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Exploring the relationships between social presence and teaching presence in online video-based learning

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Abstract

Background: Video-based learning (VBL) is the learning process of acquiring defined knowledge, competence, and skills with the systematic use of video resources. Currently, the relationship between teaching presence and social presence in VBL is underexamined.

Objectives: This study examined the relationships between social presence and teaching presence indicators in VBL.

Methods: We analysed social presence based on 3456 *danmaku* data (synchronised on-screen comments) and teaching presence based on the video content from eight pre-recorded database lectures on Bilibili. The eight lectures were categorised into theory- and application-oriented sessions. We analysed the static relationships and temporal patterns between social presence and teaching presence in theory- and application-oriented sessions respectively using bipartite network analysis and cross-correlation analysis.

Results: We identified the teaching presence indicators that had a high frequency of co-occurrence with students' social presence, including "conducting informative demonstrations" in application-oriented sessions and "offering useful illustrations" in theory-oriented sessions. The most frequently observed social presence indicator was "social sharing", which co-occurred frequently with most teaching presence indicators in both theory- and application-oriented sessions.

Conclusions: We identified the significant associations between indicators of teaching presence and social presence in VBL from both static and temporal perspectives. These indicators exhibited varying levels of association between theory- and application-oriented sessions.

Implications: This study contributes to the theoretical understanding of the relationships between teaching presence and social presence, which can benefit teaching practice and course design in VBL. Course instructors are suggested to incorporate the identified teaching presence aspects to enhance students' social presence in VBL.

KEYWORDS
bipartite network, community of inquiry, social media, social network analysis, video-based learning

1 | INTRODUCTION

In recent years, there has been an increasing trend towards video-based learning (VBL) using Massive Open Online Courses (MOOCs) and social media platforms for self-directed learning (Yuen et al., 2018). VBL is the learning process of acquiring defined knowledge, competence, and skills with the systematic use of video resources (Giannakos et al., 2016). It serves as a powerful learning resource in online teaching activities and complements traditional classroom-based and teacher-led learning methods (Yousef et al., 2014). The use of videos as a teaching resource can benefit students in various ways, such as helping students to visualise information, showing detailed information, increasing student attention, enhancing their retention and motivation, and catering to different learning styles (Choi & Johnson, 2005; Maniar et al., 2008). Common forms of online VBL include synchronous (e.g., streaming lectures via Zoom) and asynchronous (i.e., pre-recorded) lectures (Le, 2022). Certain social media platforms can support both pre-recorded and streaming lectures, which have particularly benefited students during the COVID-19 pandemic. In this study, we focused on studying the relationships between teaching presence and social presence in pre-recorded lectures, an emerging online educational resource on social media.

Social media have become a major platform supporting VBL (Greenhow & Lewin, 2016), providing the advantages of enriched discussions, increased engagement and broad connections (Chen & Bryer, 2012). The features of social media, including the sharing of photos and videos, enable teachers to share pre-recorded videos with their students and facilitate the development of online learning communities through social interactions (Patel et al., 2013). Studies examining VBL on social media, such as YouTube (Lacey & Wall, 2021) and Snapchat (Marshalsey & Sclater, 2019), have found that social media play a positive role in enhancing student engagement and satisfaction in online learning. Furthermore, the interactive features on social media facilitate connections among students and promote participatory engagement in effective and multimodal learning communities (Greenhow & Lewin, 2016), which can be examined using the community of inquiry framework (Popescu & Badea, 2020).

The Community of Inquiry (COI) framework has been widely used as a theoretical lens for conceptualising and analysing online learning communities. The goal of the Community of Inquiry framework is to define, describe and measure the elements of a collaborative and worthwhile educational experience (Garrison, Anderson, & Archer, 2010). Developed by Garrison et al. (1999), this framework assumes that learning occurs through the interactions of teaching presence (TP), social presence (SP), and cognitive presence (CP) within a community of inquiry that is composed of instructors and learners. In this study, we focused on examining the relationships between teaching presence and social presence in VBL. Social presence refers to the ability of participants to identify with the community, communicate purposefully, and build interpersonal relationships (Garrison, Anderson, & Archer, 2010). Teaching presence is defined as the design, facilitation and direction of social and cognitive processes to achieve meaningful learning outcomes for individuals (Anderson et al., 2001).

The importance of teacher behaviours to learners' perceptions of social presence in online learning has been widely acknowledged. Joksimović et al. (2015) revealed that teaching presence moderated the relationships between social presence and academic performance in online learning environments. Izmirli and Izmirli (2019) found that certain course design and facilitation strategies helped to enhance social presence, such as using humour, emoticons, sharing personal stories and experiences, greeting others, asking questions, and inviting responses. It is critical to understand the relationships between teaching behaviours and students' social behaviours in VBL, to help teachers develop their pedagogical activities strategically and to facilitate students' social presence and learning performance. However, previous studies have mainly examined teaching presence in online forums through text-based interactions and other non-video content (Akyol & Garrison, 2008; Anderson et al., 2001). The relationships between teaching presence and social presence in VBL remain understudied.

To explore the relationship between teaching presence and social presence, we analysed video content and *danmaku* data from eight sessions of a pre-recorded database course on Bilibili, a popular Chinese video-sharing platform. Specifically, we examined teachers' teaching presence based on the video content, and students' social presence based on *danmaku* (a Japanese term literally translated as "bullet curtain"). The *danmaku* are on-screen live comments (Lin et al., 2018; Yao et al., 2017) generated by users that are displayed as scrolling texts over a playing video. *Danmaku* was originally developed by a Japanese platform called Niconico (Li et al., 2020) and has become increasingly popular on various video-based social media platforms to enhance users' interactions and engagement. Students can submit their comments at a specific moment in a video as *danmaku* corresponding to the teaching video content. The comments are displayed on screen in real-time and will also be displayed to other users at the same time in the video. The comments can include students' responses to teachers' pre-recorded questions, questions to other students, or discussions about the teaching content. Students can interact with each other spontaneously by posting new *danmaku* on screen. *Danmaku* offers a unique form of interaction between students and the pre-recorded video content, as well as among students. It is a novel engaging method in social media-based VBL and provides a valuable data source to study students' social presence in video-based learning processes (Fang et al., 2018). Moreover, the time

relevance of *danmaku* comments to the teaching content enables us to explore the relationships between teaching presence and social presence in asynchronous VBL.

While analysing the social presence and teaching presence in online learning, we need to take the subject matter into consideration (Arbaugh et al., 2010). It is suggested that lectures and hands-on laboratories are both important components of computer science-related courses (Edwards, 2014; Hazzan et al., 2013; Vihavainen et al., 2014). However, the tasks differ in nature and complexity between theoretical and hands-on sessions. Different patterns of teaching presence could be required to facilitate different teaching and learning activities (Garrison, Cleveland-Innes, & Fung, 2010) as well as to engage students differently in the learning processes. Taking the theoretical and practical requirements of a technical course into consideration, we classified the eight sessions of the database course into two categories for analysing the teaching and social presence: theory-oriented sessions and application-oriented sessions. Theory-oriented sessions focus on introducing the fundamental concepts of database systems, whereas application-oriented sessions emphasise hands-on practice and implementation techniques relevant to database systems.

The three research questions (RQs) guiding this study are as follows: (1) How do the characteristics of teaching presence and social presence differ between theory- and application-oriented sessions? (2) What are the relationships between teaching presence and social presence in theory- and application-oriented sessions? (3) What are the temporal patterns of the relationships between teaching presence and social presence in theory- and application-oriented sessions? We applied chi-square analysis, bipartite network analysis, and cross-correlation analysis to analyse the three research questions respectively.

The remainder of the article is structured as follows: Session 2 reviewed previous studies about teaching presence and social presence in online VBL. Session 3 introduces the dataset and methods used in this study. Session 4 presents the results of this study. Session 5 discusses the interpretation of the results as well as the theoretical and empirical implications of this study. Session 6 presents the conclusions and limitations of this study.

2 | LITERATURE REVIEW

2.1 | Video-based learning

VBL technologies offer learners a self-paced, memorisable, and flexible method of online learning (Pal et al., 2019). VBL provides students with the affordances to become actively engaged in their learning and to spend more time on the learning process, resulting in enhanced learning outcomes (Delen et al., 2014). It is suggested for use in fostering collaborative learning and supporting students in being actively involved in online learning (Chatti et al., 2016). Giannakos (2013) characterised the technologies used in VBL from three aspects, namely the devices (mobile or stable), the learner–instructor synchronisation (synchronous and asynchronous), and the interactivity (interactive or noninteractive) of the system. According to the temporal and spatial dimensions of various VBL formats, MOOCs constitute a distant, asynchronous interaction mode, wherein pre-recorded videos are distributed online and interactions among students and teachers are asynchronous, while live-streaming learning is a distant, synchronous mode with real-time interaction (Chen et al., 2021). Concerning the technologies analysed in VBL studies, research has mainly focused on traditional online forums (Giannakos, 2013). Compared with traditional forum design, the emerging communication form of *danmaku* creates a "pseudo-synchronised" communication experience, making users feel like they are watching the video at the same time (Wu et al., 2019). Lin et al. (2018) suggested that some viewers choose to use *danmaku* comments to seek company and build a sense of belonging through social interaction, which satisfies their social needs. Chen et al. (2015) revealed that users regard *danmaku* videos as a way to entertain themselves, build a sense of belonging and companionship, and find information. Thus, analysing *danmaku* data can contribute to understanding social presence in VBL.

2.2 | Teaching presence and social presence in video-based learning

Social presence and teaching presence, the two dimensions of the community of inquiry framework, capture social engagement (Lim et al., 2015) and teaching facilitation (Watson et al., 2017) during VBL processes. Social presence includes three categories: affective expression (AF), open communication (OC), and group cohesion (CH). "Affective expression" refers to the ability of online learners to express their emotions, feelings, beliefs, and values (Garrison et al., 1999). "Open communication" refers to the provision of a risk-free learning environment, in which participants trust others and tend to reveal themselves (Boston et al., 2009). "Group cohesion" refers to the activities that build and sustain a sense of group commitment (Rourke et al., 1999), which can help to build participation and empathy.

Teaching presence is described as the methods that teachers apply to improve online instructional experiences (Bangert, 2008), and it is closely related to course design. Three categories of teaching presence were described by Anderson et al. (2001), namely facilitating discourse (FD), direct instruction (DI), as well as design and organisation (DE). "Facilitating discourse" refers to reading and commenting on students' posts, which is important for maintaining students' interest, motivation, and engagement. "Direct instruction" involves teachers demonstrating intellectual and academic leadership and sharing their knowledge with students. Direct instructional activities are closely related to quality teaching presence and include providing frequent prompts, feedback, and teaching concepts with authentic examples, as well as applying new knowledge and skills (Bangert, 2008). "Design and organisation" refers to the development of curriculum materials, the design and administration of group and individual activities, and the processes through which a teacher negotiates timelines for activities and projects.

In our literature review, we found that studies measuring the relationships between social presence and teaching presence have primarily used the community of inquiry questionnaire (Kozan, 2016) or analysed posts created by students and teachers in online forums (Nolan-Grant, 2019). Previous studies based on self-reported survey data have reported positive correlations between teaching presence and social presence (Dempsey & Zhang, 2019; Kozan, 2016; Kozan & Richardson, 2014). With the recent development of social media, user-generated content (UGC) provides a new data source for studying users' information behaviours. User-generated content refers to the content created originally by users or consumers on social media, such as posts, images, and videos (George & Scerri, 2007). Based on user-generated content from online discussion forums, Nolan-Grant (2019) examined teaching presence and social presence through discussion posts and concluded that teaching presence could enhance social presence. However, there is a lack of research analysing the relationships between teaching presence and social presence based on the recorded teacher behaviour and student-generated comments in social media-supported VBL.

Regarding the methods used to analyse the social presence and teaching presence in previous studies, qualitative approaches were commonly applied to analyse online discussion posts using coding schemes developed by Garrison et al. (1999), with the frequency of each indicator calculated (Akyol & Garrison, 2008; Zydney et al., 2012). For instance, Akyol and Garrison (2008) coded students' posts on a discussion forum and found a continual decrease in social presence and a continual increase in teaching presence over time. Zydney et al. (2012) compared students' teaching presence and social presence in two study groups that utilised different types of online discussions and found that the distributions of social and teaching presence categories differed between the two groups. However, the coding-and-counting approach has certain limitations; first, it ignores the temporality of data and second, it does not allow the analysis of patterns and connections in learning activities (Csanadi et al., 2018). The coding-and-counting approach provides the basis for frequency analysis on an empirical level, but less attention has been paid to using advanced learning analytical methods in VBL contexts (Chen & Feng, 2022). Therefore, this study builds upon the coding-and-counting method to analyse the relationships between teaching presence and social presence. This study focuses on exploring the static and temporal relationships between teaching presence and social presence in VBL using new learning analytical methods.

3 | METHODS

3.1 | Data collection

We collected video content and *danmaku* data from eight sessions of a selected course of MySQL databases on Bilibili (https://www.bilibili.com/), using a developed web crawler with Python. Bilibili is a popular Chinese social media platform featuring user-generated videos, which originally attracted younger generations with its rich resources involving anime, comics, games, and music. Today, many students in China enjoy watching educational videos on Bilibili to acquire new knowledge and skills; 183 million users watched educational videos on Bilibili in 2021 (Bilibili, 2021). *Danmaku* comments on Bilibili are anonymous and fixed to the point of insertion (Zhang & Cassany, 2020). That is, the *danmaku* interface allows users to share their comments in a synchronised manner with the video content, supplementing this content with paratextual information of peer interpretations and feedback (Li, 2017), which creates a sense of a synchronised viewing experience among users.

The video lectures analysed in this study were taught by the same instructor, uploaded in July 2019, and have become some of the most popular MySQL videos on the platform, with a large number of user-generated *danmaku* data. The *danmaku* data collected in this study to analyse student presence in the online course included *danmaku* texts, *danmaku* ID, actual published time, and timestamp relative to the video. There were 3456 *danmaku* comments posted by 1894 users in the eight sessions of the course analysed in this study. The average number of *danmaku* per user was 1.82. Among the users, 1230 (65%) posted one *danmaku* in these eight sessions, and the number of users that sent two, three, or four *danmaku* comments were 353 (19%), 131 (7%), and 64 (3%) respectively. In addition to the *danmaku* comments, we also collected the video content of the eight sessions to analyse the instructor's teaching presence.

The eight sessions were classified into theory-oriented and application-oriented sessions considering the theoretical and practical nature. In theory-oriented sessions, the instructor introduced students to the basics of SQL programming language, such as backgrounds, theories, concepts, and statements. In application-oriented sessions, the instructor guided students to practice the usage and manipulation of the software, such as MySQL installation, login, and data importation/exportation. The instructor would ask students to do hands-on practice following his instruction in application-oriented sessions.

3.2 | Data pre-processing

3.2.1 | Coding scheme

This study adopted the coding scheme proposed by Garrison et al. (1999) for online forums, which has been continuously revised by various studies (Shea et al., 2010; Stenbom et al., 2016), to analyse teaching presence and social presence in online learning. We coded the students' *danmaku* comments to analyse their social presence during each class. Teaching presence was analysed by coding teacher behaviour in the recorded lectures. It is important to note that the coding scheme of social and teaching presence supported by online forums is not entirely applicable to all distant asynchronous interaction modes, due to different interaction features supported by various platforms. In this project, we adjusted the coding scheme according to the features of the *danmaku* system on Bilibili that differ from those of online forums (see Tables 1 and 2).

TABLE 1 Coding scheme of social presence based on *danmaku*.

Category	Indicator	Definition	Example
Affective expression (AF)	Expressing emotions	Expression of emotion	Ha Ha Ha
	Use of humour	Teasing, irony, sarcasm, spoofing/making fun of teachers/telling jokes	I can even learn MySQL in an English class.
	Self-disclosure	Presenting personal experience and plans	I learned JAVA before this class.
	Expressing value	Expressing personal values, beliefs, and attitudes	Learning database is important to programmers.
Open communication (OC)	Asking questions	Asking other students questions	Can I learn this course without JAVA basis?
	Expressing agreement	Expressing agreement with the content of others' messages	This part is well explained.
	Expressing disagreement	Expressing disagreement with the content of others' messages/correcting knowledge made by teachers and/or peers	The sentence is incomplete because you did not enter a semicolon at the end of the sentence.
	Personal advice/ comments	Offering advice/expressing personal opinions and comments on the course/teachers/ peers	The teacher's voice is too low.
	Answering questions	Answering questions of teachers and/or peers	You can solve this problem by…
Group cohesion (CH)	Greeting the group	Communication that serves a purely social function; greetings or closures	Good morning everyone!
	Social sharing	Sharing information unrelated to course content	I had lunch just now.

Note: Adapted from Shea et al. (2010).

The coding scheme of social presence includes three categories, "affective expression", "open communication", and "group cohesion". "Affective expression" includes indicators related to learners' emotions, experiences, and values; "Open communication" focuses on learners' discussions of course content; "Group cohesion" includes discussions that serve a purely social function or are unrelated to course content and that create a sense of group commitment (Garrison et al., 1999; Rourke et al., 1999). Synchronisation and anonymity are two characteristics of *danmaku* comments (Wu et al., 2018). Furthermore, *danmaku* comments tend to be short and do not support the reply function that is commonly used in online forums. Therefore, we removed indicators concerning continuing a thread, quoting others' messages, and referring to others' messages from the "open communication" category, as well as the "vocatives" indicator (addressing the group as "we," "us," "our," or "group") under the "group cohesion" category. Furthermore, we adjusted the definitions of certain indicators so that the coding scheme was more suitable to capture social presence supported by the *danmaku* system. For example, some of the students answered their peers' questions and the questions raised by the instructor in pre-recorded videos by posting a new *danmaku* comment. However, there was no related indicator in the original coding scheme. Therefore, we added an indicator, "answering questions", to the "open communication" category. Likewise, we enriched the "personal advice" indicator to include learners' advice and comments on the course, teacher, and peers.

The instructor's teaching presence was coded according to the instructor's teaching behaviours. The coding scheme of teaching presence includes three categories, namely "design and organisation", "facilitating discourse" and "direct instruction". "Design and organisation" includes indicators related to course design and course requirements. "Facilitating discourse" refers to an instructor's efforts to engage students and pique their interest. "Direct instruction" includes the instructor's lecturing behaviours, such as introducing hands-on activities and using examples to teach concepts. We retained the indicators of teaching presence that could occur in pre-recorded videos. For example, the instructor pre-recorded some questions, which was a type of "drawing in participants" under the "facilitating discourse" category.

Two coders worked on the process together, following the steps suggested by Burla et al. (2008). To ensure the reliability of the coding results, the coders discussed any deviant codes to reach a consensus (Schwarz, 2015). Our coding process was as follows. First, the two coders discussed the coding scheme and revised it, referring to the characteristics of the *danmaku* system and the data of one session. Second, they coded all sessions separately. Finally, they discussed the different coding results until they reached an agreement on all the coding results.

3.2.2 | Video annotation

We analysed the teacher's teaching presence with video annotation based on the coding scheme of teaching presence shown in Table 2, which includes indicators for "facilitating discourse", "direct instruction", and "design and organisation". We coded the instructor's teaching behaviour with ELAN, a linguistic annotation tool designed for

TABLE 2 Coding scheme of teaching presence based on video content.

Category	Indicator	Definition	Example
Design and organisation (DE)	Setting curriculum and assessment methods	Communicating important course outcomes, for example, documenting course goals, topics, rubrics, and instructor expectations	This week we will be discussing…
	Designing methods	Providing clear instructions on how to participate in course learning activities	I suggest you activate this account so that I can access your database.
	Establishing time parameters	Communicating important due dates/time frames for learning activities to help students keep pace with the course	Please install the MySQL database during the break.
	Making macro-level comments on course content	Providing rationale for assignments/topics	I need to connect to your database remotely with a guest account to help you experience and have a better understanding of the program.
Facilitating Discourse (FD)	Drawing in participants	Helping keep students engaged and participating in productive dialogue	Any thoughts on this issue?
Direct Instruction (DI)	Providing valuable analogies	Attempting to rephrase/reformulate course material in ways that highlight similarities between content assumed to be understood and new content, with the goal of making the material more comprehensible	The IP address is like a computer's ID number in the network.
	Offering useful illustrations	Attempting to make course content more comprehensible by providing examples that are substantive and advance understanding	What is a port? Port is a software code. For example, 3306 is MySQL, 1521 is Oracle, and 80 is the general port of the web server.
	Conducting informative demonstrations	Attempting to make course content more comprehensible through the exhibition of processes	After setting the environment variable, please press window and R, then enter "cmd" to open the DOS window and run the command "mysql".
	Supplying clarifying information	Attempting to reduce confusion or misconceptions about course content by providing additional explanations	This software is installed on the C drive. Try to find the folder Program Files (x86), then enter this folder and find the MySQL folder.
	Making reference to outside material	Providing useful information from a variety of sources, for example, articles, textbooks, personal experiences, or links to external websites	You can refer to this website for MySQL software: xxx.

Note: Adapted from Shea et al. (2010).

text annotations for video and audio recordings (Brugman & Russel, 2004). We coded the videos with time windows of 15 s, which is suitable for identifying temporal information about teaching presence. The average number of *danmaku* in each time window was 13.6. The video segment for each time window was annotated manually, based on the main teaching behaviour presented in the segment.

3.3 | Data analysis

First, we conducted a chi-square analysis to compare the distributions of teaching presence indicators and social presence indicators in theory-oriented and application-oriented sessions (RQ1). We utilised the chi-square test of homogeneity to determine whether the frequency counts of social presence and teaching presence indicators were identically distributed across the application-oriented and theory-oriented sessions (Bolboacă et al., 2011). Then, we used network measures to analyse the quantity and diversity of the relationships between teaching presence and social presence to address RQ2. Last, we analysed the correlations between the time series of teaching presence and social presence indicators in the theory- and application-oriented sessions (RQ3). Details of the network and correlation analyses used in this study are provided below.

3.3.1 | Network analysis

A network is a collection of points joined together in pairs by lines, where the points are called nodes and the lines are called edges (Newman, 2018). Social network analysis is a method of studying social structures and relevant properties using network and graph theories (Hao et al., 2018). To address RQ2, we constructed a bipartite network modelling the co-occurrence relationships between teaching presence and social presence indicators during the learning process. A bipartite network is a type of complex network consisting of two disjointed sets of nodes, wherein each of the edges run between a node from one set and a node from the other set (Newman, 2018).

In this study, two networks were created to analyse the relationship between teaching presence and social presence in application- and theory-oriented sessions, respectively. The indicators of social presence and teaching presence represented the two sets of nodes in the bipartite network, and an edge represented the temporal co-occurrence relationship between an identified pair of teaching presence and social presence indicators within the same time window. For example, an edge denoted by (answering questions, drawing in participants, 5) indicated that "answering questions" and "drawing in participants" co-occurred within the same time window 5 times during the sessions. In this way, we could analyse the relationships between teaching presence and social presence in the online VBL sessions and examine the importance of various teaching presence indicators in terms of their connectivity to students' social presence during the learning process.

To address RQ2, we analysed the quantity and diversity of connections between teaching presence and social presence indicators in the theory- and application-oriented sessions. The quantity of connections was measured based on weighted degree centrality, and the diversity of connections of teaching presence was measured based on an adjusted entropy measure (Feng & Kirkley, 2020). Weighted degree centrality (s_i) was calculated as the sum of a node's incident connections, each weighted by their frequency (Liu et al., 2016). Referring to Opsahl et al. (2010), we calculated the weighted degrees of the bipartite network following Formula (1):

$$s_i = \frac{\sum_{j=1}^{N} w_{ij}}{\sum_{k,j=1}^{N} w_{kj}/2} \tag{1}$$

where i is the focal node, the indices j and k run across all other nodes, and N is the total number of nodes. w is the weighted N by N adjacency matrix, with w_{ij} as the number of times indicators i and j co-occur (as the network is bipartite, $w_{ij} = 0$ for all pairs i, and j that are in the same group). The degrees were normalised by the sum of the weights of the edges so that the value range was [0,1].

Shannon's Entropy, from information theory, is generally used to measure the average amount of information needed to represent an event drawn from a given probability distribution (Shannon, 2001). Referring to the diversity measure used in (Feng & Kirkley, 2020), we calculated the diversity of teaching presence indicators according to Formula (2):

$$H_i = -\frac{1}{log(n_s)} \sum_{j=1}^{N} x_{ij} log x_{ij} \tag{2}$$

where x_{ij} is the fraction of occurrences of teaching presence indicator i that coincides with social presence indicator j, and $n_s = 11$ is the total number of nodes in the social presence group. The prefactor $\log(n_s)$ ensures that the measure is normalised to [0,1], with a diversity of 0 indicating that the teaching presence indicator only co-occurs with a single social presence indicator, and a diversity of 1 indicating that the teaching presence indicator has a perfect equal distribution of frequencies of co-occurrence among all of the social presence indicators.

3.3.2 | Temporal patterns between social and teaching presence

We constructed the time series of each teaching presence and social presence indicator for the theory- and application-oriented sessions to examine the synchronisation of the patterns between teaching presence and social presence over time. To explore the relationships between teaching presence and social presence indicators over time, we first constructed the time series of frequency vectors for different indicators. For teaching presence, we used 1 and 0 to indicate that a teaching presence indicator appeared or did not appear in a given time window, respectively. According to the video annotation, each time window contained only one teaching presence indicator; therefore, the vectors associated with the teaching frequency were binary indicator vectors, each with a single entry equal to 1. We likewise calculated the frequency of each social presence indicator within a time window. To allow for comparisons between the teaching presence and social presence indicators on the same scale, we converted the social presence frequency vectors at each period into relative frequencies by normalising the frequencies by the sum of the vectors. Normalisation also has the benefit of preventing spurious correlations due to temporal trends in the magnitude of social presence vectors.

Correlation analysis was utilised to analyse the constructed time series (Rehfeld et al., 2011). Point-biserial correlation, a special case of Pearson correlation, measures the relationship between a continuous and a dichotomous variable (Demirtas & Hedeker, 2016). Teaching presence is a dichotomous variable within a given time window (1 or 0), and the social presence time series are continuous. We computed the point-biserial correlations between teaching presence and social presence indicators to examine the temporal patterns of the relationships observed in network analysis within the theory- and application-oriented sessions. In addition, we used cross-correlation with time lags to analyse the relationships between the time series of social presence indicators in the two session types. Cross-correlations analyse the relationship between two social presence time series by computing the correlation between each point in a time series of one

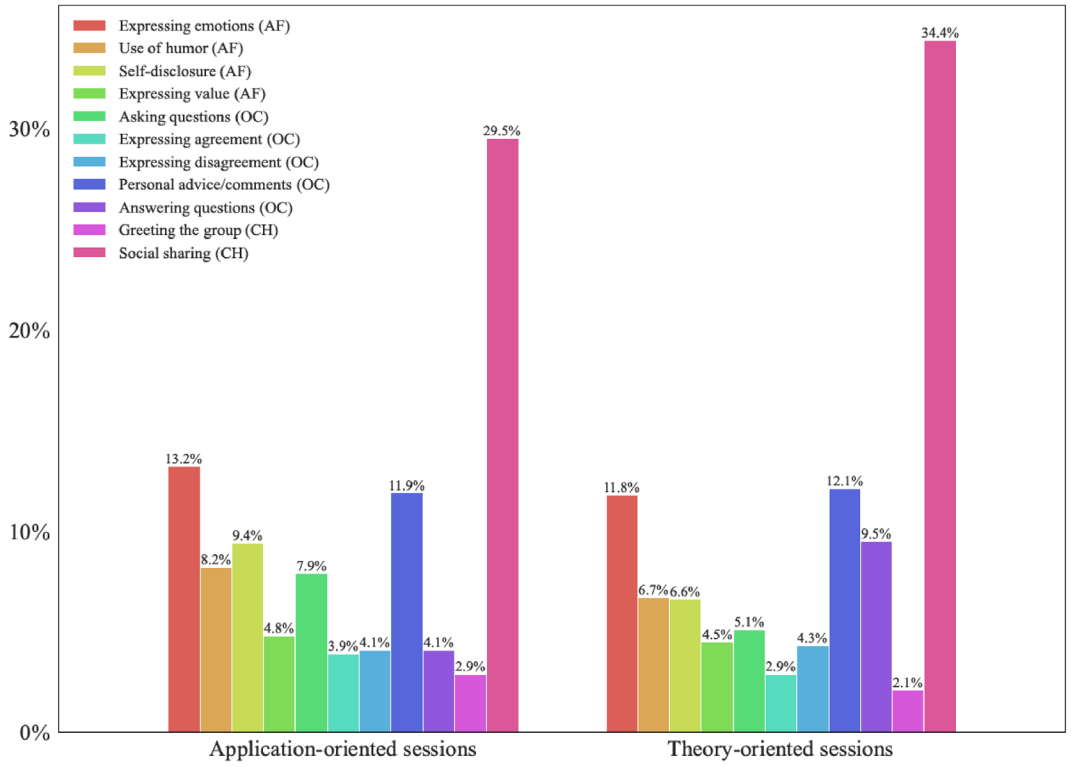

FIGURE 1 Percentages of social presence indicators in application-oriented and theory-oriented sessions. The abbreviations represent the social presence categories: AF, affective expression; CH, group cohesion; OC, open communication.

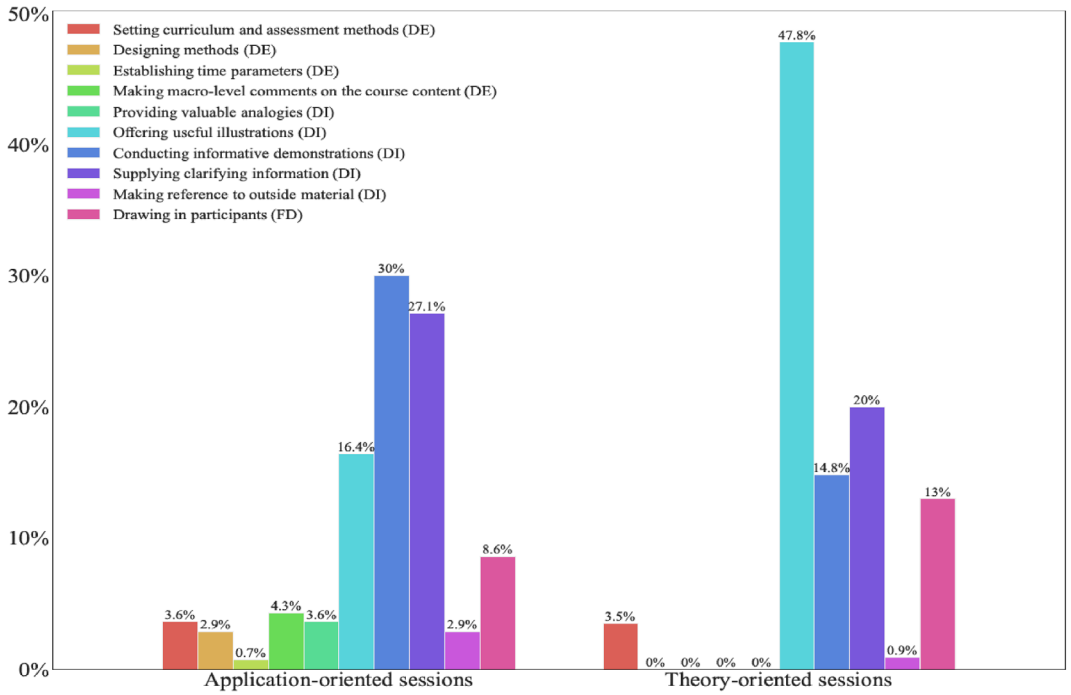

FIGURE 2 Percentages of teaching presence indicators in application-oriented and theory-oriented sessions. The abbreviations represent the teaching presence categories: DE, design and organisation; DI, direct instruction; FD, facilitating discourse.

social presence indicator and the corresponding point in the time series of another social presence indicator while accounting for the time lag between them. Cross-correlations with time lags can suggest a causal relationship between two variables, but they do not necessarily prove causality (Borysov & Balatsky, 2014). To account for the lag in users' responses to others' posts, we used a lag of one window in

the cross-correlation analysis of the time series of social presence indicators. In this study, the effect size between 0.3 and 0.5 is considered medium (Cohen, 1992).

4 | RESULTS

4.1 | Characteristics of teaching presence and social presence (RQ1)

We first compared the percentages of social presence and teaching presence indicators in the theory-oriented sessions and application-oriented sessions (see Figures 1 and 2, respectively). Among the 3456 *danmaku* comments, 1692 were posted in the theory-oriented sessions and 1764 were posted in the application-oriented sessions. Through a chi-square test of homogeneity, we found that there was a significant difference in the distributions of social presence indicators between application-oriented and theory-oriented sessions ($\chi^2(10,\ N = 3456) = 70.60,\ p = 0.00 < 0.05$). "Social sharing" presented the highest percentage in both the application-oriented and the theory-oriented sessions. The "social sharing" indicator refers to chats or discussions that are not directly related to course content. Such discussions can facilitate social interactions but may not contribute directly to helping students learn the course subject. For example, when the instructor used an example of programmer salaries in the 1980s to introduce the database query, there were comments discussing whether or not the salaries were considered high by today's standards. Although this type of comment is not directly related to course content, it can arouse the interest of students to interact with each other. Additionally, "expressing emotions" and "personal advice/comments" also had high percentages in both application- and theory-oriented sessions. In application-oriented sessions, we observed that some of the learners were active in disclosing their personal background ("self-disclosure"); for example, some students disclosed that they were programmers or project managers while the instructor introduced database applications. Besides, the learners tended to ask more questions and answered fewer questions from others in the application-oriented sessions than in the theory-oriented sessions.

We also examined teaching presence in the online course. Through a chi-square test of homogeneity, we found a significant difference in the distributions of teaching presence indicators between application- and theory-oriented sessions ($\chi^2(9, N = 3456) = 677.23$, $p = 0.00 < 0.05$). In the application-oriented sessions, "conducting informative demonstrations" showed the highest percentage, while in the theory-oriented sessions, "offering useful illustrations" showed the highest percentage. The instructor provided more demonstrations to introduce database-related applications in the application-oriented sessions, along with more information regarding the required steps ("supplying clarifying information"). In the theory-oriented sessions, the instructor elaborated more on the theories and concepts of MySQL ("offering useful illustrations"). Besides, three indicators—"designing methods", "establishing time parameters", and "making macro-level comments on course content"—appeared only in the application-oriented sessions. For example, the instructor required the students to activate their accounts while introducing software installation, which relates to how to participate in course learning activities ("designing method"). The instructor also set a time limit to complete the installation and explained the reason for this request, which were examples of "establishing time parameters" and "making macro-level comments on course content".

4.2 | Relationships between teaching presence and social presence (RQ2)

To explore the relationships between teaching presence and social presence, we constructed two bipartite networks for modelling the temporal co-occurrence between teaching presence and social presence in the theory- and application-oriented sessions. In a bipartite network, there are two sets of nodes, one representing the teaching presence indicators and the other the social presence indicators, as well as edges representing the co-occurrence between a pair of teaching presence and social presence indicators within the same time window. Edges are weighted based on the frequency of co-occurrence between a pair of teaching presence and social presence indicators within the same type of session.

Based on the constructed bipartite networks, we first computed the statistically significant edges representing the frequencies of co-occurrence that were higher than expected by random chance, given the overall frequency of the edge's teaching presence type and the total number of social presence types. Assuming that the frequencies of edges with a given teaching presence indicator are distributed across the social presence indicators following a uniform multinomial distribution, the marginal probability of a given frequency of co-occurrence with a particular social presence indicator follows a binomial distribution with a number of trials equal to the overall frequency of the teaching presence indicator, and a success probability equal to the inverse of the number of unique social presence types. Using this relationship, we computed the threshold values for significant co-occurrence for all social presence indicators for each teaching presence indicator, at a significance level of 0.05, using the inverse survival function of the binomial distribution. In this way, we identified the significant pairs of social presence and teaching presence indicators, given the total number of *danmaku* for the corresponding teaching presence indicator. We visualised the two bipartite networks with significant edges in Figure 3.

In both the application-oriented and theory-oriented sessions, we found that "social sharing" had a high frequency of co-occurrence with various teaching presence indicators. In addition, the learners tended to express their own feelings when the instructor introduced the course design and requirements ("setting curriculum and assessment methods"), offered useful illustrations, or provided additional explanations ("supplying clarifying information"). Some students wrote "Ha Ha Ha" (laughing) when the instructor used some humorous examples based on his programming skills and work experience to explain the laboratory tasks.

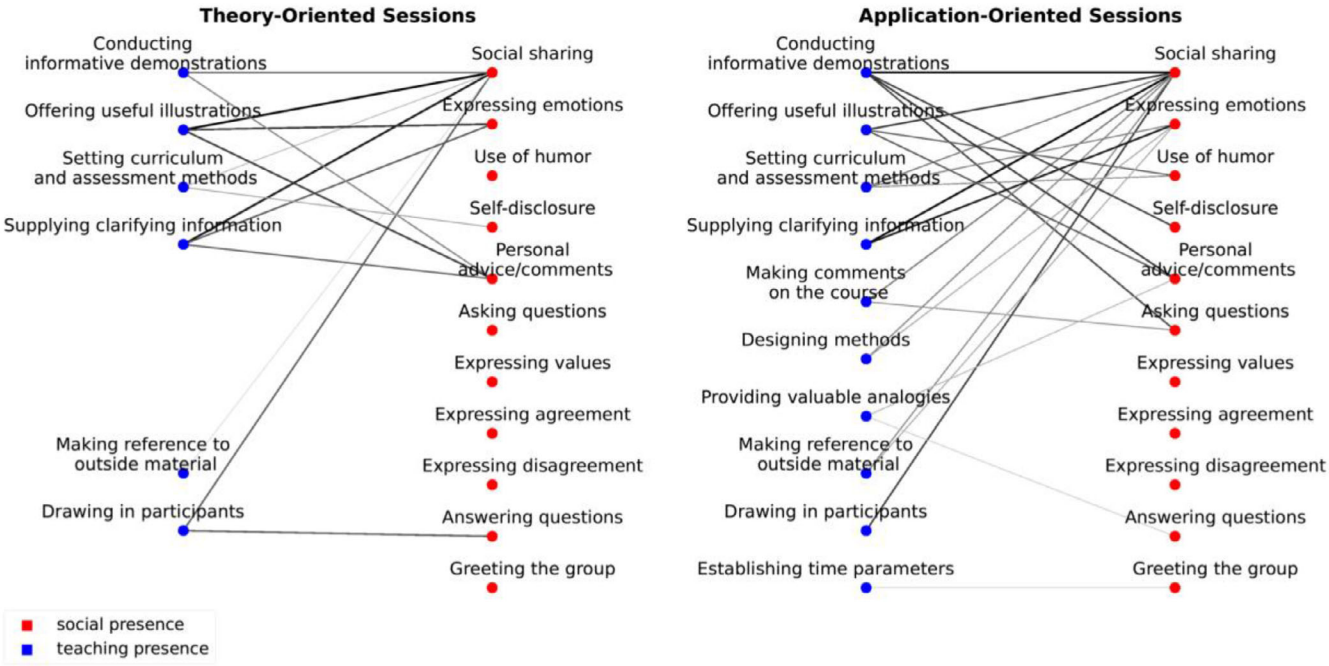

FIGURE 3 Co-occurrence network of teaching and social presence indicators in application-oriented sessions and theory-oriented sessions. This figure only shows high co-occurrences for each teaching presence indicator. Edges with darker colours indicate higher frequencies of co-occurrence.

In the application-oriented sessions, we found that the students tended to discuss the difficulties they met ("self-disclosure") when following the instructor's hands-on guidance and ask for possible solutions ("asking questions") when the instructor talked about hands-on applications ("conducting informative demonstrations"). In the theory-oriented sessions, "drawing in participants" had a high frequency of co-occurrence with "answering questions". For example, the instructor asked students to provide answers to the supplementary examples or asked whether or not the students understood certain content. The students posted their answers to the questions raised by the teacher via *danmaku* in the pre-recorded videos, which also indicates that recording questions to students can be an effective way to engage with students in pre-recorded VBL.

We further quantitatively examined differences in the relationships between teaching presence and social presence indicators between the theory- and application-oriented sessions. Figure 4 shows a heatmap comparing the frequencies among pairs of teaching presence and social presence indicators, displaying the difference in these tie values between the application-oriented and theory-oriented sessions. A positive value indicates that the frequency of the tie was higher in the application-oriented sessions than in the theory-oriented sessions, and a negative value indicates that the frequency of the tie was higher in the theory-oriented sessions than in the application-oriented sessions.

As shown in Figure 4, the largest positive differences were found in the relationships between the social presence indicators and the "conducting informative demonstrations" indicator. The connection ("social sharing", "conducting informative demonstrations") showed the largest discrepancy between the theory-oriented and application-oriented sessions. In the application-oriented sessions, the instructor introduced more hands-on applications, which had high co-occurrence with the "social sharing" indicator. Furthermore, the largest negative differences were found between the social presence indicators and "offering useful illustrations." The connection ("social sharing", "offering useful illustrations") had the largest discrepancy between the two types of sessions. In the theory-oriented sessions, the instructor introduced more theories and concepts with further illustrations, which also had high co-occurrence with the "social sharing" indicator.

We found stronger connections between teaching presence and social presence indicators in the application-oriented sessions than in the theory-oriented sessions. The students had more opportunities to discuss course-related content in the application-oriented sessions, which may be attributable to the design of the course. Studies have evaluated course designs according to Bloom's taxonomy by dividing cognitive levels into a beginner level (memorization and understanding), an intermediate level (application), and an expert level (design or creation and critique) (Betts, 2008; Kudryashova et al., 2016; Starr et al., 2008). In this study, we found that application-oriented sessions placed a higher demand on intermediate-level cognitive activities than did the theory-oriented sessions, as they involved more activities requiring students to implement theoretical knowledge. This finding suggests that instructors incorporate more hands-on activities into pre-recorded videos to enhance students' discussions in the learning process.

To examine the importance of certain teaching behaviours for students' social presence, we computed the diversity and quantity of

FIGURE 4 Differences in the co-occurrence relationships between social presence and teaching presence indicators, between application- and theory-oriented sessions. The abbreviations represent the teaching presence categories: DE, design and organisation; DI, direct instruction; FD, facilitating discourse.

TABLE 3 Diversity and quantity of teaching presence indicators.

	Application		Theory	
Indicator	**Diversity**	**Quantity**	**Diversity**	**Quantity**
Setting curriculum and assessment methods	0.831	0.052	0.747	0.022
Designing methods	0.705	0.026	Nan	Nan
Establishing time parameters	0.462	0.005	Nan	Nan
Making macro-level comments on course content	0.813	0.043	Nan	Nan
Providing valuable analogies	0.803	0.021	Nan	Nan
Offering useful illustrations	0.889	0.144	0.845	0.474
Conducting informative demonstrations	0.887	0.287	0.926	0.107
Supplying clarifying information	0.862	0.290	0.773	0.254
Making reference to outside material	0.859	0.034	0.547	0.006
Drawing in participants	0.852	0.099	0.829	0.137

Note: "Nan" represents a value that is undefined.

connections of teaching presence indicators in the bipartite networks constructed based on Formulas 1 and 2, introduced in Section 3.3.1. The diversity of a teaching presence indicator measures the extent to which the indicator influences a variety of social presence indicators. The quantity of a teaching presence indicator measures the overall influence of the indicator on students' social presence. The diversity

and quantity of all of the observed teaching presence indicators are shown in Table 3. Teaching presence indicators of high quantity and diversity are important and are considered more influential to social presence indicators. In the application-oriented sessions, "conducting informative demonstrations" and "supplying clarifying information" both had high quantity and diversity values. In the theory-oriented sessions, "offering useful illustrations" had high quantity and diversity values. These teaching presence indicators formed the most important and central nodes in the bipartite networks, and they displayed co-occurrence with all of the social presence indicators in the respective networks and were more influential in engaging students in the learning process. These three teaching presence indicators were all under the "direct instruction" category and accounted for a large proportion of video content. As shown in Figure 3, the aforementioned important teaching presence indicators had stronger connections with the social presence indicators in the bipartite networks, as the edges with darker colours indicate higher frequencies of co-occurrence.

4.3 | Temporal patterns between social and teaching presence (RQ3)

Through network analysis, we analysed the static co-occurrence relationships between teaching presence and social presence indicators during the application-oriented and theory-oriented sessions. To further examine, the possible changes in these relationships between time windows, we constructed the time series of each teaching presence and social presence indicator to explore the temporal dynamics of the relationships using point-biserial correlation and cross-correlation.

The results of our temporal analysis indicate that most of the correlations were weak or not significant; only a few relationships were significant in both temporal analysis and network analysis, including ("setting curriculum and assessment methods", "expressing emotions") ($r = 0.247$, $p = 0.003$), ("setting curriculum and assessment methods", "use of humour") ($r = 0.269$, $p = 0.001$), and ("making macro-level comments on course content", "asking questions") ($r = 0.430$, $p = 0.00$). For example, when the instructor provided an overview of the session at the beginning ("setting curriculum and assessment methods"), some learners tended to express their thoughts and emotions about the course, as well as share some humorous content that was popular among programmers. A previous study (Mesiti & Clarke, 2006) also suggested that the commencement of a class provides an opportunity to spark students' interests and promote their engagement, introduce the course content, and establish the subsequent work pattern. Another example is when the teacher introduced the importance of the course ("making macro-level comments on course content"), some students posted related questions, for instance, how they could use the skills acquired through the class in their work.

We also examined the correlations between social presence indicators using cross-correlation analysis with a lag time of one time window to account for the lag in the response of users. Figures 5 and 6 show the significant correlations between social presence indicators in the application-oriented and theory-oriented sessions, respectively. The maximum correlation coefficient was 0.462. There were several moderate correlations, marked in bold font in Figures 5 and 6.

According to Figures 5 and 6, we found that there are more pairs of social presence indicators with significant cross-correlations in application-oriented sessions than in theory-oriented sessions. In particular, although "social sharing" had a high static frequency of co-occurrence with most of the teaching presence indicators, its time series was not correlated with any teaching presence indicator in both application- and theory-oriented sessions. Instead, we found that the time series of "social sharing" was correlated with several other social presence indicators (e.g., "expressing agreement", "expressing disagreement") in both application-oriented and theory-oriented sessions. This indicates that the learners' social sharing may be more related to their peers' social presence than the instructors' teaching presence in social media-based VBL. Figure 7 shows an example of trends in social presence indicators, namely the normalised frequencies of "personal advice/comments" and "social sharing" in the application-oriented sessions ($r = 0.361$). In Figure 7, the time series of "personal advice/comments" and "social sharing" were associated: when one indicator was high over a period of time, another indicator also tended to show a high value. This is consistent with the findings of studies suggesting that social influence plays a key role in motivating users to share information on social media (Ghaisani et al., 2017).

5 | DISCUSSION

Video-based lectures uploaded to online platforms provide rich analytics data based on viewership patterns (Lau et al., 2018). Combining sociocultural frameworks of learning with analytics can help us understand people's learning processes and dispositions (Ahn, 2013). We demonstrate this idea by adopting novel analytics methods to explore how instructors' teaching presence relates to learners' social presence. Theoretically, we examined the characteristics of and relationships between teaching presence and social presence in online VBL; methodologically, we applied novel bipartite network analysis and cross-correlation analysis to examine the relationships from both static and temporal perspectives.

Our study identified some common patterns in the relationships between social presence and teaching presence in both theory- and application-oriented sessions. We found that students tended to post information about "social sharing", "expressing emotions" and "personal advice/comments" in both theory-oriented and application-oriented sessions, referring to the results of RQ1. Based on the results of RQ2, we found that the two social presence indicators, "social sharing" and "expressing emotions", had a high co-occurrence frequency with multiple teaching presence indicators. This suggests that students tended to engage more effectively and socially in social media-based learning environments. The study by Ghaisani et al. (2017) drew similar conclusions that students preferred sharing

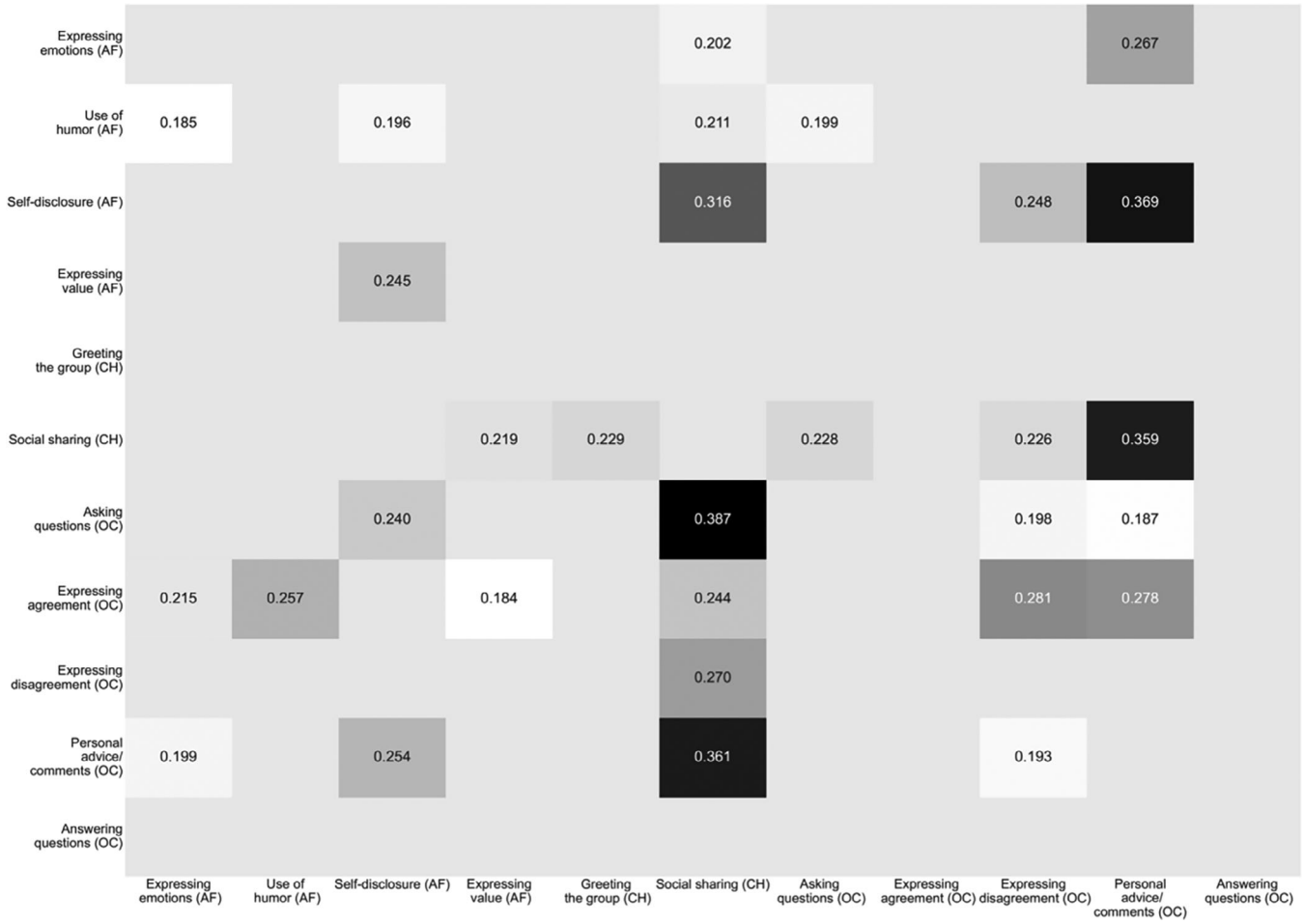

FIGURE 5 Correlation matrix of social presence indicators in application-oriented sessions. The abbreviations represent the social presence categories: AF, affective expression; CH, group cohesion; OC, open communication.

information to maintain relationships with friends and express their impressions on social media. In RQ3, based on the time series analysis, we found more pairs of social presence indicators with significant cross-correlations in application-oriented than in theory-oriented sessions. This result is consistent with previous research (Dempsey & Zhang, 2019; Kozan, 2016), indicating that the students' social presence was more closely linked to that of their peers.

In addition to the common patterns between the two session types, we identified several differences in the relationships between teaching and social presence between application- and theory-oriented sessions. In the application-oriented sessions, "answering questions", "personal advice/comments", and "greeting the group" had high frequencies of co-occurrence with a few of the teaching presence indicators. However, in the theory-oriented sessions, only "answering questions" had a high frequency of co-occurrence with a teaching presence indicator. This may be attributed to the different nature of application- and theory-oriented sessions. The instructor provided hands-on practice and opportunities for students to participate and engage in peer discussions in the application-oriented sessions, whereas the instructor introduced students to the fundamental concepts of the programming language and students primarily listened to the instructor in the theory-oriented sessions. This finding further emphasises the impact of the course design on social presence (Aragon, 2003; Swan & Shih, 2005) and teaching presence.

The results of this study shed light on teaching practice and course design for VBL. When preparing teaching materials for VBL, teachers are recommended to consider the relationship between teaching presence and social presence to enhance their course design. For example, using humorous examples and content to promote students' affective expressions as well as engagement in VBL is suggested. Humour reduces social distance and conveys goodwill within the learning environment (Aragon, 2003). Previous studies have highlighted the importance of emotions in self-directed learning, and learners who can regulate their own emotions and generate positive emotions tend to be more self-directed, leading to better academic achievement (Rager, 2009; Zhoc et al., 2018). Additionally, teachers can facilitate peer-to-peer interaction and discussion by asking questions that help students recall prior knowledge and explore the subject matter more comprehensively (Tofade et al., 2013). By understanding

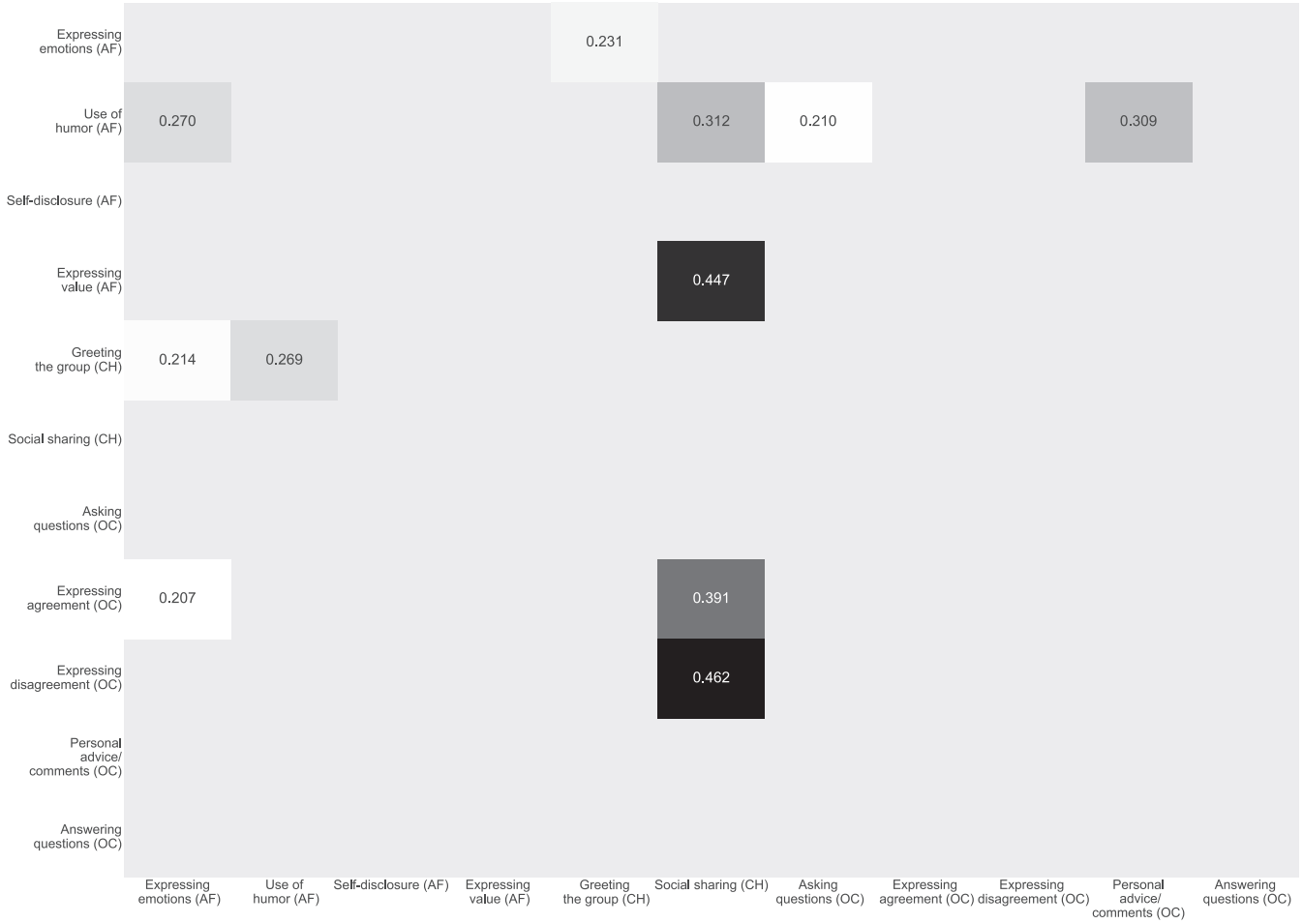

FIGURE 6 Correlation matrix of social presence indicators in theory-oriented sessions. The abbreviations represent the social presence categories: AF, affective expression; CH, group cohesion; OC, open communication.

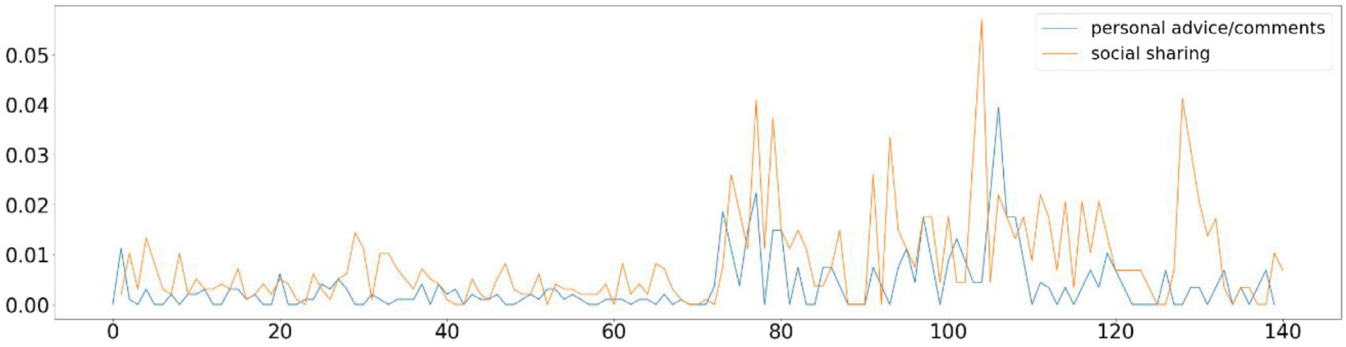

FIGURE 7 Normalised frequencies of "personal advice/comments" and "social sharing" in application-oriented sessions with a lag of one time window.

how certain teaching strategies can impact students' social presence, this study can assist in the development of effective VBL courses.

This study also contributes to the theoretical understanding of the relationships between teaching presence and social presence. Future studies can form the hypothesis referring to our analytical results and re-examine the relationships between teaching presence and social presence in other subject contexts. Methodologically, our contribution has two layers: (1) we adopted a novel data source, *danmaku* comments, to study social presence; (2) we proposed and adopted novel network analysis and time series analysis methods to

analyse the relationships between social presence and teaching presence from both static and temporal perspectives. Our novel bipartite network analysis may be used in future studies to explore the community of inquiry framework in VBL.

6 | CONCLUSION

In this study, we explored the relationships between teaching presence and social presence in online VBL, using novel learning analytical methods. The results of this study contribute to the theoretical understanding of the relationships between social presence and teaching presence in VBL, as well as help guide instructors in designing learning activities in pre-recorded VBL to facilitate a high level of social presence among students. Based on the results of this study, we have several suggestions for improving the teaching practice and course design of pre-recorded videos. (1) Course instructors are recommended to consider including practical activities to promote students' social presence. Wang and Liu (2020) found that the frequency of "design and organisation" and "facilitating discourse" indicators had a positive effect on student interactions but that too much "direct instruction" may hinder student interactions in online learning. Similarly, we found that too many "direct instruction" indicators without interactive activities may hinder student engagement in online VBL. (2) Teachers are recommended to ask engaging questions in pre-recorded videos to draw the attention of online learners. The online learners answered the questions via *danmaku* comments, even if this was a pre-recorded course, which improved learner engagement. (3) Instructors can provide detailed, hands-on explanations in application-oriented courses to improve online learners' discussions of course content. (4) Course instructors can give additional explanations by providing related examples, which influences students' emotions. The learners posted *danmaku* comments to express their happiness when the instructor used interesting examples to supplement their explanations, contributing to the students' self-directed learning.

This research, however, is subject to several limitations. First, this study analysed data from one online course. Future studies are suggested to collect data from different subjects to examine and compare the relationships between teaching presence and social presence in VBL across disciplines. Second, this study examined the relationships between teaching presence and social presence from both static and temporal perspectives. However, as the cross-correlation analysis cannot prove causality, future studies are recommended to examine the causal relationships between teaching presence and social presence using experimental studies or well-designed observational studies. Lastly, students' social presence is analysed based on their *danmaku* comments in this study. There are other ways to examine students' social presence in VBL processes, such as comments in live streaming and facial expressions. Future studies are recommended to examine students' social presence in VBL contexts from a multi-modal perspective.

The use of more advanced machine learning techniques is recommended for further studies to analyse user-generated data and provide timely support for online learners. For instance, future studies may classify and sort *danmaku* comments through supervised machine learning methods so that users can choose to show the *danmaku* texts they are interested in to stay focused. This would prevent learners from becoming overwhelmed by the volume of *danmaku* comments. Future research may also examine *danmaku* data using machine learning methods to investigate online learners' communication behaviours with an expanded dataset and validate the conclusions drawn in this study.

AUTHOR CONTRIBUTIONS

Xiuyu Chen: Conceptualization, Data Collection and Analysis, Writing – original draft preparation; **Shihui Feng**: Methodology, Conceptualization, Writing – Reviewing & Editing.

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PEER REVIEW

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available upon requests.

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