15.9% of the variance in the data was explained by the Y-axis, whereas 45.8% is explained by the X-axis. There was a strong goodness of fit observed between the underlying patterns in the data and the epistemic networks, as indicated by the Pearson (1.00) and Spearman (1.00) in the X-axis and the Pearson (1.00) and Spearman (0.99) in the Y-axis from the model (Bowman et al., 2021; Tan et al., 2024). Additionally, Table 5 presented an ENA weight matrix pertaining to the correlation between social and cognitive presences. The indicators of social presence are mainly distributed on the left-hand side, the AF.Emotion and AF.SD in the category of affective expression was over the X-axis. The X-axis makes a distinction between the initial phases of cognitive presence (trigger event and exploration) and the higher phases (integration and resolution) based on their relative distance.

Figure 1

Overall Network for the Relationship Between Social Presence and Cognitive Presence
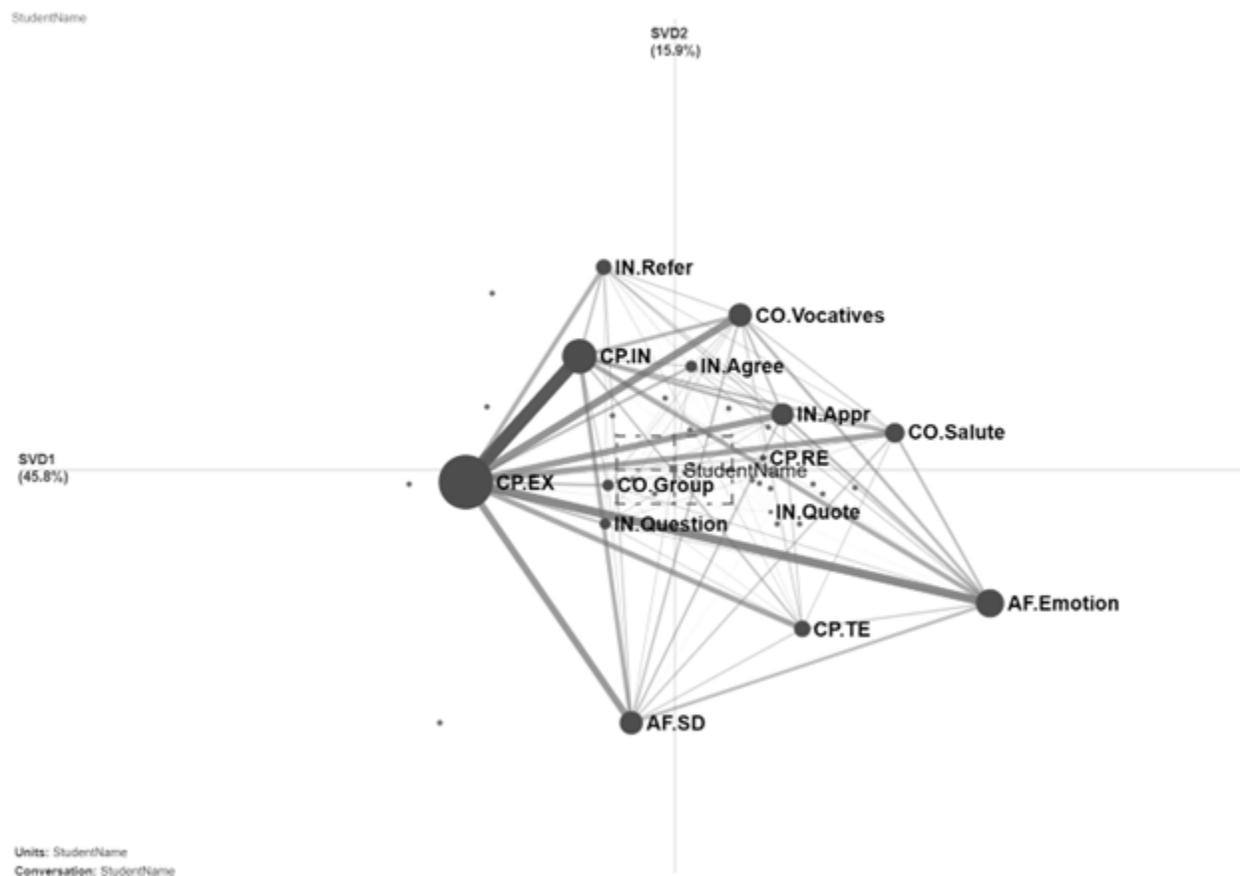
Table 5

Symmetric Matrix of ENA Weights for the Interrelationship Between Social Presence and Cognitive Presence

	CP.TE	CP.EX	CP.IN	CP.RE	AF. Emotion	AF.SD	IN. Quote	IN. Refer	IN. Question	IN. Appr	IN. Agree	CO. Vocatives	CO. Group	CO. Salute
CP.TE	0.00	0.19	0.08	0.00	0.06	0.06	0.00	0.03	0.04	0.05	0.02	0.05	0.02	0.04
CP.EX	_	0.00	0.46	0.04	0.30	0.24	0.01	0.15	0.10	0.23	0.10	0.26	0.10	0.20
CP.IN	_	_	0.00	0.03	0.17	0.14	0.00	0.09	0.04	0.12	0.06	0.13	0.05	0.11
CP.RE	_	_	_	0.00	0.02	0.02	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
AF. Emotion	_	_	_	_	0.00	0.11	0.00	0.06	0.04	0.11	0.05	0.11	0.05	0.10
AF.SD	_	_	_	_	_	0.00	0.01	0.06	0.03	0.07	0.04	0.08	0.03	0.07
IN. Quote	_	_	_	_	_	_	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN. Refer	_	_	_	_	_	_	_	0.00	0.02	0.05	0.02	0.05	0.02	0.04
IN. Question	_	_	_	_	_	_	_	_	0.00	0.03	0.01	0.03	0.01	0.03
IN. Appr	_	_	_	_	_	_	_	_	_	0.00	0.03	0.09	0.03	0.07
IN. Agree	_	_	_	_	_	_	_	_	_	_	0.00	0.04	0.02	0.03
CO. Vocatives	_	_	_	_	_	_	_	_	_	_	_	0.00	0.03	0.06
CO. Group	_	_	_	_	_	_	_	_	_	_	_	_	0.00	0.03
CO. Salute	_	_	_	_	_	_	_	_	_	_	_	_	_	0.00

CP.TE had a relationship with IN.Question (0.04), as the trigger event is a phase of a sense of puzzlement and asking questions. For example, this student stated,

> I wonder what the correlation between age and cognitive load is, and if younger students with less developed schemas would be able to benefit from the use of this instructional model? In my experience, behavior, emotional maturity (especially post-covid) and an overall lack of independence can make it challenging to accomplish this sort of learning with our youngest students.

Students mostly asked questions and then they went on to the exploration phase of cognitive presence in a moving stanza, so the relationship between CP.TE and CP.EX (0.19) was much stronger compared to CP.TE with IN.Question (0.04). Furthermore, the network showed a strong relationship between CP.EX and indicators of social presence, for instance, CP.EX-AF.SD (0.24), CP.EX-AF.Emotion (0.30), CP.EX-IN.Refer (0.15), CP.EX-IN.Appr (0.23), CP.EX-CO.Salute (0.20), and CP.EX-CO.Vocatives(0.26). Also, CP.IN had a weaker connection with those indicators of social presence than CP.EX, for instance, CP.IN-AF.SD (0.14), CP.IN-AF.Emotion (0.17), CP.IN-IN.Refer (0.09), CP.IN-IN.Appr (0.12), CP.IN-CO.Salute (0.11) and

CP.IN-CO.Vocatives (0.13). However, there was no significant relationship between CP.RE and the social presence indicators like CP.RE-AF.Emotion (0.02).

CP.EX was the biggest node, which represented most of the students' discussions in the second phase of cognitive presence, as they preferred knowledge sharing and brainstorming. In contrast to CP.EX, CP.TE had a weak connection to the affective category of social presence, which demonstrated that students may prefer to raise questions and express their puzzlement at the beginning of the discussion rather than express their emotions. On the other hand, AF.SD had a close relationship with CP.EX and CP.IN. For instance, this student said, "I've been teaching middle school for over a decade, and something I have noticed in my experience that is lacking in this definition, but in my opinion, an important factor in learning is motivation." This indicated that students would like to share their personal experiences in the second and third phases of cognitive presence to connect and demonstrate their ideas. Besides, the interactive category had much closer relationships in the exploration phase of cognitive presence, showing the participants were actively involved in online interaction as the interactive category in social presence included IN. Question, IN.Refer, IN. Quote, IN.Appr and IN.Appr, and IN.Agree in this study. Additionally, according to the findings, CP.EX and CP.IN were closely related to CO.Vocatives and CO.Salute in the cohesive category of social presence. However, CO.Group had weak connections with cognitive presence, suggesting that students did not address groups very often. As illustrated by the student's post, "We picked the same decade, but for different reasons," the student demonstrates the use of we, addressing the group collectively. However, this expression of group reference was not evident in any of the phases of cognitive presence.

RQ2: Interrelationships Between Social Presence and Cognitive Presence Differ Between the High-Active Class and Low-Active Class

Regarding research question 2, we compared the visualizations for the low-active and high-active classes' mean networks. Based on the group mean network visualization, we interpreted as follows: thicker lines between nodes indicate more connections, while nodes positioned closer together indicate fewer variances. We also performed a quantitative comparison of the mean networks using t-tests along the X- and Y-axis dimensions. For the first dimension in our model, the co-registration correlations were 1 (Pearson) and 1 (Spearman), and for the second dimension, they were 1 (Pearson) and 0.99 (Spearman). The model itself is shown to be a visually accurate representation of the underlying data by these measurements, which showed a strong goodness of fit between the visualization and the original model. Along the X axis, a two-sample t-test assuming unequal variance showed 1 ($M = 0.16$, $SD = 0.11$, $n = 11$) was statistically significantly different at the alpha=0.05 level from 2 ($M = -0.16$, $SD = 0.24$, $n = 11$; t (13.80) = 4.11, $p = .001$, Cohen's $d = 1.75$).

From the comparison plot in Figure 2 and the individual class plot in Figures 3 and 4. Figure 3 represents high-active class, while Figure 4 represents low-active class. Students in the high-active showed more centralized connections, whereas students in the low-active were more dispersed. In addition, there are also some apparent differences between high-active class and low-active class. The line between CP.EX and AF.Emotion in high-active (0.25) was stronger than the low-active class (0.20). Similarly, the line between CP.EX and CO.Salute in high-active (0.28) was stronger than low-active class (0.12). The line between CO.EX and IN.Appr in high-

active (0.25) was stronger than low-active class (0.20). Unexpectedly, the line between CP.EX and AF.SD in low-active class (0.28) was stronger than high-active (0.20), suggesting that low-active classes may exhibit stronger individual connections in certain contexts. The line between CP.EX and IN.Refer in the low-active class (0.18) was stronger than high-active (0.13). Overall, more social presence was observed in the high-active class, which means the high-active class has more sense of community than the low-active class.

Table 6 summarized the frequencies of codes in high-active class and low-active class. For cognitive presence, it was evident that high-active class showed a higher frequency across all phases of cognitive presence compared to low-active class. This suggested that the high-active class might have more active cognitive engagement and possibly more in-depth discussions. Regarding social presence, the high-active class demonstrated a greater frequency of emotional expression, suggesting that the students in this class were more emotionally engaged and expressive. Additionally, the high-active class was more active in quoting, questioning, and appreciating contributions, which pointed to a more interactive and participative classroom environment. Moreover, the high-active class showed higher usage of vocatives, group references, and salutations, reflecting a stronger sense of community and connection among the students. Overall, the high-active class demonstrates higher frequencies in all measured areas compared to the low-active class, suggesting that high-active class is characterized by a more engaged, interactive, and cohesive classroom environment.

Table 6

Frequency of Codes in High-Active Class and Low-Active Class

	CP.TE	CP.EX	CP.IN	CP.RE	AF. Emotion	AF.SD	IN. Quote	IN. Refer	IN. Question	IN. Appr	IN. Agree	CO. Vocatives	CO. Group	CO. Salute
High-active Class	246	1396	624	55	564	361	20	145	165	332	100	264	141	314
Low-active Class	130	1169	452	26	230	348	2	135	70	156	69	151	71	67

Figure 2

Comparison Plot Between High-Active Class and Low-Active Class
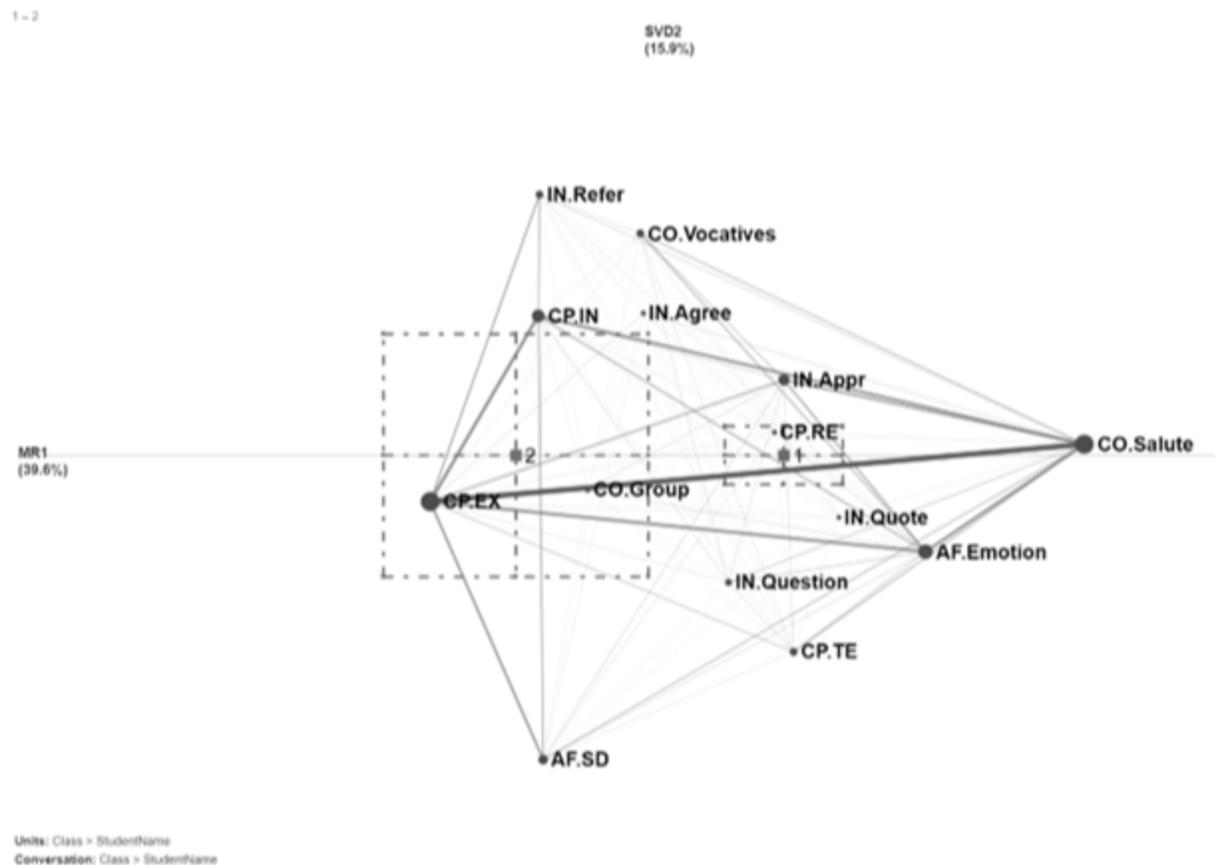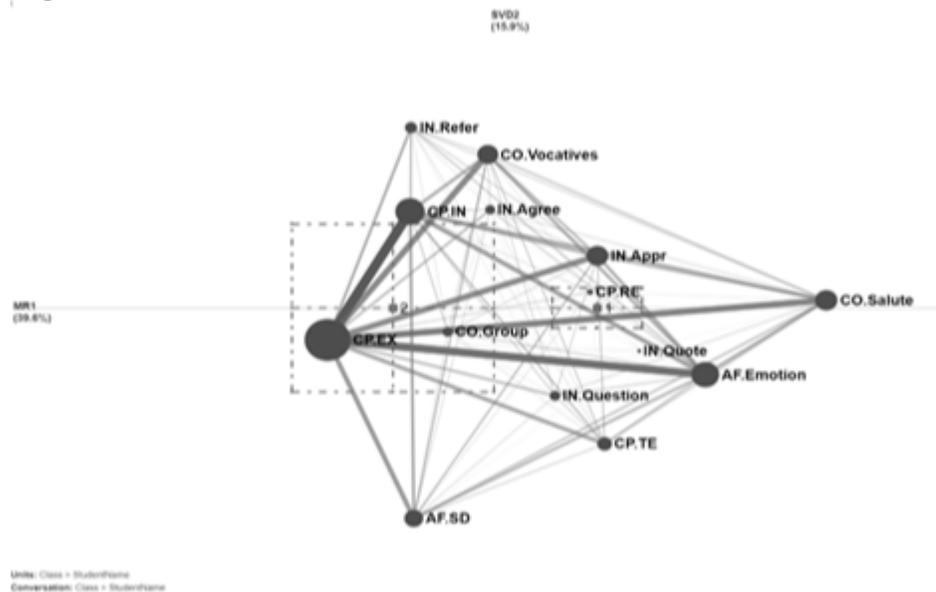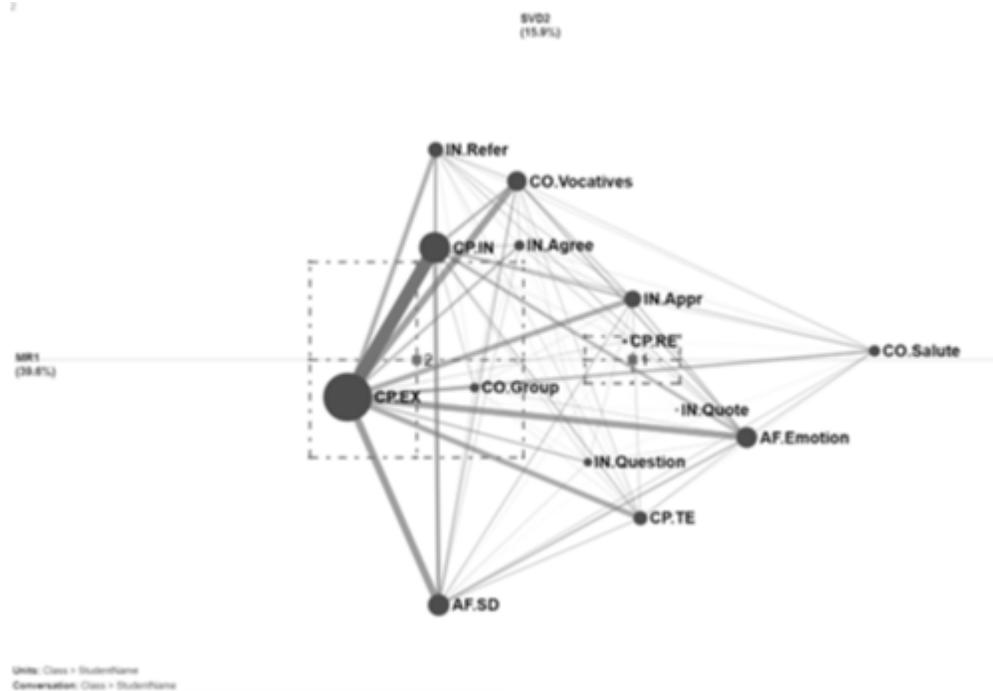
Figure 3

High-Active Class Plot

Figure 4

Low-Active Class Plot

RQ3: Interrelationships Between Social and Cognitive Presence Evolve Over Time Across the Various Instructional Strategies Used in AODs

To answer this question, we summarized the weekly frequency of posts of indicators of social presence and phases of cognitive presence (Table 7) and generated the weekly ENA plots (Figure 5). Interestingly, the number of posts by students did not decrease over the week, indicating sustained engagement throughout the course. As illustrated in Figure 5, we discussed the students' performance of each week as below:

Table 7

Frequency of Indicators of Social Presence and Phases of Cognitive Presence in Every Week

	CP.TE	CP.EX	CP.IN	CP.RE	AF. Emotion	AF.SD	IN. Quote	IN. Refer	IN. Question	IN. Appr	IN. Agree	CO. Vocatives	CO. Group	CO. Salute
Week 1	75	476	228	28	98	193	11	63	41	72	30	60	42	78
Week 2	54	636	246	10	201	166	7	84	33	130	61	104	75	90
Week 3	51	434	179	19	184	81	2	44	36	118	22	91	22	73
Week 4	81	347	159	5	145	93	0	38	46	90	28	80	33	76
Week 5	115	672	264	19	166	176	2	51	79	78	28	80	40	64

In Week 1, students were required to create a definition of LDT and then compare and contrast their own definition with those in the textbook. The instructional strategy used in this discussion topic encouraged active engagement in cognitive presence through exploration, integration, and the development of higher-order thinking skills. However, students are not very active in both high-active class and low-active class in contrast to the quantity of posts in other weeks. This may be attributed to students' low engagement during the first week, their unfamiliarity with one another, and the difficulty of the compare-and-contrast strategy. As first-year master's students, they lacked sufficient knowledge to effectively connect ideas and complete the activity. We also found that there are some apparent correlations between social presence and cognitive presence, including CP.IN-AF.SD (0.20), CP.EX-AF.Emotion (0.21), and CP.EX-IN.Refer (0.16). This correlation suggests a moderate positive relationship between cognitive presence in the integration phase and social presence in affective expression category. Students who share personal experiences and have emotional engagement may find it easier to integrate new knowledge effectively and facilitate exploratory activities. Moreover, IN.Refer appeared a lot this week, which indicates that students are moderately likely to refer to the definitions in the textbook when defending their ideas.

Similarly, in Week 4, students were required to compare and contrast two theories. The analysis showed that CP.EX was correlated with AF.Emotion (0.24), CO.Vocatives (0.23), and IN.Appr (0.24), while CP.IN was moderately related to AF.Emotion (0.16). Despite being more emotionally engaged than in Week 1, likely due to discussion prompt, students remained relatively inactive during this week. Their participation in the exploration and integration phases of cognitive presence was limited, and few students reached the resolution phase. The codes of IN.Quote and IN.Refer also had the lowest occurrence during this week, suggesting that the task

of comparing and contrasting theories appeared to be cognitively demanding. Students found it difficult to meaningfully build on their peers' original posts. As a result, the number of sentences in their posts was lower compared to other weeks.

In week 2, there was a notable rise in the quantity of comments posted by students in both the low-active and high-active classes, which indicated higher levels of engagement. As the topic this week is to discuss the instructional design timeline and defend your choice for the best decade. Students were more emotionally engaged in the discussions, as CP.EX has a higher link with AF.Emotion (0.30). Additionally, CP.EX and CP.IN had a very strong link (0.43), indicating that students who engaged deeply in exploring ideas were also effectively integrating and synthesizing this information. IN. Refer occurred most frequently compared to other weeks, suggesting that students were more likely to build on their peers' statements and connect their ideas to additional resources during this week.

In Week 3, students were just required to post a description of their assigned model, which gave them much freedom to express their ideas. CP.EX has a strong link with AF.Emotion (0.30), IN.Appr (0.30), IN.Refer (0.11), CO.Salute (0.19) and CO.Vacatives (0.32). This demonstrated that the instructional strategy in this discussion topic encourages sharing personal insights and experiences in order to enhance cognitive and emotional engagement.

In Week 5, students were required to bring their own reading and summarize it to their peers. This discussion topic allowed students to select readings that interest them, potentially increasing motivation and engagement. Additionally, summarizing and presenting information promoted active learning and deeper cognitive engagement. CP.EX and CP.IN had the strongest links (0.49) than in other weeks, and both appeared more frequently than in previous weeks. This suggests that students who engage deeply in exploring ideas are also effectively integrating and synthesizing this information. AF.SD had a higher frequency because students could present more details of life outside of class or express vulnerability. Although it was Week 5, students still participated actively in this week.

Figure 5

Weekly Plot
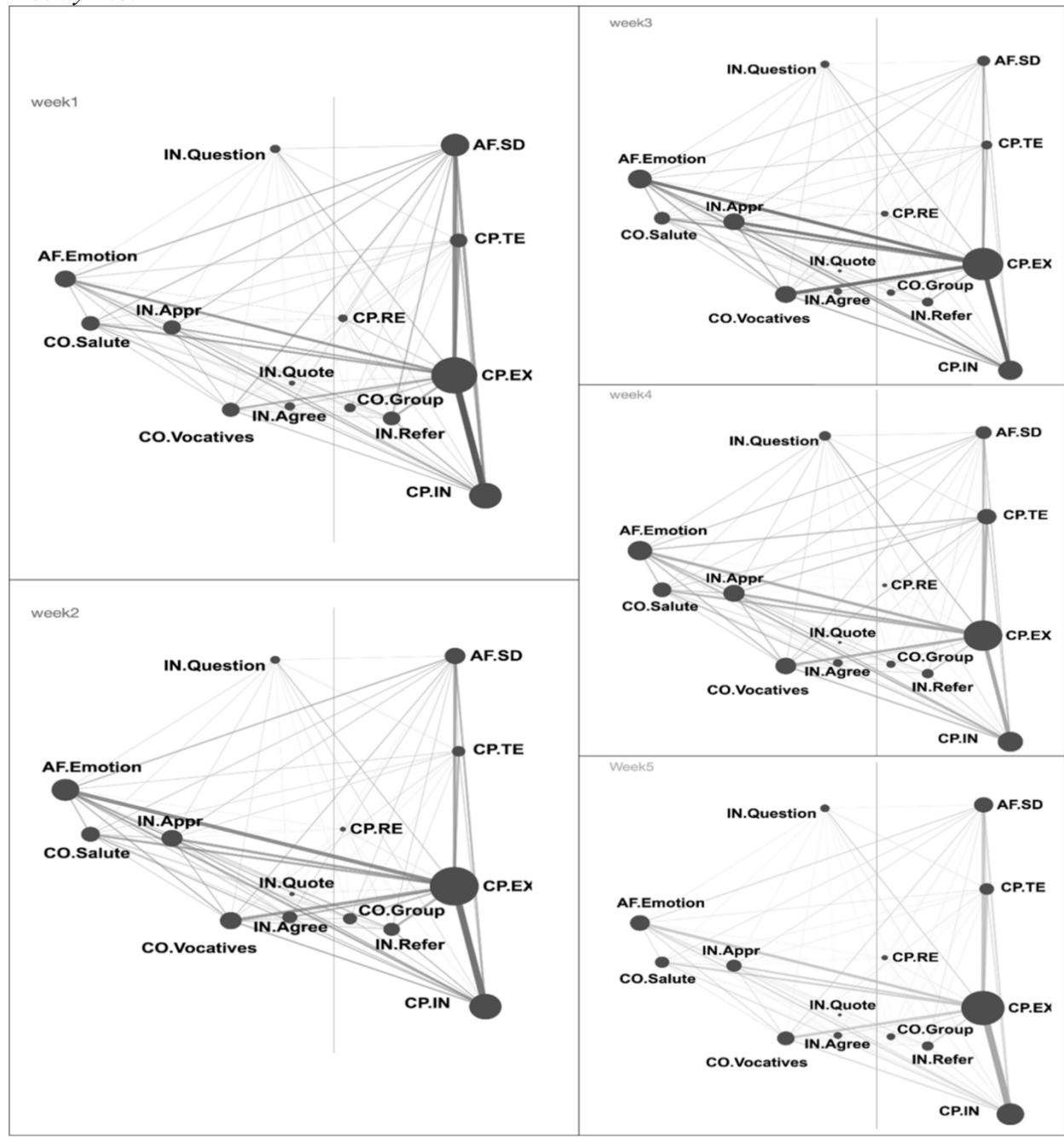
Discussion and Implications

This study employed the ENA approach to investigate the interrelationships and evolution of social and cognitive presence indicators within the CoI framework across classes with varying levels of activity and various instructional strategies used in AODs, offering in-

depth insights into these dynamics. The ENA models related to research question 1 reveal that the exploration phase of cognitive presence showed the strongest connections with social presence indicators, particularly affective expression (AF.Emotion) and interactive indicators (IN.Refer and IN.Appr), suggesting that emotional engagement plays a crucial role in facilitating cognitive activities and enhancing cognitive processing and engagement (Maguire et al., 2017; Molinillo et al., 2018; Saadatmand et al., 2017). During the exploration phase, students are more likely to engage emotionally and interactively as they brainstorm ideas and exchange information, often employing sociolinguistic politeness to facilitate open and respectful communication. Moreover, the majority of students' cognitive presence was at the exploration level (Garrison & Arbaugh, 2007; Guo et al., 2021). It was noted that IN.Question has a close relationship with the trigger event and exploration phase, similar to findings by Rolim et al. (2019). However, the resolution phase (CP.RE) does not exhibit a significant relationship with social presence indicators, aligning with Rolim et al. (2019). These findings highlight that the resolution phase emphasizes the practical application of ideas and tends to be less socially interactive compared to the earlier phases of cognitive presence, such as exploration and integration. Moreover, fewer students can reach the resolution level (Akyol & Garrison, 2008; Garrison & Arbaugh, 2007; Olesova et al., 2016). However, it is also important to consider that this may have been influenced by the instructional strategies, as students were not explicitly required to generate any solutions.

Our results also indicated that social and cognitive presence and their interrelationships are also presented differently in different active levels of class. The social presence and cognitive presence indicators showed more and stronger correlations in high-active class, suggesting a higher social interaction and cognitive engagement (Lee, 2014) In addition, learners in high-active class reported higher social presence compared to those in low-active class, which was also demonstrated in the Poquet et al. (2018). Moreover, the high-active class preferred using more cohesion indicators, like vocatives or addressing others by name and salutation, which is consistent with Guo et al. (2021). Finally, high-active class also showed a higher frequency across all phases of cognitive presence, suggesting that high-active class might have more active cognitive engagement and possibly more in-depth discussions. Therefore, higher levels of social presence can positively correlate with cognitive presence (Costley, 2019; Gutiérrez-Santiuste et al., 2015).

While prior literature suggests an increase in posts over time (Akyol & Garrison, 2008; Fathali, 2024; Rolim et al., 2019), our findings revealed a different result, likely due to the influence of different instructional strategies used in discussion topics (Darabi et al., 2011). For example, debate (Week 2) and personalized tasks (Week 5) led to higher levels of cognitive presence and increased participation, because these instructional strategies encourage students to articulate their ideas, consider multiple perspectives, and support their arguments with evidence (Olesova et al., 2016). This is in line with existing literature that suggests "debate" requires students to critically analyze their ideas and foster higher-order thinking skills, and this kind of strategy appears to be effective in promoting active participation and deeper engagement with the content (Darabi et al., 2011; DeNoyelles et al., 2014; Zare & Othman, 2015). Personalized tasks, such as selecting their own reading materials (e.g., Week 5), also promoted higher cognitive engagement and active participation (Cornelisz & van Klaveren, 2018). Future online discussion designs should incorporate more debate and personalized strategies to enhance

engagement and foster cognitive presence. However, compare and contrast is one of the difficult instructional strategies as it requires students' higher level of cognitive connections among topics to address similarities and differences (Hammann & Stevens, 2003). Therefore, Week 1 and Week 4 were less active than other weeks. Educators should ensure students have the necessary cognitive resources to support students to engage in meaningful comparisons (Rittle-Johnson et al., 2020). By providing a detailed, week-by-week analysis of how social and cognitive presence indicators interact and evolve, the design of online courses can benefit from this deeper comprehension in order to encourage continued participation and in-depth study.

Limitations

While our study provides a novel approach to analyzing CoI presences and suggests strategies for designing AODs, several limitations must be considered. First, the study involved a small sample of 22 graduate students from a single course, which limits the generalizability of the findings. Future research should replicate the study across different disciplines and course levels. Secondly, while this study focuses on a 5-week period and provides valuable insights into the short-term dynamics of AODs, it is important to acknowledge that many online learning environments span much longer durations. Future research should examine the longitudinal impact of instructional strategies on the development of social and cognitive presences over the course of an entire semester or academic year. Lastly, this study did not account for the influence of teaching presence, which may significantly affect student interaction and engagement. Future research should place greater emphasis on examining the role of teaching presence to better understand its potential impact on students' course interactions and overall engagement.

Conclusion

In conclusion, this study serves as a methodological demonstration of applying ENA in CoI research and offers valuable insights into the interrelationships between social and cognitive presence. The findings provide practical implications for instructional designers and instructors by informing the development of more engaging online courses and optimizing the use of AODs. Recognizing the strong correlation between social and cognitive presence can assist instructors in fostering a sense of community and designing more interactive and effective online learning environments (Han et al., 2022). By strategically implementing instructional practices that support both cognitive and social presence, educators can create a more inclusive and supportive environment that enhances cognitive engagement and improves student learning outcomes.

Conflict of Interest Statement

The authors declare no potential conflict of interest in the work.

Ethics Approval

The data for this study was approved by Purdue University Institutional Review Board with number: 1502015791.

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