Using Inquiry Phases to Inform the Design of Blended Project-Based Courses

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Abstract. When designing blended courses, the most common practitioner question is which activities belong online and which belong in the classroom. This paper suggests instead of deciding by content type, we propose planning activities and choosing the mode of instruction, defined as online or face-to-face activities, based on the phase of the project, or phase of inquiry, that an activity belongs to.

We use the Community of Inquiry framework, which describes learning as a progression through four phases: a triggering event, exploration, integration, and resolution. We examine the phases separately using survey data from 232 undergraduate computing education students in ten blended project-based courses at seven higher education institutions in Norway, Sweden, and Finland. Using structural equation modelling, we explored how teaching presence was related to each phase directly, and how much of that relationship was mediated through social presence.

The findings suggest that a teacher's direct instruction and facilitation are needed at most phases of project work, while the exploration phase showed the strongest indirect pathway through social presence. This may suggest that learning environments that support rich peer interaction are particularly important during the exploration phase. The other three phases are carried mainly by teaching presence. Briefing and framing the project (triggering event), integrating the work (integration phase), and presenting the final solution or artefacts (resolution phase) seem to work across both modes, because what students need in these phases is clear structure, criteria and feedback.

Keywords: Blended learning, project-based learning, computing education, higher education, Community of Inquiry.

1 Introduction

Blended learning has become a common educational approach in higher education because it combines the flexibility of online learning with opportunities for face-to-face (F2F) interaction (Garrison & Kanuka, 2004). Despite its widespread adoption, a fundamental design question remains unresolved: Which learning activities should be conducted online and which should occur F2F? A common response in the literature is to distribute activities according to content type. Therefore, an inclusion of online lectures,

readings, and content delivery are frequently assigned to online environments, while discussions, collaborative activities, and application tasks are reserved for classroom settings (Picciano et al., 2022). Such recommendations are useful in content-oriented courses but become more difficult to apply in project-based learning environments, because in project-based courses, students regularly transition between online and in-person modes of learning and collaboration.

The computing education discipline provides a particularly interesting context for the implementation of blended learning environments in project-based contexts. Students continuously move between lectures, project meetings, collaborative software development platforms, communication tools, presentations, mentoring sessions, and team discussions (Sindre et al., 2018). Rather than engaging with isolated content units, they progress through an inquiry process in which they identify problems, explore alternatives, develop solutions, and create project artefacts. Consequently, blended learning design in project-based learning cannot easily be reduced to deciding where content should be delivered.

An alternative approach is to focus on the inquiry process itself. The Community of Inquiry (CoI) framework conceptualizes learning as a collaborative process of inquiry supported by teaching presence, social presence, and cognitive presence (Garrison et al., 2010). The process of inquiry is understood through Practical Inquiry Model (PIM), which conceptualizes cognitive presence through four phases: triggering event, exploration, integration, and resolution. These phases describe how learners move from identifying a problem to implementing a solution through inquiry and reflection. Although the CoI framework has been extensively used to understand online, discussion-based, and blended learning, most research has examined cognitive presence as a single construct. This study therefore investigates how teaching presence and social presence are associated with the four phases of inquiry in blended project-based learning (BPBL) environments. Rather than asking which content should be assigned to which mode of delivery, we explore whether the phase of inquiry itself may provide a more meaningful basis for instructional design decisions.

The study addresses the following research question:

How do students perceive the roles of peer interaction and teaching presence across different phases of inquiry in blended project-based courses?

In addition, we will discuss the implications of these relationships/associations on the design of blended project-based courses.

2 Related work

Blended learning, which is commonly referred to as the combination of online and F2F modes of learning, has two contested conceptualizations. The first conceptualization views blended learning primarily as a method for content delivery, while the second conceptualization positions it as an intentional pedagogical design (Picciano et al., 2022). From a content delivery perspective, blended learning is understood in terms of its structural characteristics, which is a combination of different instructional modes and technologies. Here the focus is placed on the arrangement of learning activities

across online and F2F environments. In practice, this often involves adding recorded lectures, online learning materials, discussion forums, or other digital technologies to an existing classroom-based course. Although such implementations increase flexibility and access to learning resources, they do not necessarily alter the underlying pedagogical approach.

In contrast, Garrison and Kanuka (2004) define blended learning as an intentional design. This conceptualization shifts the focus from use of technology as a delivery method to thoughtful use of active learning strategies and interactions complemented by online and F2F activities to enhance the learning process. Prior research suggests that the instructional methods used in blended learning environment impacts students' learning outcomes, while the structural features of technology primarily affect access, flexibility, and convenience. This means that pedagogical design determines the quality of student engagement, knowledge construction, and critical thinking (Picciano et al., 2022).

Blended learning has been integrated with various pedagogical approaches to improve student engagement and learning outcomes, including peer assessment platforms, inquiry-based learning, WebQuests, game-based learning, classroom participation tools, and project-based learning (Rais Ahmed & Kolås, 2026). Among these approaches, project-based learning is particularly relevant because blended learning supports the implementation of its pedagogical design. PBL is a student-centered approach in which learning is organized around authentic problems, collaborative inquiry, learner autonomy, and the creation of artefacts (Sindre et al., 2018). As students work on complex projects over extended periods of time, they coordinate activities, share resources, communicate with team members, and document their work. Therefore, in PBL, technology has become an important medium for supporting collaboration and coordination. In this way, PBL aligns closely with the conceptualization of blended learning as an intentional design that strategically integrates F2F and online learning experiences. The emphasis on collaboration and practical work processes also helps explain why the combination of blended learning and project-based learning has become increasingly common in engineering and computing education disciplines (Rais Ahmed et al., 2026).

A central aim of PBL is to prepare students for professional practice through engagement in authentic tasks and work processes (Suleiman et al., 2025). Contemporary professional work in engineering and computing disciplines increasingly occurs across both physical and digital environments and relies on collaborative technologies for communication, coordination, and development activities. The combination of blended and project-based learning enables teachers to simulate workplace conditions, involve industry partners in learning activities, and extend collaboration beyond the classroom (Anggola et al., 2026).

As the use of blended learning within project-based courses has grown, researchers have begun conceptualizing this combination as a distinct pedagogical approach. The combination of blended and project-based learning is referred to as blended project-based learning (Barbosa, 2022). Based on a synthesis of 34 studies, Rais Ahmed et al., (2026) defined BPBL as *"an integrated pedagogical approach that combines online and F2F modalities and intentionally connects teacher-designed and student self-chosen learning components, such as content, activities, assessment, and technology use,*

through purposeful sequencing and alignment. Blended learning fosters learner autonomy and flexibility while supporting hands-on collaborative project work" (p. 16).

Viewing blended learning in project-based courses as an intentional design strategy rather than a method of content delivery implies that different phases of a project may require different forms of support. For example, idea generation may depend heavily on communication among students, whereas project planning, integration, and final delivery may depend more strongly on instructional guidance. Understanding these differences may provide a useful basis for designing blended project-based courses.

2.1 Community of Inquiry Framework

The CoI framework offers a useful lens for examining these processes because it explains how teaching, social interaction and cognitive engagement contribute to learning experiences in blended environment. The framework is particularly relevant for BPBL, where students engage in collaborative inquiry across both online and F2F settings.

The CoI framework is built on the idea that learning occurs when teachers and students form a collaborative learning community where they reflect, discuss, and solve problems together (Garrison et al., 1999). The CoI framework has its roots in socio-constructive learning theories and conceptualises learning as an active dynamic process as opposed to a passive transmission of knowledge through traditional lecture-based methods (Garrison et al., 1999). Here learning as dynamic process means a group of students, and teachers work together to explore ideas, ask questions, and solve problems.

According to the CoI framework an educational experience is defined as an interaction of three interdependent presences namely teaching, social and cognitive presences (Garrison et al., 1999). Teaching presence is the mechanism through which learning activities and interactions are designed and facilitated, while social presence supports communication, collaboration, and group cohesion. Together, these presences contribute to the development of cognitive presence, which is operationalized through the Practical Inquiry Model (PIM) consisting of four phases: triggering event, exploration, integration, and resolution (Swan, Shea, et al., 2008; Swan, Garrison, & Richardson, 2009). Previous literature has consistently reported the associations among the presences with teaching presence directly associated with social presence and cognitive presence, and social presence having indirect association with cognitive presence (Garrison et al., 2010; Swan et al., 2008). However, Garrison et at., (2010) further suggested moving beyond aggregated constructs and investigating associations among sub-dimensions of three presences.

Investigating the associations and relationships among presences and subdimensions are particularly relevant to BPBL because project work is mostly collaborative and inquiry driven. Students are required to identify problems, explore alternatives, develop solutions, and apply knowledge while collaborating with peers, teachers, and often external stakeholders. These activities closely resemble the phases of practical inquiry model described in the CoI model. The framework provides a way of examining how instructional support, social interaction, and cognitive engagement contribute to

students' project-learning experiences. In addition, the CoI framework shifts the focus of blended learning design question from what content should be delivered online versus F2F, to the question: what types of interactions and support learners need to engage in meaningful inquiry. Based on the CoI framework, there is a validated survey (Swan et al., 2008), which can help answer this question by investigating students' perceptions of teaching, social, and cognitive presences within blended project-based courses. The findings can be used to design courses that better support learners across different phases of inquiry.

2.2 Project-based learning as a process of inquiry

Project-based learning is frequently described as an iterative process in which students engage in ongoing cycles of problem identification, design, development, evaluation, and application, revisiting and refining earlier work in response to new insights and feedback. Several educational frameworks/models are phase-oriented. Although these frameworks/models originate from different traditions, they share the idea that different stages of project work require different forms of support.

A well-known framework in engineering education is the CDIO framework (CDIO Office – Chalmers University of Technology). The CDIO framework provides the overall project architecture, both for student projects and for teacher's planning, through four phases: Conceive, Design, Implement and Operate. Students move with iterations from understanding a problem, through the design and development of a solution, to implementation and operation in realistic contexts.

Similarly, the Gold Standard PBL framework (Larmer et al., 2015) describes projects as extended processes involving authentic problems, inquiry, reflection, critique and the communication of final products. While not organized as a strict sequence of phases, the framework highlights how project work unfolds through a series of interconnected activities that require different forms of student engagement and instructional support.

Within the CoI framework cognitive presence is operationalized through the Practical Inquiry Model, which consists of four phases: triggering event, exploration, integration, and resolution (Swan et al., 2008). The first phase is triggering event, involving the identification and understanding of a problem. The second phase is exploration, involving searching for information, exchanging ideas, and considering alternatives. Integration involves connecting ideas and constructing solutions, while the final phase resolution, the student is testing, implementing, and applying solutions in practice (Swan et al., 2008). These phases provide a useful lens for understanding project-based learning, where students repeatedly engage in problem-solving processes over an extended period.

While frameworks such as CDIO and Gold Standard PBL describe the overall structure and progression of project work, the practical inquiry model provides a more detailed account of the cognitive processes that underpin learning within different project phases. It is therefore particularly suited for investigating how students experience teacher support and peer interaction during BPBL. This study therefore uses the practical inquiry model as a framework to examine whether the influence of teaching

presence and social presence varies across different phases of project work in blended project-based courses.

3 Methods

The study employed a cross-sectional survey design using data collected from undergraduate students enrolled in blended project-based computing courses. A higher-order structural equation modelling (SEM) approach was used to investigate relationships among teaching presence, social presence, and the four phases of the PIM. The sample consisted of 232 undergraduate computing students enrolled in ten blended project-based courses across seven higher education institutions in Norway, Sweden, and Finland.

3.1 Instrument

Data were collected using the validated CoI survey (Swan et al., 2008). The survey consisted of 34 items measured on a five-point Likert scale, and the items cluster into three core presences. Teaching presence was measured through thirteen items and is divided into three sub-dimensions namely Design & Organization, Facilitation, Direct Instruction. Social presence was measured through nine items, and is divided into three sub-dimensions namely Affective expression, Open communication and Group cohesion. Cognitive presence was measured through 12 items and consisted of four sub-dimensions: Triggering event, Exploration, Integration and Resolution. The attachment shows the survey constructs, sub-dimensions, and associated survey items.

3.2 Research Context and Participants

This study was conducted across ten project-based computing courses offered by seven universities in three Nordic countries: Norway, Sweden, and Finland. The courses incorporated collaborative project work and blended learning arrangements, providing students with experience of both F2F and online learning activities. In total, 232 students participated in the study. Most participants were enrolled at Norwegian universities (n = 154, 66.4%), followed by Swedish (n = 54, 23.3%) and Finnish universities (n = 24, 10.3%). The participating universities included four universities in Norway, one in Sweden, and two in Finland.

Data collection was conducted from November 2025 to April 2026 using both on-site and online survey administration. On-site administration achieved near-complete participation, with all 96 students who were present in class completing the survey (100%). The online survey received 136 responses from 504 invited students, corresponding to a response rate of 27.0%. Combined across both administration modes, 232 of 600 students completed the survey, yielding an overall response rate of 38.7%.

3.3 Description of Courses in the study

The courses covered a broad spectrum of computing disciplines, including game development, software engineering, interaction design, agile project management, web development, databases, and frontend development.

These courses used two distinct forms of blended learning. Three courses employed a hybrid model in which students worked together on campus while having online mentorship session from industry professionals. In addition, students also used online tools to share project repositories, and to collaborate within teams. These courses were designed as simulated work environments where project teams collaborated F2F, while external mentors from industry engaged through video meetings, digital feedback, and online consultation sessions. Students therefore experienced a combination of co-located teamwork and distributed industry interaction.

The remaining seven courses followed a flipped classroom model. In these courses, theoretical content was primarily delivered through online materials such as recorded lectures, videos, digital learning resources, and self-paced study modules. Students attended selected on-campus activities, including seminars, workshops, project presentations, team formation activities, and supervision meetings. Team collaboration frequently occurred online using digital communication and project management tools, although major project milestones, presentations, and assessment activities were generally conducted F2F. Several courses also incorporated interaction with external stakeholders, clients, guest lecturers, or industry partners.

Across all ten courses, project-based learning was a central pedagogical approach. Students worked in teams to design, develop, and evaluate software systems, digital products, games, web applications, or interactive solutions. The courses emphasized authentic project experiences, including teamwork, agile development practices, communication, stakeholder engagement, project management, and iterative design processes. As a result, the study context represents a diverse set of contemporary computing education environments where students regularly transition between online and in-person modes of learning and collaboration.

Despite differences in subject matter and instructional arrangements, all courses required students to engage in collaborative project work over an extended period, making them suitable contexts for investigating student experiences in blended learning environments. The diversity of institutions, countries, disciplines, and blended learning arrangements is capturing a wide range of authentic computing education contexts within Nordic higher education.

3.4 Data Analysis

Data were analyzed using R (lavaan package; Rosseel, 2012). Descriptive statistics (means, standard deviations, and Cronbach's α) were calculated for teaching presence, social presence, and the four phases of practical inquiry model that are the sub-dimensions of cognitive presence. Because the survey items were measured on five-point Likert scales, indicators were treated as ordinal and estimated using the Weighted Least Squares Mean and Variance adjusted (WLSMV) estimator. A higher-order

confirmatory factor analysis (CFA) was conducted in which Cognitive Presence was specified as a second-order construct reflected by Triggering Event, Exploration, Integration, and Resolution. Structural equation modelling (SEM) was subsequently used to examine association among Teaching Presence, Social Presence, and Triggering Event, Exploration, Integration, and Resolution. Model fit was evaluated using the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR).

4 Results

The measurement model demonstrated satisfactory psychometric properties. All factor loadings were statistically significant and exceeded recommended thresholds, indicating adequate convergent validity. The higher-order cognitive presence construct was well represented by its four sub-dimensions, with standardized factor loadings ranging from .755 to .987, suggesting that Triggering Event ($\lambda = .849$), Exploration ($\lambda = .909$), Integration ($\lambda = .987$), and Resolution ($\lambda = .755$) collectively reflected a coherent underlying cognitive presence construct.

The structural model demonstrated acceptable fit to the data ($\chi^2 = 1357.56$, df = 514, CFI = .973, TLI = .971, RMSEA = .084, SRMR = .084). Collectively, the model accounted for 31.4% of the variance in social presence and 74.2% of the variance in cognitive presence, indicating substantial explanatory power for the latter construct.

As shown in Figure 1 and Table 1, teaching presence was positively associated with all four sub-dimensions of cognitive presence. In addition, the magnitude of the indirect associations through social presence varied considerably across sub-dimensions, suggesting that the role of social presence differed across phases of the inquiry process.

Teaching presence was strongly associated with triggering event ($\beta = .668$, $p < .001$), while the indirect association through social presence was comparatively small ($\beta = .063$). The total standardized association was substantial ($\beta = .731$, $p < .001$).

Teaching presence was positively associated with exploration ($\beta = .286$, $p < .001$). The indirect pathway through social presence was comparatively larger ($\beta = .363$, $p < .001$), resulting in a total standardized association of $\beta = .649$ ($p < .001$). Among the four sub-dimensions, exploration exhibited the strongest indirect association through social presence.

Teaching presence showed a strong positive association with integration ($\beta = .754$, $p < .001$), together with a smaller indirect association through social presence ($\beta = .097$, $p < .01$). The total standardized association was $\beta = .851$ ($p < .001$), representing the largest overall association among the four sub-dimensions.

Teaching presence was positively associated with resolution ($\beta = .542$, $p < .001$), whereas the indirect association through social presence was comparatively small ($\beta = .087$). The total standardized association was $\beta = .629$ ($p < .001$).

The findings indicate consistent positive associations between teaching presence and all four sub-dimensions of cognitive presence. However, the indirect pathway through social presence differed across these sub-dimensions, with the strongest indirect association observed for exploration.

Table 1: Dimension-Level Mediation Results for the sub-dimensions of Cognitive Presence

Cognitive Presence Dimension	Direct Pathways (TP → CP sub-dimension)	Indirect Pathways (TP → SP → CP-sub-dimension)	Total Association	Interpretation
Triggering Event	0.668***	0.063†	0.731***	Association primarily through TP
Exploration	0.286***	0.363***	0.649***	Strongest indirect association through SP
Integration	0.754***	0.097**	0.851***	Strong direct association with modest indirect association through SP
Resolution	0.542***	0.087†	0.629***	Mainly direct association of TP

Note. Standardized coefficients are reported. TP = Teaching Presence; SP = Social Presence.* p ≈ .05, ** p < .01, *** p < .001.

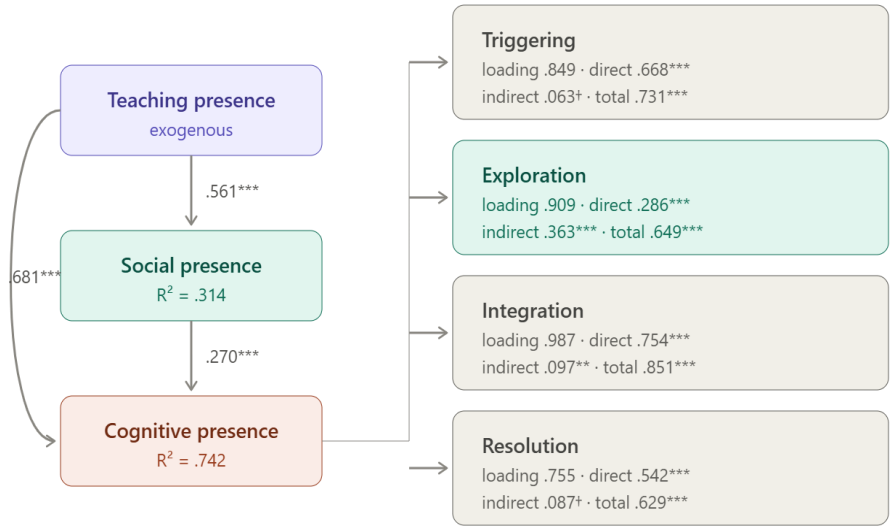


Fig.1 Relationships among Teaching presence, Social presence and sub-dimensions of Cognitive presence.

5 Discussion

The first part of the discussion section will discuss the findings related to the research question: How do students perceive the roles of peer interaction and teaching presence across different phases of inquiry in blended project-based courses?

The results showed that teaching presence was positively associated with all four phases of the Practical Inquiry Model (Swan et al., 2008). However, the pathway through which this association operated differed across phases. For triggering event, integration and resolution, the association was observed primarily through the direct path from teaching presence, with the indirect path through social presence contributing a relatively small influence. The exploration phase of inquiry has the indirect path through social presence ($\beta = .363$) that exceeded the direct path from teaching presence ($\beta = .286$). Exploration was therefore the most socially mediated phase of inquiry in these courses, while the remaining three phases were associated primarily with direct instructional influence, with social presence playing a facilitative role. Even though the findings indicate that teacher support is important throughout all phases of project work, the different phases have different needs. The integration phase has the strongest total association with teaching presence among all phases ($\beta = .851$), driven by the largest direct effect in the model ($\beta = .754$). This suggests that students experience the integration phase as teacher-dependent, where learners connect ideas and construct tentative project solutions (Garrison et al., 2001).

The triggering phase involves stimulating curiosity and motivation among students to identify and understand a problem (Martin et al., 2022). As the entry point to the inquiry process, this phase requires learners to recognize a problem and develop a sense of direction for further investigation. Our results suggest that students' perceptions of the triggering event phase were more strongly associated with teaching presence than social presence. This suggests that students' recognition of problems during project work is more strongly associated with the structure and direction established by teaching presence.

During the exploration phase, students explore problems through a variety of information sources to solve problems, generate ideas, discuss alternatives, challenge assumptions, and collectively make sense of project problems (Martin et al., 2022). These activities are constitutively interactional. They require open communication, sufficient trust to advance an underdeveloped idea, and willingness to have that idea questioned. Our findings suggest that collaborative discourse, open communication, exchange of perspectives, and group interaction are particularly important during the exploration phase. Prior literature shows that students' inquiry process in usual online and discussion-based courses stalls at exploration phase, and do not progress to integration without teachers' facilitation (Garrison et al., 2001). However, our findings suggest that, with teachers' continuous scaffolding, students continue to progress through the phases of inquiry.

During integration, students are required to connect ideas, synthesize information to address project problems and construct solutions (Martin et al., 2022). Our findings indicate that this process is primarily supported by instructional guidance, scaffolding, and structured learning activities.

During resolution, students are expected to test, apply, and present their newly constructed knowledge in real-world or simulated environments (Swan et al., 2008). Our findings showed that the direct association of teaching presence was substantial, whereas the indirect pathway through social presence was relatively small. This pattern suggests that applying, testing, implementing, and validating newly acquired

knowledge are dependent on instructional facilitation rather than social interaction alone.

5.1 Implications for the design of blended project-based courses

This section discusses the implications of the findings for the design of blended project-based courses. The findings suggest a practical design principle for BPBL specifically decisions about whether activities are conducted online or F2F should not be based primarily on content considerations. Rather, they should be informed by the phase of inquiry and the extent to which students require social interaction, collaboration, and support. The findings may indicate that inquiry phases characterized by greater needs for social interaction may be better suited to F2F learning environments that facilitate such engagement. In contrast, phases involving more independent work may be supported in either online or F2F settings.

O'Connor et al. (2023) argue that the CDIO framework must adapt to increasingly blended and hybrid learning environments, yet their systematic review of CDIO studies found little research examining how blended learning can be integrated into phase-oriented project work. Our study provides one possible response to this challenge. Rather than viewing blended learning as a division between online theory and F2F practice, our findings suggest that course design should consider the specific phase of project work being supported. In particular, exploration showed the strongest indirect association through social presence, whereas triggering event, integration, and resolution were more strongly associated with teaching presence. Such findings offer a more nuanced basis for designing blended project-based courses within CDIO-inspired educational settings.

Triggering event, integration, and resolution appear more strongly associated with teaching presence and may function effectively across online and F2F environments provided that learners receive appropriate structure, guidance, and feedback. For example, project briefings, milestone reviews, feedback sessions, and final presentations can potentially be conducted effectively in either mode when supported by strong instructional design. Exploration appears to benefit most from opportunities for interaction among students and may therefore justify greater use of F2F activities. Because exploration is strongly associated with peer interaction, teachers should pay particular attention to creating opportunities for rich social engagement during this phase. Activities such as brainstorming sessions, collaborative workshops, project kick-offs, design sprints, and group discussions may benefit from F2F interaction or synchronous formats that enable active communication among students. The purpose is not simply to share information, but to foster the social conditions that support collective problem solving and idea generation.

The findings suggest that exploration showed the strongest indirect association through social presence therefore exploration phase may benefit from learning environments that facilitate rich interaction among students. Social presence is more difficult to establish and sustain in online settings, particularly early in a project and among teams whose members do not yet know one another. This premise is well supported in the blended learning literature, students experience isolation, lack of motivation and

alienation in the online component of environment (Rasheed et al., 2020). Similarly, in a quantitative study of blended project work in Nordic computing education that used the CoI survey instrument, Mielikäinen et al. (2024) found that students were less likely to agree with items related to using online media for academic discussion than with items related to social interaction. These findings suggest that fostering social presence may be particularly important during the exploration phase, where students engage in the exchange, discussion, and examination of ideas.

Our findings suggest that teachers' direction and facilitation are important at all phases of inquiry. Learner autonomy is important to project-based learning. However, the understanding of "learner autonomy" has evolved considerably since Henri Holec's original definition of autonomy as the ability to take charge of one's own learning (Li & Tınmaz, 2025). Early conceptualizations emphasized individual control over learning goals, methods, and evaluation. Over time learner autonomy came to be understood as a multidimensional construct that encompasses cognitive, metacognitive, motivational, and social dimensions. More recent perspectives highlight the importance of contextual influences, collaboration, and digital learning environments, viewing autonomy not merely as independent learning but as a socially mediated and dynamic process (Li & Tınmaz, 2025). Our findings further suggest that the common assumption that higher education students are autonomous learners may need to be reconsidered in the context of BPBL. Rather assuming that students possess the skills necessary to manage their own learning, educators may need to provide deliberate support for the development of autonomy. Learner autonomy may therefore need to be scaffolded in project-based learning, and consideration should be given to how such scaffolding can be adapted across different phases of inquiry.

6 Conclusions

This study examined how teaching presence and social presence contribute to different phases of inquiry in blended project-based computing courses. Using the Community of Inquiry framework and data from 232 undergraduate students across ten courses in Norway, Sweden, and Finland, we investigated whether the relationships between teaching presence, social presence, and cognitive presence differ across the four phases of the Practical Inquiry Model. The findings of this study suggest that blended learning in project-based computing education should be understood as an intentional pedagogical design as opposed to a content delivery method, and as such aligns with the definition of BPBL above. The distinguishing characteristic of blended learning is not the combination of both online and F2F activities, but the deliberate and intentional use of online and F2F components to design activities to support inquiry, collaboration, reflection, and knowledge construction. In project-based learning environments, a blended learning environment supports how students interact with peers, teachers, mentors, learning resources, and work on authentic project challenges. The findings suggest that the mode of instruction may be aligned with the social and instructional needs associated with different inquiry phases. The study also contributes to ongoing discussions about learner autonomy in BPBL environments. Although project-

based learning is often associated with self-directed and autonomous learning, the results indicate that students continue to rely on instructional support throughout the inquiry process. BPBL appears to change the nature of teaching towards designing, facilitating, and scaffolding learning activities that support inquiry across learning modes.

7 Limitations and Recommendations for Future studies

This is a self-reported survey, which only recorded students' experiences of CoI inquiry and it did not ask for students' experiences of online and F2F components of the blended learning. In addition, the study was conducted within project-based computing courses in Nordic higher education, which may limit transferability to other disciplinary or cultural contexts. The participants are from different courses and this is common in CoI research. While it may enhance the generalizability of the findings, differences between courses may also have influenced students' perceptions of teaching, social, and cognitive presence. Future research could examine these relationships within specific course contexts or account for course-level variation. In addition, future research could combine survey data with observations, learning analytics, and communication data to better understand how students progress through the phases of inquiry in practice. Future studies should also examine online and F2F activities directly in order to determine how different learning environments support the various phases of inquiry.

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8 Attachment

Community of Inquiry survey instrument: presences, sub-dimensions and items

Presence and sub-dimensions	Items
Teaching Presence	
Design and organisation	1. The instructor(s) clearly communicated important course topics.
	2. The instructor clearly communicated 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.
Facilitation	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.
Direct instruction	11. The instructor helped to focus discussion on relevant issues in a way that helped me to learn.
	12. The instructor provided 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.
Social Presence	
Affective expression	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 or web-based communication is an excellent medium for social interaction.
Open communication	17. I felt comfortable conversing through the online medium.
	18. I felt comfortable participating in the course discussions.
	19. I felt comfortable interacting with other course participants.
Group cohesion	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.
Cognitive Presence	

Triggering event	23. Problems posed increased my interest in course issues.
	24. Course activities piqued my curiosity.
	25. I felt motivated to explore content related questions.
Exploration	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.
Integration	29. Combining new information helped me answer questions raised in course activities.
	30. Learning activities helped me construct explanations/solutions.
	31. Reflection on course content and discussions helped me understand fundamental concepts in this class.
Resolution	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.