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Exploring the Influence of Using Collaborative Tools on the Community of Inquiry in an Interdisciplinary Project-Based Learning Context

Yu-Chiung Hsu [1], Ya-Ming Shiue [2*]
[1] Kun-Shan University, Tainan, TAIWAN
[2] Chia-Nan University of Pharmacy and Science, Tainan, TAIWAN

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ABSTRACT
This study aims to explore the relationships among three presences, namely cognitive presence, social presence and teaching presence in a Community of Inquiry (CoI) framework in the context of interdisciplinary project-based learning (IPBL) through the collaborative technology Google Applications. The survey data was collected from 138 students with mixed subject specialism participated in a cultural creativity project. All participants were randomly assigned into one of two groups. The control group used online discussion boards, while the treatment group used the Google Applications as a collaborative technology to support the project learning. The results of the study showed that the students' cognitive presence was positively influenced by the teaching and social presence, which supported the theoretical CoI framework. Moreover, in an IPBL context with the support of the Google Applications, social presence had more predictive power in explaining students' cognitive presence than the support provided by the online discussion boards.

Keywords: Community of inquiry, Google Applications, Collaborative technology, Interdisciplinary project-based learning

INTRODUCTION

A central challenge of interdisciplinary integration in professional education is the radical restructuring of the whole learning process, and the introduction of modern pedagogical methodologies, techniques and information technologies (Chu et al., 2010; Di Blas et al., 2014; Sampson et al., 2014), as well as the need to spark communication and collaboration that clearly crosses traditional disciplinary boundaries. Interdisciplinary project-based learning (IPBL) is regarded as crucial pedagogy that can provide sufficient training in teamwork by developing multidiscipline teams similar to those that operate in industry. In responding to this need in higher education, a number of scholars have conducted the studies that involve complex technical, engineering, educational and social projects based on cross-disciplinary domain knowledge for students with different subject specialisms, so that they can contribute their individual efforts and resources to promote learning (Carpenter et al. 2007; Johansen et al., 2009; Maxim, 2006; Stozhko et al., 2015; Whitney, 2014). Such works suggest that this kind of IPBL can help students to further develop creativity and overcome the barriers framed by disciplinary egocentrism. Empirical studies have proved that IPBL can help students to develop knowledge management processes, arouse their interest and motivation in the subject course, foster their involvement in the learning process, and increase the level of cognition and satisfaction with learning outcomes (Bisasutti, & El-Deghaidy, 2012, 2015; Dekhane & Tsoi, 2010; Yueh et al., 2015), demonstrating the need, relevance and importance of interdisciplinary integration through IPBL in current pedagogical methodologies.

Nowadays, different discipline areas employ various information applications, which encourage teachers and students to collaborate in learning, using open-source electronic platforms to enhance the interdisciplinary technology-mediated training of students (Urban, 2014). As a creative pedagogic approach, IPBL could further integrate and work more effectively through the use of online collaborative technologies. Learners could be well

✉ ychsu@mail.ksu.edu.tw ✉ shiue@mail.cnu.edu.tw **(*Correspondence)**

Contribution of this paper to the literature

- The study confirms CoI model as a valid theoretical framework in describing and explaining the relationships among three presences, cognitive, social and teaching, in the context of IPBL.
- By employing collaborative tools, namely Google Applications, to facilitate the learners' community of inquiry, this study sheds light on the importance of collaborative technology being incorporated into IPBL for promoting the development of learners' perceptions of cognitive presence.
- With the support of collaborative technologies, such as Google Applications in an IPBL context, instructional designers and faculty could focus more attention on the most significant component in the model, namely social presence, which can foster cognitive presence in guiding the course development of the IPBL, with the aid of these technologies.

prepared to collaborate in the IPBL learning environment in which complex tasks can be accomplished with an abundance of available collaborative tools through the internet, which has made the tracing of collaborative activities and interactions easier than ever before. Numerous online collaborative applications allow learners with a common learning goal to share, discuss, and edit their project work online synchronously, such as Google Applications (Cheung & Vogel, 2013). With the support of such online collaborative tools, students with different domain knowledge are able to co-construct knowledge and make connections with other learners and professionals, and thus develop a deeper sense of learning community and collaborative inquiry.

Communities of learning and collaborative inquiry are crucial within such an IPBL learning context, as the areas of teaching and learning are expanding as new interactive technologies support innovative forms of pedagogy in higher education. Among numerous efforts that have been dedicated to systematically explore the integration of new pedagogical ideals and new communication technologies, one promising theoretical perspective, based on the collaborative constructivist principle, is the Community of Inquiry (CoI) framework (Garrison et al., 2000). Conceptually useful in describing, explaining, and enhancing students learning in purely online environment, the CoI model has proved to be more productive that other approaches as it focuses more directly on teaching and learning in a completely technology-mediated environment (Shea & Bidjerano, 2009). Scholars contend that the CoI model can provide online faculty and instructional designers with a mechanism for the integration of technology and pedagogy in ways that impact online learning across many disciplines (Shea & Bidjerano, 2009). The CoI framework identifies three core elements, namely the teaching, social and cognitive presences, which are required to create and sustain purposeful inquiry and meaningful collaboration. The overlapping relationships of these presences provide the structure to understand the dynamics of deep and meaningful online learning experiences (Garrison et al., 2010).

As scholars (Garrison et al., 2010) have pointed out, unique patterns of relationships among these three presences are formulated within different disciplines, thus producing the interactive and inquiry-based focus of online communities of inquiry. They conducted an empirical study to test the relationships among the three presences using a sample of students enrolled in programs of interdisciplinary study and distance education in courses across multiple subject areas in the social science domain. An online conferencing platform was provided to further assess student engagement and group interaction. The results verified the theoretical assumptions of the CoI framework, showing that students' perceptions of teaching presence and social presence predicted the significant effects on the perception of cognitive presence. Moreover, a significant direct effect of the focal programs on cognitive presence was found, particularly in the program of interdisciplinary study. This provides empirical evidence of the need for further research to explore the dynamic relationships among the three presences across disciplines and online learning settings.

As the integration of Google Applications to support project-based collaborative learning has become an important issue in higher educational institutes, it is thus of interest to explore the influence of these applications on learners' perceptions of teaching, social, and cognitive presences in IPBL to verify the CoI model in this context. To date, a growing body of conceptual and empirical literature has been dedicated to articulating and expanding the explanatory power of the CoI framework. However, little has been done to investigate the relationships among the three presences, or comparing different online learning environments in terms of IPBL. To verify the utility of the CoI framework in describing, explaining, and ultimately improving learning in different online educational environments, it is crucial to depict and test the constructs within different online learning settings, as is done in the current work.

LITERATURE REVIEW

Interdisciplinary Project-Based Learning (IPBL)

In current pedagogy, interdisciplinarity is seen as "the hallmark of contemporary knowledge production and professional life" (Boix Mansilla & Dawes Dursising, 2007:215), and there have thus been many debates and discussions dedicated to its definition, and the approaches employed to achieve it are often very significantly different, thus resulting in divergent philosophies, contexts of practice and views of the function of particular educational systems (Klein, 2013). As a long-term theorist of interdisciplinary teaching and learning, Klein (2013) argues for the need to shift away from a focus on discrete disciplines of knowledge to more holistic thinking that looks at the productive relationships that can arise among disciplines, and she particularly emphasizes the use of participation and collaboration. Resonating with project-based learning outcomes, interdisciplinary project-based learning (IPBL) can be defined as when the learners are actively involved in a learning process by developing projects for which insights from various disciplines are integrated in response to solving a particular problem or issue.

The ability of individuals to work together productively and creatively is highly desirable by the employers, and is regarded as a pre-condition for employment. In the higher education training, interdisciplinary group projects are seen as important tools for students to be equipped with such professional world environments to which they aspire. Interdisciplinary group projects emphasis teamwork and collaborative learning, which foster the development of effective communication skills, problem solving skills as well as the community involvement they need in the real world experience (Johansen et al., 2009).

There is number of researches that investigate the students collaborate together in the group projects which the course design and development are based on cross-disciplinary domain knowledge (Biasutti & El-Deghaidy, 2012; Carpenter et al., 2007; Goff et al., 2006; Gorev & Masalimova, 2017; Marchioro et al., 2014; Maxim, 2006; Whitney, 2014; Zhu & Qiu, 2017), suggesting that interdisciplinary integration is important as the restructured learning process enable learners to synchronize team efforts, contributing their individual strengths, so as to develop their creativity and to balance their independent learning. Within such interdisciplinary collaboration environment, learning becomes a comparable process of shared creation, where individual with various academic disciplines can bring different sets of knowledges and skills to the partnership (Miles & Rainbird, 2015).

IPBL can provide a sufficient way of enhancing learners' cognition and learning, helping leaners to develop knowledge management processes and raising their satisfaction while collaborating in designing interdisciplinary projects, in particular, with the facilitation of technology support. Stozhko et al. (2015) employed a computer-assisted learning system (CALS) in an analytical chemistry course with students from different academic specialisms, and find that IPBL can significantly enhance learning and positively impact students' cognitive level. The literature shows that online collaborative tools can play an important role in facilitating the IPBL environment. Bisasutti and El-Deghaidy (2012) examine the use of wikis as an online didactic tool to develop learners' knowledge management processes, which are essential professional skills in higher education. The results reveal that wikis can be used as a facilitating tool for IPBL and help learners to develop their knowledge management processes, as well as raise student satisfaction when collaborating in designing interdisciplinary projects.

Collaborative Technologies Facilitate Online Learning

Collaborative technologies, as one of the most important applications of e-learning, have triggered a new wave of free online wikis, word processors, spreadsheets, presentation and discussion forum software packages since they were first introduced in 2005 (Rienzo & Han, 2009). Collaborative technologies have attracted much attention from educational scholars, as they can provide students with a context/platform on which they can discuss, exchange, and share their opinions and ideas, as well as construct their own knowledge collaboratively. Cheung and Vogel (2013) define collaborative learning technologies as "a set of tools for task-specific collaborations, and are associated with goal and work-oriented activities" (pp.161).

As part of the growing new wave of free web-based collaborative learning technologies, Google Applications can help learning communities to create, edit, and share content online. Cheung and Vogel (2013) investigate the adoption behaviors of e-collaboration technologies in the web 2.0 environment for the information sharing, learning activities, communication, and interactions within group-based project work, which are trackable and monitored through a computer-supported collaborative platform. By employing the social learning approach in a web-based collaborative platform, individual and group perspectives are all involved in the learning through participation in joint activities and the social practice mediated by the collaborative tools.

With the support of effective collaborative technologies, knowledge can be transferred not only from the teacher to students, but also the students can effectively construct knowledge through collaboration in the learning process.

Due to the rapid development of online collaborative technologies, more educational institutions are now working to prepare students to learn in a collaborative environment in which learning tasks can be accomplished with online (Cheung and Vogel, 2013). Such synchronous collaborative technologies can promote "meaningful discourse" with regard to the learning activities where knowledge is constructed through learners' social communication with their peers and communities in the learning process, just as it is in the physical, face-to-face classrooms.

Collaborative technologies also provide an effective way to integrate technology into the curriculum in the project-based learning (PBL) context. PBL is intended to engage students in authentic tasks to enhance learning, and is thus a dynamic instructional strategy in which students explore real-world problems and challenges, simultaneously developing cross-curriculum skills while working in small collaborative groups. Asan and Haliloglu (2005) indicate that PBL is also a model for computer classroom activities that moves away from short, isolated, teacher-centered lessons. Instead, it emphasizes learning activities that are long-term, interdisciplinary, student-centered, and integrated with real world issues and practices. PBL, in which students work in teams to explore a question or create a project, also helps maximize the students' abilities to develop computer skills. Prokofieva (2013) employs wikis as the focal collaborative technology to facilitate an online project learning, and find that student-content interaction was dominant in this process. Moreover, the results also show that the instructor's attitude is particularly important for encouraging student-student interactions.

A recent study by Lee and Lee (2016) investigates college students' interaction and collaborative learning in the Google Drive facilitated computer supported communication learning (CSCL) setting of performing team-based project design tasks. They found that learners' interaction pattern and team's achievement are significant different between two achievement groups (high v.s. low), showing that for learners in CSCL, social interaction plays an important role in building shared knowledge and academic achievement in collaborative project learning activities. In particular, when learners perceive their project goal and task are highly rely on their team members, the greater extent to which they interact with their team members will be achieved in online collaborative learning across different knowledge domains. Thus, such kind of knowledge boundary spinning will be more effective in the interdisciplinary e-collaboration project learning environment, which in turn will influence their project quality and performance (Zhu & Qiu, 2017).

Community of Inquiry Model

Garrison et al. (2000) develop the concept of the Community of Inquiry (CoI) as a comprehensive theoretical framework to better understand the order and structural elements needed in the process of online learning and the practice of online instruction. Rooted in the philosophical foundation of collaborative constructivism, the CoI model emerged in a computer-supported context in higher education, providing the ideas and beliefs that are consistent with the ideals and values of higher education in our post-Internet society (Garrison et al., 2010).

Within a collaborative constructivist learning environment, the CoI framework consists of three core dimensions, namely cognitive presence, teaching presence, and social presence, and the dynamic relationships among these need to be understood in order to construct the deep and meaningful online learning environments needed to support purposeful inquiry and meaningful collaboration. Cognitive presence reflects the learning and inquiry process, which can be divided into four phases of activation, exploration, integration, and resolution (Garrison et al., 2010). Within this context, cognitive presence represents the purposeful nature of collaborative knowledge construction inherent in educational experience among constructivists (Arbaugh et al, 2008). Garrison et al. (2000, 2001) define cognitive presence as the extent to which learners are able to construct meaning through sustained communication, in which group work with valued personal contributions and a secure learning environment is encouraged to foster exchanges (Matheson et al., 2012).

Teaching presence has been shown to be crucial in establishing and sustaining the success of a formal educational community of inquiry (Garrison & Arbaugh, 2007), and is defined as "the design, facilitation and direction of cognitive and social processes for the purpose of realizing personally meaningful and educational worthwhile outcomes" (Anderson et al., 2001, p.5). A growing body of literature confirms the importance of teaching presence for successful online learning (Garrison & Cleveland-Innes, 2005; Garrison et al., 2010; Murphy, 2004; Swan, 2002; Wu & Hiltz, 2004), as well as noting that it is a significant determinant of perceived learning, student satisfaction, and sense of community (Arbaugh et al., 2008; Shea et al., 2005).

Theoretically, the CoI model posits that teaching presence has direct influences on the creation and sustainability of social and cognitive presences. Teachers are responsible for designing, organizing, facilitating discourse, and directing instruction to obtain desirable outcomes based on their students' need and capabilities. However, in an IPBL context the teachers play the role of facilitator, setting project goals and providing guidelines and resources, moving from group to group while providing suggestions and support for student learning activities. With the aid of collaborative technology to support communication with others, students can actively make choices about how to generate, obtain, manipulate, or display information. Moreover, when technology is

used as a tool to support students in performing authentic tasks, the students are in the position of defining their goals, making design decisions, and evaluating their progress. Social presence is critical within such a learning context, as the utilization of technology can increase the level of collaboration, as well as students' regulation of their own learning. Technology use allows many more students to be actively thinking about information, making choices, and executing skills than is typical in teacher-led lessons.

Social presence is essential in online learning environments (Swan et al., 2009), and is defined as "the ability of participants to identify with the community (e.g., course of study), communicate purposefully in a trusting environment, and develop inter-personal relationships by way of projecting their individual personalities" (Garrison, 2009, pp. 352). In the CoI model, social presence is regarded as a mediating variable between perceived teaching presence and cognitive presence, reflecting online discourse promotes positive affect, cohesion, and interaction (Rourke et al. 1999), as well as supports a collegial, collaborative environment (Shea & Bidjerano, 2012). Furthermore, social presence is foundational for online interaction, a powerful activity supporting joint knowledge construction to foster cognitive learning, because it represents learners' ability to get to know others, form distinct impressions of classmates, participate in web-based communication and interact comfortable and feel acknowledged by others through those interaction (Shea & Bidjerano, 2012).

Previous studies find a causal relation between teaching presence and social presence with regard to the cognitive presence (Garrison, et al., 2010; Archibald, 2010), as well as a significant correlation between social and cognitive presence (Shea & Bedjerano, 2009; 2012). Although collaborative research efforts have validated the structure of the CoI framework, there are still some limitations with regard to explaining the interaction effects of the presences within the contextual dynamics of an online learning environment with the support of various technologies. Gutierrez-Santiuste et al. (2015) investigate students' perceptions of synchronous and asynchronous virtual learning in various text-based communication formats, namely chats, forums, and emails, and find that cognitive presence is predicted more strongly by social presence than by teaching presence, which implies the importance of social presence in achieving the focal learning objectives.

When carrying out IPBL with the use of collaborative tools, group activities can be facilitated by enabling ease of communication and coordination among group members. There is growing evidence of a variety of benefits from the use of collaborative tools. Lou et al. (2001) found that the use of such tools for the group learning has more positive impacts on cognitive processes when compared to their use in individual learning. Moreover, the quality of the social interactions between students and students, and between students and teachers, is also improved through the use of collaborative tools, as these make the interactions among users more visible, thus improving their understanding of each other (Ma, 2009). Within a collaborative-technology supported interactive process, learners are better able to construct meaningful knowledge at a social level (Kreijns et al., 2003). The atmosphere and relationships among student peers might thus have more weight than the act of teaching (Gutiérrez-Santiuste et al., 2015).

Cheung and Vogel (2013) conduct a study addressing the need for implementation of a web 2.0 environment, using the communications and activities of project groups working with Google Applications as collaborative tasks within a social networking environment. The findings show that the 26 peer groups with strong social ties were associated with strong investments of time, reciprocity and sharing, whereas the instructor should be considered as a "weak social tie" when moving toward a student-centered learning environment. They conclude that the influence of peers is more powerful with regard to the adoption of collaborative technology than with other e-learning applications (Cheung & Vogel, 2013).

In summary, it is important to create and sustain a collaborative community of inquiry, and a growing body of literature uses the CoI model to investigate various aspects of online and blended learning environments. However, there is a need to turn from descriptive to more predictive quantitative studies that can verify the dynamic effects of the social and teaching presences on cognitive presence in different online learning settings (Garrison, et al. 2010; Gutiérrez-Santiuste et al., 2015). Earlier works suggest that future research should explore the relationships among the three presences in different online learning settings, as research shows that cognitive presence is predicted more strongly by social presence than by teaching presence, which implies the importance of social presence in achieving the stated learning objectives.

METHODOLOGY

Based on the theoretical model of the CoI, the following research questions were addressed in this study:

1. Do students' perceptions of teaching and social presence have significantly positive effects on cognitive presence in the interdisciplinary project-based learning (IPBL) environment?
2. Do students' perceptions of teaching presence have significantly positive effects on social presence in the interdisciplinary project-based learning (IPBL) environment?

3. Compared with the students using the discussion board supported by the Wisdom Master Pro online learning platform, is students' cognitive presence better explained by social presence than by teaching presence in the IPBL environment with the utilization of collaborative tools?

Measurement

A valid and reliable CoI survey instrument, the Community of Inquiry framework developed collaboratively by previous scholars (Garrison et al., 2010; Arbaugh et al., 2008), was employed in this study with modifications to incorporate and adapt to the Google Applications context. The CoI survey consists of three dimensions of presence, a total of 34 items (see Appendix, i.e., items 1-13 for Teaching Presence, items 14-22 for Social Presence, and items 23-34 for Cognitive Presence) with a Cronbach's alpha reliability of .84 (Arbaugh et al., 2008). A five-point Likert type scale ranging from 1 *(strongly agree*) to 5 (*strongly disagree*) was provided to students so that they could make their responses. The factorial validity of the scale has been established in previous research (Garrison et al., 2010; Shea & Bidjerano, 2009), and thus the CoI model is a reliable measure of the theoretical constructs of the three presences. Details of the students' demographic backgrounds were also obtained, including age, gender and major, with the data then subjected to descriptive analysis.

Participants

The subjects were 142 undergraduate students who enrolled in a "Digital Content Marketing" course conducted at a university of technical and vocational education in Tainan, Taiwan. The participating students came from several academic disciplines, within business, informatics, and design knowledge domains. The structured questionnaire was developed with two sections: demographics and the CoI framework survey instrument, and was distributed to the students enrolled in the course. The total number of valid respondents was 138, and their answer were used in the data analysis. The distribution by sex was 43% male to 57% female. The average age of the respondents was 20.6 years old. Approximately 37% were majoring in business-related disciplines, 30% in informatics disciplines, and 33% in design discipline.

Utilization of Google Applications as Collaborative Tools

Google Applications, such as Google Docs, Google Group Forums and Google Drive, are used to support the online collaborative learning for the project examined in this study. As researchers (Cheung & Vogel, 2013) point out, online collaborative technologies offer a more "authentic learning experience," as learning activities, communications, interactions and collaborations are visible and trackable simultaneously throughout the learning process. Moreover, students are able to exercise the ubiquitous possibilities for content creation, editing and sharing, and so gain a deeper sense of discipline knowledge through social communications with their learning partners and communities, as in real-world workplaces.

Procedure

The data was collected from the students enrolled in a 16-week "Digital Content Marketing" course, which required the students to work collaboratively for an interdisciplinary integration project. Before the course started, a face-to-face session was held to explain the purpose and procedure of the study. A total of 142 students were randomly divided into 24 groups, each with five to six members. To fulfill the goals of the interdisciplinary project learning, each group required students from three different subject areas for the specific cross-disciplinary project tasks. The project tasks consist of product design, 3D printer modeling, market research, planning and promotion, which relied on design, informatics, and marketing domain knowledge. During the course, students were required to work collaboratively in groups to complete a cross-disciplinary integration project for specific brands, particularly in the cultural creativity industry. By having students work together on the same project in the so-called "industrial-academic cooperation" model, the instructors in these different disciplines made attempts to challenge students with varied domain knowledges by engaging them in tasks that reached across disciplinary boundaries. The goal was to create a "real world" context for the students equipped with specific knowledge and skills, in recognition of the applied nature of their disciplines.

In particular, among the 24 groups of participants, 12 groups (72 participants) were randomly selected as the experimental group who used Google Applications to facilitate collaborations and interactions in the online learning community, including Google Docs, Google's share space, and discussion forums. In contrast, the other 12 groups (70 participants) were treated as the control group, using online discussion boards supported by Wisdom Master Pro, the most commonly used e-learning platform among higher educational institutes in Taiwan. The experiment sessions were developed over ten weeks.

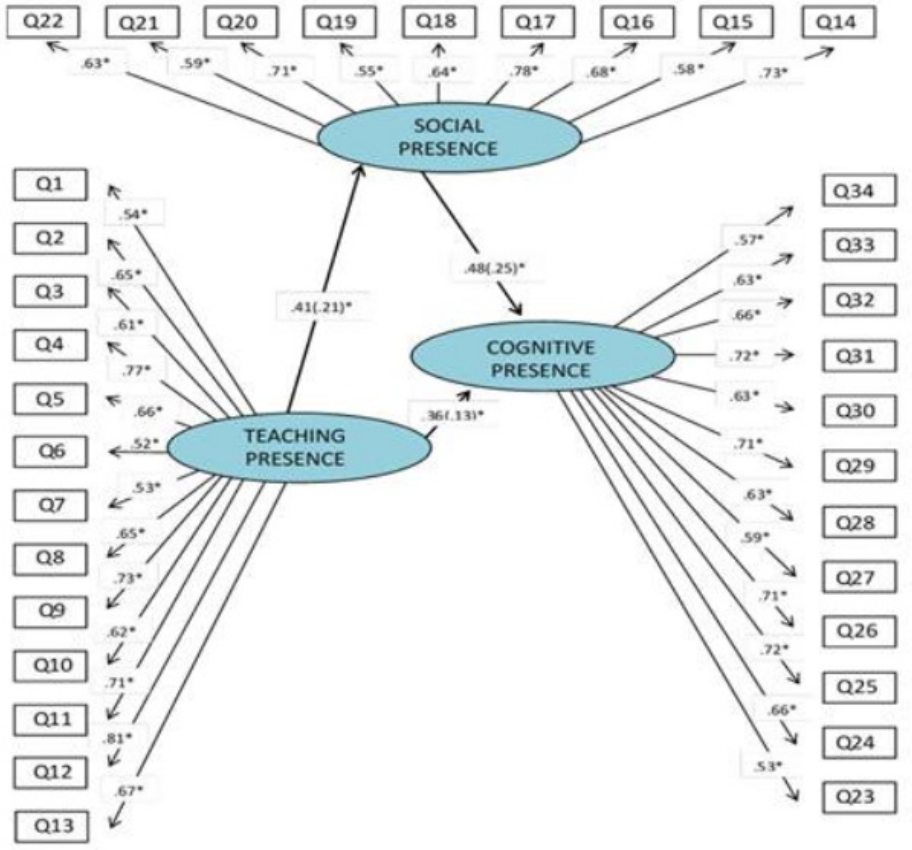


Figure 1. Model of the relationships among the factors in the community of inquiry

All the participants were assigned the same tasks, course schedule, and same instructors during the experiment, only using different communication tools to support their online project learning activities. After a 70-minute lecture session, the experimental group stayed in a computer lab for further discussion of the project tasks they had been assigned, with this lasting for 30 minutes. The students in the control groups used the online discussion boards as a communication tool for project discussion and summarizing ideas.

The students in the experimental group were required to utilize various collaborative tools supported by the Google Applications for discussing, sharing, editing their project work. Different from the e-learning discussion board, Google collaborative tools allow students to modify the project work and monitor the modifications made by other group members simultaneously, which makes their collaboration more effective in the IPBL environment. After the 10-week experiment session, the CoI survey was administered to the142 students who participated in this course, and a total of 138 valid questionnaires were collected and used for the data analysis.

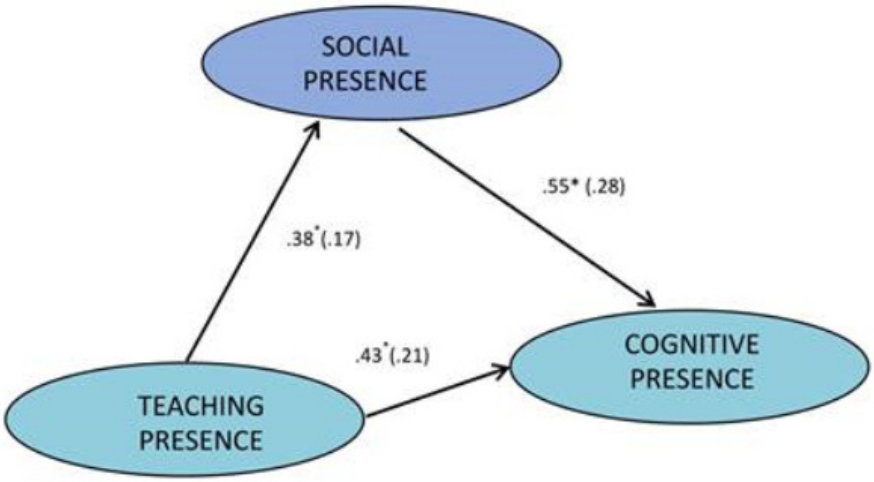
RESULTS

Factor Analysis

Principle axis factor analysis using an oblimin rotation was used to extract three factors. A three-factor solution provided clean loadings and interpretability in terms of the theoretical framework (see **Figure 1**). The loadings of all the CoI items were higher than 0.40, as expected, across the three presences. The first extracted factor was consistent with the items included in the teaching presence subscale, with 13 items with a reliability of .91. The second and third extracted factors were associated with social presence and cognitive presence, respectively. The factor of social presence had nine items with a reliability of 0.89. The last extracted factor, cognitive presence, consisted of 12 items with a reliability of 0.93.

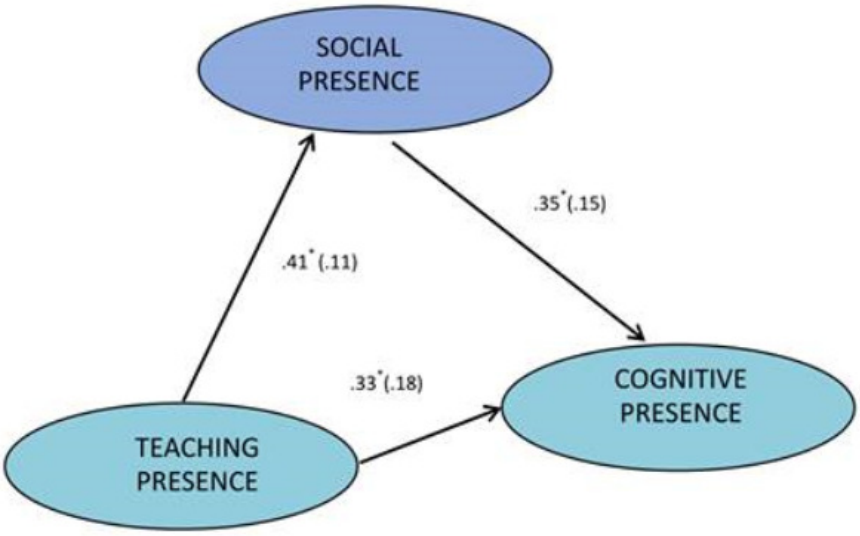
Structural Equation Model

This study aims to explore the relationships among teaching, social and cognitive presences for students involved in an interdisciplinary project-based learning environment with the utilization of Google Applications.



Note: Marker coefficients (*) are significant at p<0.05

Figure 2. The structural model for the collaborative tools



Note: Marker coefficients (*) are significant at p<0.05

Figure 3. The structural model for the online discussion boards

Consistent with the previous literature, the structural equation model confirmed that the model can be used to verify the predictive relationship of cognitive presence with regard to the social and teaching presences in an IPBL environment (see **Figure 1**). The students' perceptions of teaching presence predicted a significant direct effect on their perceptions of cognitive presence. In addition, the perceptions of teaching presence were significant associated with social presence. The indirect effect of social influence on cognitive presence was also confirmed.

Analysis of Collaborative Tools and Online Discussion Boards

Further analysis was carried out to investigate whether the factors which affected students' cognitive presence with regard to the collaborative tools were similar to those related to the online discussion boards, as shown in **Figures 2** and **3**. Two points should be observed in these. First, cognitive presence was mainly influenced by social presence, followed by teaching presence, in the collaborative tool supported learning environment (see **Figure 2**). Second, cognitive presence was mainly influenced by teaching presence, followed by social presence, with the online discussion boards (see **Figure 3**). Therefore, it can be concluded that social presence significantly encouraged students to use the collaborative tools, while teaching presence significantly encouraged students to use the online discussion boards.

DISCUSSION

This study made an attempt to investigate the theoretical framework of the three presences embodied in the Community of Inquiry (CoI) framework with regard to describing, explaining, and improving the interdisciplinary project-based learning environment through online collaborative technologies. Consistent with the previous research (Arbaugh et al., 2008; Shea & Bidjerano, 2009, 2012; Archibald, 2010), the findings of this study verified the theoretical assumptions of the CoI framework, showing that the students' perceptions of teaching and social presences have direct, positive effects on cognitive presence. Our study shows that the CoI model can be applied to collaborative technologies for IPBL. In light of this verification it is thus suggested that the CoI framework and three constructs of teaching, social, and cognitive presences represent a valid model for delineating and explaining students' online collaborative learning communities in cross-disciplinary knowledge domains.

In addition to verifying the CoI model in IPBL context, this study also examined the differences in students' perceptions of three presences in different online learning settings (Google Applications v. s. online discussion board). While other studies made attempts to explore the relationships among the three presences when using different communication tools (Gutierrez-Santiuste et al., 2015) or in different online delivery formats (Shea & Bidjerano, 2010; 2012), this work, in particular, investigated the impact of synchronized online collaborative tools, and found that social presence has greater predictive power in the online learning environment with the facilitation of Google's collaborative tools, confirming the findings from Gutierrez-Santiuste et al. (2015), showing that cognitive presence is predicted to a greater extent by social presence than by teaching presence. This important finding suggests that the collaborative technologies may contribute to the salience of prompt communication and high interaction among group members in IPBL, creating a more effective community of inquiry. As argued by Cheung & Vogel (2013), peer influence is particular important in a collaborative technologies learning context because of the highly interactive nature of the collaborative platform. Such collaborative-interactive mechanism may further create the social interdependence among members with different professions, which in turn facilitate the effective understanding and applying the practical knowledge across professional boundaries (Zhu & Qiu, 2015).

Compared with the other e-learning applications, collaborative technologies may better help to create sufficient online interactions IPBL needs for collaboration across professional boundaries. Chi (2009) contends that the online interaction has constructive in nature, involving learners' to co-construction knowledge, enhance understandings through building upon each other's contributions. Such online interaction, as a powerful activity supporting joint knowledge construction, can benefit learners' cognitive learning from partner's contributions to additional information, new perspectives, corrective feedback, a new line of reasoning (Shea & Bidjerano, 2012), which in turn scaffold the integrated knowledge in IPBL context. Since social presence construct is crucial for such constructive online interaction, it is not surprising that learners' social presence has more predictive power on the cognitive presence in the IPBL with Google applications compared to their counterparts with online discussion boards.

In addition, this investigation may further reinforce the previous scholars' assertions that learners' perceived level of social presence could be affected by the characteristics of the tools they used (Horzum, 2015), and the usage of online interactive tools can positively increase social presence (Weinel et al., 2009). This might be explained by the fact that students can get instant feedback, trace the editing, and interact with their group members through using synchronized communication tools when working collaboratively on a cross-disciplinary project. This could overcome the problem of implementing and monitoring the collaborative activities in group-based project work on a regular basis. Google Applications, which enables synchronous discussing, sharing, editing, and interacting among users, have a degree of social presence due to their capability of communicating authentic messages and providing a more immersive experience for users. The virtual learning communities that can be supported by collaborative tools can orient communication to high level of critical thinking, which is associated with the notion of cognitive presence (Garrison et al., 2007). Within such a learning context, social presence thus plays a crucial role in enabling communication oriented to the learning objectives.

Implications for IT Practitioners

As numerous researchers have worked to apply web 2.0 technologies to facilitate online learning communities for different modes of collaborative project-based learning, the associated constructs of teaching, social, and cognitive presences delineated in the CoI framework represent an alternative theoretical model for describing and explaining the new learning experiences that take place within such an online environment. Given that the students' social presence has demonstrated greater predictive power with regard to cognitive rather than teaching presence, future educators should thus consider the utilization of web 2.0 collaborative communication tools in order to foster learner perceptions of social presence to guide the development of online collaborative and interdisciplinary learning communities in higher education. Cheung and Vogel (2013) suggest that the communications and activities of project groups that use Google Applications can be regarded as collaborative tasks within a social network

environment, and thus instructional designers can serve as "weak social ties" and formulate activities and strategies to foster the "strong social ties" which were associated with strong investments of time, reciprocity, and sharing among group members (Wellman, 1997). Moreover, the intensity level of social network tie may represent different quality of social presence for learners to communicate comfortably via the online medium and feel connected, as well as socially supported by their peers and instructors. As Shea and Bidjerano (2012) assured the importance of learning presence as represented as self-regulated learning (SRL) on cognitive presence which is likely to depend on the characteristics the leaner (i.g. SRL) bring to the learning environment when quality of teaching or the quality of social interaction are low or inadequate, selection criteria for enrolled in such IPBL program may extended to assess learners' different level of SRL to better fit the various types and functions of online interaction supported by different collaborative learning technologies.

Limitations and Future Research

As this study examined the responses from a relative small sample size, the results should be interpreted with a degree of caution. Furthermore, while various online collaborative tools provide different functions for collaborative learning, this study was limited to the features of Google Applications with regard to Forms, Docs, and share space. As these applications have been widely employed as collaborative tools, more research is needed to provide reliable findings that can be generalized to other technologies for use in IPBL environments. Finally, the individual difference characteristics were not considered in the present study, which may provide the opportunities for the prospective researchers. As scholars (Shea & Bidjerano, 2012) pointed out that the individual-level determinants can play equally important role in students' perceptions of cognitive engagement and gains, future work should address whether individual-level determinants (i.e. SRL, psychological needs of motivation) have significantly mediating effects on the three presences in the development of community of inquiry in IPBL, a task specific learning context supported by online collaborative tools.

In conclusion, the results of this study support the explaining power of the CoI model and filled the gaps in the literature by testing the most significant elements in the model that foster cognitive presence in an IPBL environment with the facilitation of web 2.0 collaborative tools. This investigation has demonstrated that social presence plays a more important role in predicting cognitive presence for students employing collaborative communication tools in an IPBL environment. Future research can further test the influence of the social network ties between the teacher and students on student perceptions of cognitive presence, which in turn can enhance their learning. As IPBL is of growing importance with regard to interdisciplinary integration in professional education, more research should be devoted to verifying the influences of teaching and social presences on cognitive presence for students involved in the cross-disciplinary collaborative learning in various online learning settings.

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APPENDIX

Questionnaire Items for the Constructs Used in This Study

1. The instructor clearly communicate important course topics.
2. The instructor clearly communicate important course goals.
3. The instructor provided clear instructions on how to participate in course learning activities.
4. The instructor clearly communicated important due/dates/time frames for learning activities.
5. The instructor was helpful in identifying areas of agreement and disagreement on course topics that helped me to learn.
6. The instructor was helpful in guiding the class towards understanding course topics in a way that helped me clarify my thinking.
7. The instructor helped to keep course participants engaged and participating in productive dialogue.
8. The instructor helped keep the course participants on task in a way that helped me to learn.
9. The instructor encouraged course participants to explore new concepts in this course.
10. Instructor actions reinforced the development of a sense of community among course participants.
11. The instructor helped to focus discussion on relevant issues in a way that helped me to learn.
12. The instructor provide feedback that helped me understand my strengths and weaknesses relative to the course's goals and objectives.
13. The instructor provided feedback in a timely fashion.
14. Getting to know other course participants gave me a sense of belonging in the course.
15. I was able to form distinct impressions of some course participants.
16. Online discussion board/Google Applications is an excellent medium for social interaction.
17. I felt comfortable conversing through the Online discussion board/Google Applications medium.
18. I felt comfortable participating in the course discussions.
19. I felt comfortable interacting with other course participants.
20. I felt comfortable disagreeing with other course participants while still maintaining a sense of trust.
21. I felt that my point of view was acknowledged by other course participants.
22. Online discussions help me to develop a sense of collaboration.
23. Problems posed increased my interest in course issues.
24. Course activities piqued my curiosity.
25. I felt motivated to explore content related questions.
26. I utilized a variety of information sources to explore problems posed in this course.
27. Brainstorming and finding relevant information helped me resolve content related questions.
28. Online discussions were valuable in helping me appreciate different perspectives.
29. Combing new information helped me answer questions raised in course activities.
30. Interdisciplinary project-based learning (IPBL) activities helped me construct explanations/solutions.
31. Reflection on course content and discussions helped me understand fundamental concepts in this class.
32. I can describe ways to test and apply the knowledge created in this course.
33. I have developed solutions to course problems that can be applied in practice.
34. I can apply the knowledge created in this course to my work or other non-class related activities.