Teaching Engineering Online: Examining Instructor Practices Through the Community of Inquiry Framework

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Abstract
A growing number of engineering instructors, previously accustomed to face-to-face teaching, have transitioned to online instruction, particularly after the pandemic. The teaching strategies used have become more critical in ensuring the design and delivery of quality online courses. Thus, there is a need to examine engineering instructors' approaches to designing and delivering quality online engineering courses to enhance online teaching. This study examined the online teaching practices of engineering instructors and whether and how cognitive, social, and teaching presence were integrated into their online learning environments. In this case study, the Community of Inquiry (CoI) framework was used to guide the research design. Semi-structured interviews were conducted with seven engineering instructors whose courses received Quality Matters (QM) certification across the United States. The findings revealed similarities and differences in how instructors teach online and establish teacher, cognitive, and social presence. Social presence, particularly group cohesion and affective expression emerged as an area that received comparatively less emphasis in the online teaching environment. While similarities exist across instructors, the limited emphasis on social presence suggests a need for further exploration and support in this aspect of online instruction.

Keywords: Case study; Community of Inquiry; quality online education; teaching engineering online

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Online education has emerged as a significant development in higher education over the past three decades and has been ubiquitously adopted in many disciplines. Its penetration into engineering education has gathered speed and attracted increasing interest in recent years (Koclar et al., 2021). Conventionally, engineering education has been content- and teacher-centered, but this trend has shifted towards applying more contemporary pedagogies with more hands-on and practical applications in engineering courses (Broo et al., 2022). The COVID-19 pandemic has further accelerated the growth of online education in engineering education, with many universities transitioning to remote learning and prompting a surge in demand for online engineering courses and programs.

Quality online education requires educators to employ effective teaching methods, conduct careful instructional design and planning, and follow a systematic course development model (Hodges et al., 2020). Efforts worldwide have been made to analyze standards for assessing quality, some of which include course design, faculty support, and teacher interaction (Mathes, 2019; Online Learning Consortium, n.d.). However, the term "quality" in online education is complex and relative, formed within the context and process of learning (Ossiannilsson et al., 2015). McNeil and Ohland (2015) discovered that engineering faculty lacked a common understanding of quality online teaching, with many advocating for better student admissions to improve education. Faculty encounter challenges in teaching effectively online, often due to a lack of recognition and collaboration regarding quality standards. Inconsistencies in applying these standards are observed at institutional and course levels. Therefore, there is a need to understand quality online teaching practices in engineering education.

The Community of Inquiry (CoI) framework is one of the most widely used frameworks for designing and teaching meaningful online learning experiences (Valverde-Berrocoso et al., 2020). While the CoI has been extensively applied across various disciplines since its emergence, its adoption in engineering education is relatively new. In this study, the CoI framework is used as a theoretical lens to investigate instructors' approaches to designing and teaching quality online engineering courses. Examining instructors' online teaching practices using this framework helps understand both the design of online courses and the execution of teaching strategies online to provide quality learning experiences. Thus, the primary focus of this study is to investigate how instructors design and teach quality online engineering courses.

Literature Review

Online Education in Engineering Education

Despite the widespread acceptance and integration of online education in higher education, its adoption in engineering education has been slower compared to other fields. This delay can be attributed to the field's reliance on hands-on laboratories, challenges in ensuring the integrity of assessments, and the technical complexity of engineering courses that necessitate instructional guidance (Kanyarusoke & Uziak, 2011; Odom et al., 2019). In recent years, there has been a surge in the implementation of online education within the field of engineering education (Koclar et al., 2021). Insights gathered from interviews with the majority of the leaders at renowned engineering education programs indicate a widespread acceptance of online education, with many institutions expressing an interest in blending online and on-campus

learning; however, reservations about the effectiveness of online learning persist for some (Graham, 2018).

The number of institutions offering the Accreditation Board for Engineering and Technology (ABET)-accredited online engineering programs has seen a significant rise from 11 in 2019 to 40 in 2023, a shift that could be influenced by the COVID-19 pandemic. According to the ABET website, there are currently 66 accredited online engineering programs, including 59 undergraduate and seven master's programs. However, it should be noted that ABET evaluates all delivery methods (on-site instruction, online instruction, and a combination of both) using the same criteria, lacking separate criteria for face-to-face and online delivery, with the definition of online learning remaining ambiguous during the evaluation process. Given the increasing number of online engineering programs and a lack of a well-defined definition of online learning, crucial questions emerge: Do these expanding online programs ensure quality engineering education? Are online engineering instructors adequately trained and supported in designing and teaching online courses?

Enhancing engineering education involves focusing on six critical areas, including interdisciplinary curricula, team-based learning, research-based teaching, academia-industry collaborations, distance learning skills, and support for underrepresented students, with online learning recognized as one of the key components (Mann & Tan, 2021). While research suggests that incorporating new technologies like augmented and mixed reality, along with virtual labs, can enrich the learning experience by providing hands-on skills and practical application of theoretical knowledge in a more accessible, flexible, and cost-effective manner, concerns about faculty preparedness persist in online courses. Thus, the literature recommends adopting online education models, such as the CoI framework, to address these concerns and further enhance student learning (Koclar et al., 2021). These approaches can play an important role in designing and teaching quality online courses.

The CoI Framework for Designing and Implementing Quality Online Courses

Developed by Garrison, Anderson, and Archer (2000), the CoI framework is designed to foster collaborative learning, meaningful discussion, and inquiry-based activities to enhance the quality of online learning experiences. The CoI framework consists of three interdependent components: cognitive presence, social presence, and teaching presence, as shown in Figure 1.

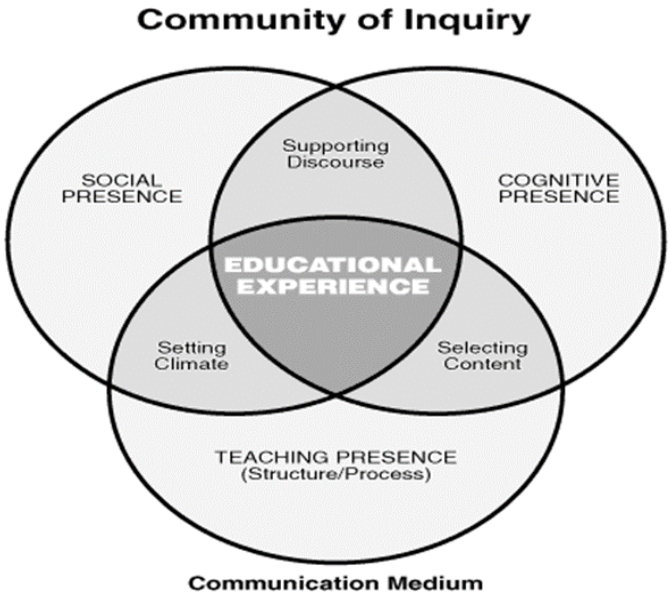
Cognitive Presence

Cognitive presence is "the extent to which learners are able to construct meaning through sustained reflection and discourse" (Garrison et al., 2001, p. 11) and involves four elements. The first element is a triggering event or a stimulus that captures learners' attention and motivates them to engage in further exploration and inquiry. The second element is exploration, which refers to the phase in which learners engage in searching for information or clarification through critical reflection to help understand the initial stimulus (Akyol & Garrison, 2011). The third element, integration, refers to the process of synthesizing and integrating the information using the ideas generated in the exploration phase and constructing meaning (Garrison, 2017). The fourth element, resolution, is the final phase of cognitive presence and is described as an application of new understanding or knowledge to real-world situations, including educational and workplace environments (Garrison, 2017). All categories of cognitive presence work

together to promote higher-order knowledge acquisition and application in which learners engage in critical thinking, reflection, and collaborative knowledge construction.

Figure 1

Community of Inquiry Framework (Garrison et al., 2000)



Research has explored how students engage with each phase of cognitive presence in online environments. Students in the triggering and exploration phases respond to a triggering question and build initial understanding through dialogue, representing lower levels of cognitive presence, whereas integration and resolution involve synthesizing information, reflecting higher-level cognitive engagement (Sadaf & Olesova, 2017). Studies show that triggering and exploration are the most commonly observed phases in online learning environments (Chen et al., 2019; Jo et al., 2017; Sadaf et al., 2021; Shea et al., 2010), while integration and resolution is less frequently achieved, often limited to surface-level exploration (Sadaf & Olesova, 2017; Shea & Bidjerano, 2009). However, some studies report integration as the most active phase (Akyol & Garrison, 2011; Richardson & Ice, 2010). Overall, reaching integration, and especially resolution, is uncommon, with resolution sometimes nearly absent (Moore & Miller, 2022; Vaughan & Garrison, 2005). Factors such as course duration (Akyol et al., 2011), discussion and facilitation strategies, and the types of questions posed in discussions influence the depth of cognitive engagement (Chen et al., 2019; Darabi et al., 2011).

Social Presence

Rooted in the idea that community involves the interests of individuals and groups on a sociological and psychological level reflectively and collaboratively, social presence is defined as a collaborative experience in which learners project their personality socially and emotionally (Garrison et al., 2000; Garrison, 2017). It is established when learners have a sense of acceptance and belonging, perceive others as real, and feel connected in a group environment to achieve meaningful learning outcomes (Garrison, 2017). The first element of social presence is affective

expression. It is defined as the expression of emotion and feelings related to educational experience (Garrison et al., 2000) and includes using emojis, humor, and self-disclosure. Teasing and joking are effective in decreasing social distance and constructing group cohesion in a learning environment. Likewise, sharing experiences and interests with group members aids in establishing trust and lessens the feeling of social isolation. The second element of social presence is open communication (Garrison & Akyol, 2013). It refers to the degree to which individuals communicate openly and respectfully with each other in the online environment. Open communication promotes mutual awareness, recognition of others' contributions, and dialogue among participants. Group cohesion, the third category of social presence, is defined as a sense of belonging and group commitment (Garrison & Akyol, 2013). This includes the connection between individuals and shared values and emphasizes that learning is optimized when learners see themselves as part of the learning community.

Research on social presence has shown a positive correlation with perceived learning (Richardson et al., 2017; Türel, 2016), student satisfaction (Borup et al., 2012; Richardson et al., 2017), and a sense of belonging within a learning community (Delmas, 2017). However, social presence is complex, as its indicators can vary depending on factors such as group size, type of task (e.g., reading vs. project-based), prior relationships among group members, instructor involvement, student needs, and communication styles (Lowenthal & Dunlap, 2020). To foster social presence, studies recommend the use of small group discussions, collaborative and problem-solving tasks to promote group cohesion, meaningful connections between students and between students and instructors, as well as setting course rules such as netiquette for open communication, along with opportunities to share personal information and emotions to support emotional expression and strengthen social presence (Fiock, 2020; Richardson et al., 2012).

Teaching Presence

Teaching presence is a binding element between social and cognitive presence and is described as "the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes" (Garrison & Arbaugh, 2007, p. 163). Teaching presence consists of three interrelated elements. The first one is design and organization, and it is described as the planning and designing of learning activities prior to and during the educational experience, preparation of methods and assessments aligned with the learning outcomes and the needs of the learners and designating time parameters and netiquette. The second element, facilitation of discourse, is concerned with creating a learning environment that maintains participants' interaction, motivation, interest, and engagement (Anderson et al., 2001). The teacher reads and comments on students' posts, encourages less participating individuals to be more active, identifies agreement and disagreement areas, and models netiquette. The third is direct instruction, described as providing learners with subject matter knowledge, feedback, guidance, and support. The teacher presents the course content, identifies misconceptions, guides learners to information resources, and answers students' questions.

Studies have shown that teaching presence positively influences students' learning engagement behaviors in online learning (McNeill et al., 2019; Zhang et al., 2016), fosters deep and meaningful learning (Garrison & Cleveland-Innes, 2005), and enhances perceived satisfaction related to autonomy and competence (Turk et al., 2022). Teaching presence also plays a critical role in supporting the transition from social to cognitive presence (Garrison &

Cleveland-Innes, 2005) and in promoting both social and cognitive presence (Adam et al., 2025; Kozan, 2016). The dimensions of teaching presence account for 45.3% of behavioral engagement, 34.3% of cognitive engagement, and 40.9% of emotional engagement in online courses (Wang, 2022). Direct feedback, effective course organization, and instructor facilitation have been found to support students' critical thinking and help them maintain focus (Hosler & Arend, 2012). Overall, these studies show that course design, facilitation, and direct instruction are closely linked to the development of social and cognitive presence and play a key role in enhancing learner engagement in online learning environments.

Although the CoI framework was developed to be generic and applicable across most educational environments (Garrison, 2023), how it is applied and perceived varies across disciplines due to different values and emphasis associated with each discipline (Richardson et al., 2024). For example, research has shown that the strength of the relationship between social presence and students' perceived learning and satisfaction varies by academic field, with stronger effects found in disciplines such as life sciences and computer skills, followed by education and business (Richardson et al., 2017). Gorsky et al. (2010) found that teaching presence was more prominent among science students than in humanities, where it was almost absent. They also observed that all cognitive presence categories, except for resolution, were commonly found in science courses, and science instructors posted more messages related to exploration than their humanities counterparts. Instructors in the sciences show higher levels of direct instruction, including giving feedback and clarifying misconceptions, whereas humanities instructors place more emphasis on facilitating discourse and encouraging reflection (Arbaugh, 2010).

Reflecting these disciplinary trends, Kim and Gurvitch (2020) conducted a systematic review of research on the CoI framework from 2009 to 2019 and found that the majority of studies focused on education, followed by business, with relatively few studies in engineering, mathematics, and computer science, highlighting a research gap in STEM fields. Research on the CoI framework continues to lag in STEM disciplines, where online courses consistently face high student withdrawal rates (Faculconer & Chamberlain, 2022). In engineering courses, instructors are less likely to share personal beliefs, provide alternative perspectives, or summarize discussions, compared to instructors in other disciplines (Richardson et al., 2024). Students in engineering, information sciences, and mathematics tend to report lower levels of social presence (Lim & Richardson, 2022; Padayachee & Campbell, 2021), with affective expression being particularly uncommon in STEM fields (Faculconer & Chamberlain, 2022). Even within STEM, there are variations. Olesova et al. (2024) found that students in a graduate Data Analytics program reported higher levels of cognitive presence than those in an Applied Information Technology program. Given these disparities and the limited attention engineering has received in CoI research, this study focuses on online teaching practices in engineering through the lens of the CoI framework, an area that remains underexplored.

The CoI Framework in Engineering Education

Given the surge in online engineering courses, an increasing number of studies have begun to use the CoI framework to examine different aspects of online engineering education. Prior work has focused on student perceptions of online learning experiences and the CoI presences (Baytiyeh, 2018; Jaksic, 2021; Lim & Richardson, 2022; Purwandari et al., 2022; Szeto, 2015). Lim and Richardson's (2022) findings revealed that students' perceptions of social

presence varied across academic disciplines. In contrast to students in the social sciences, engineering students did not consider social presence as crucial to achieving learning outcomes; instead, they emphasized the importance of teaching presence. Another study found that teaching presence had a more significant impact on cognitive presence than social presence (Purwandari et al., 2022). Similarly, teaching presence was discovered to have a greater influence on the attainment of learning outcomes than cognitive and social presence, highlighting its importance (Szeto, 2015). These results indicate that engineering students value teaching presence the most.

Other studies have investigated the effects of technology use and self-regulation on the development of cognitive presence (Kovanović et al., 2015) and the impact of feedback on the three presences (Rutz & Ehrlich, 2016). Some have employed the CoI framework to (re)design engineering courses (Cabrera et al., 2017) and to develop educational models and recommendations to increase student satisfaction (Chernosky et al., 2021; Dunlap et al., 2016). As expected, studies on online learning in engineering education have gained momentum, particularly in response to the pandemic. Few studies explored different aspects, such as how engineering faculty supported student success during emergency remote teaching (Douglas et al., 2022), the effectiveness of online discussion forums in fostering a community of learning (Padayachee & Campbell, 2022), and comparisons of different online instructional practices (Beneroso & Robinson, 2022).

Most studies mentioned above employed the CoI framework to investigate student perceptions of the CoI presences, (re)design courses, and promote student learning. These studies predominantly focused on the students' perspectives and used quantitative surveys to explore student learning and their perceptions of online learning. Instructor perceptions and how they design and teach online courses were given limited attention, with only a few studies including interviews with instructors. In these cases, instructor interviews were typically conducted alongside student interviews and were not the primary focus (Douglas et al., 2021; Szeto, 2015). Additionally, some of the courses in these studies were transitioned to online formats during emergency remote teaching without adequate preparation and under time and budget constraints. Thus, there is a major gap in studies exploring how engineering instructors teach quality online courses and how they view the integration of teaching, social, and cognitive elements, if present, in their online courses. The following research question is addressed in the study: What teaching practices do engineering instructors use to establish teaching, social, and cognitive presence within the CoI framework, if any, in quality online courses?

Methods

This study employed a multiple case study design, "a special effort to examine something having lots of cases, parts, or members" (Stake, 2013, p. vi). The primary goal is to understand a specific phenomenon or an issue, which Stake refers to as a "quintain," and how this quintain functions within various contexts. By examining the individual parts or cases of the quintain, a more comprehensive understanding of the whole can be achieved. Each case has its own unique story to contribute; thus, analyzing each case within its specific setting enhances the understanding of the quintain. In this study, each instructor, their teaching background, context, and institution is treated as an individual case. By exploring seven cases in distinct contexts, the purpose is to gain insights into how engineering instructors design and teach quality online courses, comparing their similarities and differences.

Context

In this study, online engineering instructors who designed and/or taught Quality Matters (QM)-certified courses were interviewed. QM is dedicated to ensuring quality online education by reviewing and evaluating online and hybrid courses using its framework and rubric (Quality Matters, n.d.). Its primary aim is to equip instructors with the skills to evaluate courses according to the rubric's standards, grant certification for the quality of online and blended courses in higher education and K–12 settings and offer guidance for improving course quality (Quality Matters, n.d.). A review team, comprising a team chair, one subject matter expert, and an external reviewer, assesses courses using the rubric and provides feedback to enhance the course's quality. QM has documented positive impacts on student learning and satisfaction (Varonis, 2014), and its guidelines are used to develop new online courses and enhance existing ones in engineering programs (Eggleston & Rabb, 2021; Wang, 2018).

We should note that neither of the authors is affiliated with the QM program. The first author participated in a training session on applying the QM rubric and obtained certification. However, apart from this, neither of the authors has submitted a course for QM review or served as a reviewer. In this study, QM-certified instructors were chosen for the interviews due to the strong emphasis on course quality and student learning in their online courses.

Recruitment and Sampling

To identify engineering instructors whose courses were QM-certified (Quality Matters, n.d.), the QM website was manually scoured in September of 2023. This website is regularly updated to reflect newly certified courses. At the time of the review, the website included courses certified between 2019 and 2023. We focused on courses in higher education and carefully reviewed engineering courses certified in 2022 and 2023. This involved sifting through a total of 337 institutions and 1,986 courses listed under higher education.

The courses on the QM website are categorized by subject, and we included all those under the engineering category. This search process yielded 34 engineering courses at the graduate and undergraduate levels. We reviewed and contacted 30 instructors via email for participation in our study (four courses were taught by the same instructors). We reached out to potential participants three times, with approximately one week between each email. Nine instructors volunteered to take part in interviews. However, upon conducting the interviews, we found that two of the courses were not fully online—one was flipped with no online students, and the other was a hybrid course with both face-to-face and online components. As our study exclusively focused on fully online courses, these two were excluded.

Participants

The participants of this study were seven instructors who designed and/or taught QM-certified online courses in engineering in the U.S. These instructors taught in five different institutions across the country. Among them, one was an associate professor, one was an associate teaching professor, two were adjunct professors, two served as assistant teaching professors, and one was a professor and chaired the engineering department, as shown in Table 1. Their educational backgrounds included engineering, computer science, and statistics, with degrees earned from various U.S. universities. Participants were affiliated with departments such

as the School of Engineering, Mechanical and Materials Engineering, Computer and Information Sciences, and Electrical and Computer Engineering.

Participants' institutions encompassed five universities: two very high research-activity universities, two master's universities, and one baccalaureate college (Carnegie Classification, n.d.). Three participants came from a Southeastern university, two from Southern universities, and two from Midwestern universities. Of seven participants, five identified themselves as White, one was White and Hispanic/Latinx, and one was Hispanic/Latinx. Six instructors had taught at least one QM-certified online course at the time of the interview, while one designed a QM course but had not taught it yet.

Table 1

Characteristics of Participants

Pseudonym	Gender	Rank	Current department	Online teaching experience
Albert	Male	Professor & Department Chair	Engineering Department	3 years
Alfred	Male	Assistant Teaching Professor	Mechanical and Materials Engineering	2 years
Carolina	Female	Adjunct Instructor	School of Engineering	4 years
Jean	Female	Assistant Teaching Professor	School of Computing and Information Science	20 years
John	Male	Associate Teaching Professor	Statistics	2 Years
Sasha	Male	Associate Professor	Electrical and Computer Engineering	10 Years
Willie	Male	Adjunct Instructor	Engineering Department	2 years

Case Vignettes

In this section, we offer detailed descriptions of each participant in the form of case vignettes. Vignettes are detailed depictions of scenarios with the goal of uncovering participants' beliefs, emotions, judgments, attitudes, and values regarding particular phenomena (Skilling & Stylianides, 2020). In this study, the vignettes aim to provide background and contextual information about each instructor and their online courses. Pseudonyms selected by participants will be used throughout the rest of the paper.

Case Vignette 1: An Online Engineering Course with a Focus on Economics

Carolina is an adjunct instructor within the School of Engineering at a university located in the Southern region of the U.S. She comes from a systems engineering background and has a total of nine years of teaching experience, the last four of which have been dedicated to teaching online. She is currently teaching an engineering course with a focus on economics. This is a required asynchronous course with approximately 50 junior-level students. Her experience with this course spans nine years, initially conducted in a face-to-face format before transitioning to an online mode for the past four years.

This course is the only QM-certified course she teaches and remains the only QM-certified online engineering offering within her institution. She believes that one impact that the certification process has been on accessibility. Each semester, Carolina welcomes students with disabilities, and the certification has proven useful in enhancing the course's accessibility. In evaluating her comfort and effectiveness as an online instructor, Carolina rates herself at a nine because she recognizes the need for continuous improvement.

Case Vignette 2: An Online Mechanical and Materials Engineering Course

Alfred is an assistant teaching professor with 11 years of industry experience in the mechanical and materials engineering department at a southeastern university in the U.S. His institution is one of the largest Hispanic-serving institutions across the country. Alfred's university requires QM certification for online courses. Faculty receive financial incentives if their courses receive this certification. He has a total of three years of teaching experience, with the last two years dedicated to online course delivery. Alfred is currently teaching a senior-level course, the only QM-certified course he teaches. The course has an asynchronous format with an average enrollment of approximately 60 students.

Reflecting on his experiences, Alfred notes that the certification process has contributed a sense of structure, logic, and alignment with best practices in online teaching. Alfred describes his online teaching approach as creating opportunities for students to connect to real-world applications through the examples he provides and his prior industry experience. On a scale of 1 to 10, Alfred rates his comfort and effectiveness in teaching online at an eight. However, he acknowledges that increased interaction with students and greater input from them could further enhance his confidence and effectiveness in online instruction.

Case Vignette 3: An Online Electrical Engineering Course

Albert is a professor in the engineering department at a Midwestern university and serves as the chair of the same department. His teaching experience spans a period of 28 years. For the past three years, he has been teaching an asynchronous junior-level online course typically attended by approximately 20-25 students. It is a required course for electrical engineering and computer science students.

At Albert's institution, all online courses must undergo the QM certification process if taught more than once. Additionally, in response to the institution's recent launch of an online engineering program and the need to adhere to ABET guidelines, Albert, as department chair, sought to set an example by going through the certification process and observed a noticeable improvement in course quality. Albert rated his comfort and effectiveness in online teaching at 8 and 7, respectively, because of challenges related to the absence of formal online teaching training and limitations in hands-on lab equipment for online lab sessions.

Case Vignette 4: An Online Engineering Course with a Focus on Technology and Ethics

Jean is an assistant teaching professor in the School of Computing and Information Science within the College of Engineering at a university in the southeastern U.S. While she works in the same institution as Alfred, she belongs to a different department. It is a requirement for all online courses to undergo QM certification at her institution. Jean currently has four QM-certified courses. With 30 years of teaching experience, including the last 20 years of online teaching, Jean holds a Ph.D. in educational technology.

Among the courses she currently teaches is one focused on the global impact of technology, an asynchronous course with approximately 60 junior-level enrolled students. Jean's teaching approach is student-centered, emphasizing active student involvement. She places significant importance on building connections with her students, positivity, and enjoyment while teaching, grading, and interacting with students. Jean feels highly confident and effective in her online teaching abilities, rating herself a ten out of ten.

Case Vignette 5: An Online Electrical and Computer Engineering Course

Sasha is an associate professor in the department of electrical and computer engineering at a university in the Southeastern region of the United States. His engineering program has achieved full accreditation from ABET. He has an extensive 20-year teaching background, including 10 years of experience in online teaching. Sasha works at the same institution as Alfred and Jean, and like the other two participants, he mentioned an institution-wide initiative to achieve QM certification for online courses.

In his QM course, Sasha has approximately 70 students. It is an elective course for senior-level students, conducted asynchronously. He strongly values the thoughtful design of online courses and sees his role as an online course instructor overseeing the course content and student activities. According to him, QM makes a significant contribution by setting standards for designing high-quality online courses. Sasha rates his comfort and effectiveness in teaching as a ten out of ten. He attributes this to his structured, pre-planned approach and well-defined roadmap for online course delivery.

Case Vignette 6: An Online Electrical Engineering Course

Willie serves as an adjunct professor at a community college in the Southern region of the United States. In this study, he stands out as the only participant with QM certification at a community college. He has over 30 years of experience in the engineering industry and 13 years of teaching, including two years of online teaching experience. In his QM-certified course, he typically has 12 students, delivering a required course asynchronously.

Willie pursued the certification of this course, positioning himself as a leading instructor in this regard within his department. He characterized his approach to online teaching as one that incorporates students' needs into the online course platform, offering an organized and structured learning experience. Regarding his comfort level in teaching online, Willie expressed complete comfort, rating himself at a ten on a scale of 1 to 10. He emphasized his effectiveness as an online instructor by giving himself a rating of eight, underlining his continuous efforts for improvement in his teaching practices.

Case Vignette 7: An Online Engineering Course with a Focus on Statistics

John is an associate teaching professor at a midwestern University. He has nine years of teaching experience, with two years of online teaching experience. He has developed an online QM-certified course for engineering students, offered at a junior level and conducted asynchronously. This course typically enrolls approximately 60 students.

When it comes to his online teaching approach, John emphasizes the importance of fostering interaction with his students by organizing live meetings and utilizing real-world examples to capture their interest. He rates his comfort level with online teaching at an eight and

acknowledges that further familiarity with technological tools would enhance his confidence in delivering online courses. In terms of effectiveness, he self-assesses at a seven and anticipates that his effectiveness will improve with more experience teaching the same course.

Data Collection

We conducted semi-structured interviews with seven instructors, each lasting between 60 and 90 minutes. These interviews aimed to gather insights into their online teaching practices, and strategies for establishing teaching presence, social presence, and cognitive presence in online courses. Before the actual interviews, each participant completed a demographics survey. Additionally, to ensure the effectiveness of our interview protocol, we conducted a pilot interview with an engineering faculty member who did not participate in the study. We revised the interview questions based on the faculty member's feedback for better clarity.

The interview questions covered various aspects, including the specific context of the courses they taught, their comfort and effectiveness in online teaching, any prior training they had received in online teaching, their motivation for obtaining QM certification for their courses and the ways they establish the three presences, as shown in Table 2. The interview questions related to the CoI framework were informed by the CoI survey. In cases where participants provided short answers or did not fully address a question, follow-up or clarifying questions were asked. All interviews were conducted and recorded using the Webex platform. After each interview, memo writing was carried out to record observations of the events experienced during the interview.

Table 2
Example Interview Questions and Their Categories

Category	Question
Background/Context	For how long have you been teaching online? Can you tell me about the context of the course? How would you describe your online teaching approach as an instructor? How did you decide to get this course QM-certified?
Teaching Presence	Can you tell me about how you planned and designed this course? How do you communicate course instructions, topics, goals, and due dates to students in this course? How do you facilitate student learning and the learning environment? How do you check if your students are understanding the material and provide feedback to them?
Cognitive Presence	How do you make your online courses interesting and encourage students to be curious about the subject? How do you encourage students to search for information, knowledge, and clarification? After students explore information, how do you encourage students to integrate the searched information into course activities/assignments? How do you motivate students to use what they've learned outside of class?
Social Presence	How do you make sure your students feel included and valued in the course? How do you encourage your students to express themselves personally and convey their values?

	Can you tell me how you create a safe and open environment for students to interact with each other? How do you encourage collaboration among your online students?

Data Analysis

This study included seven cases involving online instructors and their specific teaching environments. To ensure the accuracy and completeness of our analysis, we used verbatim transcripts from Webex and read through all of them while simultaneously listening to the recordings to ensure there was no missing information and that the recording and the transcript matched. Our first approach followed Saldaña's (2016) structural coding method, which allows researchers to assign conceptual labels to a portion of data related to specific interview questions used during the interviews. For instance, we had main codes, such as social presence, cognitive presence, and teaching presence, each further broken down into sub-codes, such as design and organization, facilitation, and direct instruction, all elements of teaching presence. This structural coding process helps identify significant text segments, which serve as the foundation for more in-depth analyses within or across various topics (Saldaña, 2016).

After labeling the seven transcripts using structural coding, we thoroughly examined all transcripts. After structural coding, we employed open coding for further data analysis. This process also involved developing in-vivo codes using the exact words of the study participants. We used the elements of the CoI framework to label the main categories in the codebook; however, we remained open to participant responses to authentically elicit their teaching practices under these categories, which are listed as key findings in Table 3. We identified the similarities and differences between participant responses and refined or rephrased some codes after carefully examining the transcripts through several iterations.

Trustworthiness

To ensure trustworthiness, we implemented various strategies as recommended by Lincoln and Cuba (1985). Initially, the first author coded the transcripts, while the second author independently reviewed and examined the coded transcripts to address any inconsistencies. To enhance the credibility of our findings, regular peer debriefing meetings were conducted on a weekly basis. These sessions not only fostered consistency but also served as a platform for resolving any disagreements between the authors. In addition, we actively engaged in member checking to validate the accuracy of our data. This involved sending the completed manuscript to the participants via email, seeking confirmation from them, and providing an opportunity for them to identify and correct any potential errors. Some participants responded with recommendations, and we incorporated their feedback, making necessary corrections to improve the overall accuracy of the research.

To enhance the transferability of our findings, we incorporated thick participant descriptions through case vignettes and presentation of results. These detailed descriptions provided rich insights into the backgrounds and experiences of the participants, shedding light on how they design and deliver online courses. For increased confirmability, both authors maintained a reflective stance throughout the research process. The first author has experience as an instructional designer and has been actively involved in developing online courses. The second author, a faculty member in educational technology, has extensive experience as an

online instructor and course developer, utilizing the CoI framework in her research. Throughout the research process, we were mindful of the potential impact of our positions and backgrounds on the investigation.

Results

In this section, we present our findings on the practices of engineering educators regarding the integration of teaching, social, and cognitive elements within quality online courses. We organize the participant responses according to each presence and their respective components. Table 3 summarizes the key findings.

Table 3
Key Findings of How Instructors Establish the Three Presences in Online Engineering Courses

Strategies used to establish cognitive presence	**# of occurrence**	**Strategies used to establish social presence**	**# of occurrence**	**Strategies used to establish teaching presence**	**# of occurrence**
Triggering Event		*Affective Expression*		*Design and Organization*	
Link assignments/examples to real-world	6	Use of humor (GIFs, comics, jokes)	5	Maintain consistent course structure	7
Add an element of fun and engagement into assignments	2	Share personal information (hobbies, likes and dislikes)	2	Welcome students to the online course	6
Build well-structured courses	1	Emojis	2	Send weekly 'to do' emails	5
Build well-structured courses	1	Listen to students' feelings and try to help out	2	Be available for student inquiries on multiple channels in a timely manner	5
Create personalized lecture videos	1	Use of visuals	1		
Exploration		*Open Communication*		*Facilitation*	
Encourage students to use outside resources	5	Netiquette statement in the syllabus	3	Monitor discussion forums and grades	4
Provide additional learning	3			Encourage student participation and a positive learning environment	2

resources on course site					
Encourage students to ask questions	1				
Integration		*Group Cohesion*		*Direct Instruction*	
Require students to cite outside resources when submitting assignments	3	Respect their preferred names	2	Assess student progress	7
		Discussion boards and collaborative projects	1	Provide feedback	7
		Inclusivity statement	1		
Resolution					
Provide real-world examples	3				
Design hands-on activities	3				
Share career stories	2				
Emphasize the link between skills taught and students' future careers	2				

Note. The numbers provided in the table represent the number of participants who used each strategy.

Cognitive Presence

Triggering Event

To capture students' attention and enhance engagement, instructors employed diverse strategies. The approaches included linking assignments and examples to real-world scenarios, injecting an element of fun into assignments, designing well-structured courses, improving the effectiveness and engagement of lecture slides, and creating personalized lecture videos.

A predominant theme among six instructors was the integration of real-world examples into their online courses to establish relevance for students as Albert stated, "When I'm discussing a topic, I always explain how that topic is applicable to something in real life. Like, a television, how this certain algorithm would work. I think that gets the students interested." John and Jean stressed the significance of connecting examples to students' interests, stating that relevance sparks curiosity. Alfred underscored the value of relating course content to real-life scenarios, drawing on his industry experience and allowing students to select project topics aligned with their interests.

Carolina and Jean focused on adding a fun element to assignments to sustain student interest. Jean employed online quizzes such as Kahoot to enhance engagement. Carolina used surveys to find out students' movie and TV preferences, incorporating related examples into problem-solving tasks. Similarly, Jean incorporated an engaging approach by having students watch a movie and using it as a scenario for assignments. She shared:

> After the last Jurassic Park movie came out, I had them do a little research on dinosaurs, they did the inheritance based on urban version carnivores, and then they basically did a small dino- family tree of a couple levels. It was fun because it kind of connected with something cultural.

Additionally, Sasha emphasized the importance of a well-structured and organized course, stressing the need for guidance throughout the week to maintain student motivation. Willie enhanced engagement by incorporating elements like animations into PowerPoint slides. Carolina created personalized lecture videos instead of relying on generic content from platforms like YouTube. This yielded benefits, as evidenced by the student feedback that she shared. Students appreciated the ability to rewind and rewatch the videos, which contributed to increased interest in the subject matter and overall course engagement. Overall, instructors predominantly utilized real-world scenarios and introduced elements of fun to enhance course appeal and capture students' interest.

Exploration

Instructors used three methods to encourage students to search for information or clarification and understand the course content, which included encouraging students to use outside resources, incorporating additional learning resources into the course learning management system (LMS), and creating a learning environment where students feel comfortable asking questions. Five instructors specifically encouraged students to use outside resources, such as books and journals, to supplement their understanding of the course material. Alfred, for instance, mentioned that students often approach him seeking additional data, and he acts as a guide by directing them to specific journals. Sasha and Alfred both recognized this approach as a valuable means of fostering student independence, encouraging autonomy and self-directed inquiry in the learning process.

The second method employed involved providing supplementary learning resources within the course LMS. This included integrating extra links to tutorials, reading materials, and websites, offering students additional venues for learning information. Albert noted the existence of a folder on the course site containing materials, such as examples of lab reports and reference guides, providing students easy access to course-related documents and outside resources. Similarly, Sasha emphasized the foundational knowledge gained while encouraging students to seek additional resources for a more comprehensive understanding. Sasha remarked, "By using additional resources, they can augment that knowledge. It might clarify for them and might give them a deeper understanding. It might also even broaden their understanding because it might interject additional items that I might not have covered."

Another strategy employed to promote exploration involved encouraging students to pose questions. Among the instructors, Carolina was the only instructor taking this approach, highlighting the creation of a supportive environment for student inquiries through forums and emails. Carolina facilitates a comfortable atmosphere by allowing anonymous postings on the course forum pages, aiming to foster confidence in students to ask questions, seek new information, or clarify questions.

In contrast to other instructors, John did not employ the mentioned methods; however, he expressed his willingness to encourage exploration when students seek help during office hours or discussions, primarily on a case-by-case basis. Overall, the responses from instructors indicate

that the methods employed were to guide students to use external resources, incorporate additional learning materials into the course LMS, and motivate them to ask questions.

Integration

Instructors' responses revealed that three instructors, Jean, Alfred, and Sasha, actively support the integration of information into course assignments. Jean takes an approach by encouraging her students to watch a relevant movie, conduct research on its characters, and connect it to the assignment. Similarly, Sasha and Alfred encourage students to cite external sources when incorporating information into assignments, emphasizing responsible and accountable integration. Additionally, Sasha expressed openness to incorporating valuable student-found resources into the course to enhance the learning experience.

The other four instructors noted that due to the technical nature of the course content, there is limited opportunity to integrate searched information into assignments. Willie stated, "Since this is basically a subset of physics, the resolution of criteria for the course is kind of cut and dried. You might have to do that with things like social issues, but in this particular field, not so much." These examples illustrate that the majority of instructors do not encourage the integration of information into course assignments due to the nature of the course subject.

Resolution

Instructors employed four different ways to encourage students to apply new knowledge to real-world situations, including providing real-life scenarios, designing hands-on course activities, sharing their personal career stories, and emphasizing the link between the skills taught in class and students' future professions. Carolina, Jean, and Alfred used real-life scenarios to motivate students to apply their acquired knowledge beyond the classroom. They achieved this by connecting the scenarios to students' personal lives and demonstrating everyday relevance. Their goal was to emphasize that the knowledge gained in class is theoretical but can be applied to everyday situations, highlighting the practical value and relevance of what students learn.

Another approach was the design of hands-on activities that mimic professional workplace scenarios. For instance, Jean, Alfred, and Willie indicated that they structure course projects to encourage students to apply their knowledge to real-world settings. Willie further elaborated on this approach, stating that he allows students to choose project topics aligned with their interests, extending the application of their learning beyond the classroom. Additionally, Alfred pointed out that discussion forums play a role in helping students reflect on how the knowledge gained in the course can be directly applicable to their own work.

Albert, drawing from his past experience in the industry, noted that he uses stories from his own career as a motivational tool. Through these anecdotes, he aims to underscore the significance of specific skills in professional settings. Similarly, Alfred shared that he tries to be a role model for students, leveraging his industry experience to guide them, emphasizing the relevance and importance of what they learn in class within the workplace.

The final approach involved explaining to students the connection between what is learned in class and their future careers. Sasha and John used this strategy, emphasizing to students that the skill sets acquired through the course would be essential in their field when seeking employment. These approaches collectively highlight that instructors employ different

methods to demonstrate to students the relevance of the course material to their future careers through underscoring the real-world applicability of acquired skills and incorporating hands-on activities and real-world scenarios for practical application and reinforcement of learned concepts.

Instructors' responses revealed diverse strategies to foster cognitive presence within their courses. They employ a variety of methods to enhance engagement and sustain students' interest. Encouraging the utilization of external resources and highlighting the real-world applications of course topics and assignments are common practices among these instructors. Our findings indicate that integration is the least used component of cognitive presence. Instructors attribute this to the technical and non-subjective nature of the course content. The majority of instructors do not encourage integrating researched information into assignments; however, they express openness to incorporating external resources into their courses.

Social Presence

Affective Expression

Instructors employed five strategies to foster students' affective expression. These included the use of humor, sharing personal information, emojis, listening to students' feelings and encourage them to express feelings, and use of visuals. While these methods reflected instructors' own emotional expression, they were primarily used to model affective behavior and invite students to feel comfortable engaging emotionally in the online classroom.

Most instructors emphasized the use humor to convey feelings and build relationships with students, encouraging them to express themselves more freely. Carolina, for instance, used GIFs and shared personal information to create an emotionally open environment. She explained:

> I like to use humor, I put like the GIF so that they don't feel like I'm this very like serious person that they cannot like, kind of like, look approachable. But also, my introduction, I put it in a funny way. This is what I like, my degrees, but then I turn to the dark side after graduating, and I put fun things like, Oh, I like Mac and cheese or fun facts.

Jean also created space for affective engagement by beginning her weekly announcements with personal reflections and references to common experiences like the weather or weekend events. Her goal was to normalize emotional expression and encourage a connection between students and herself and among students. She used emojis intentionally, acknowledging their role in conveying warmth and tone in the absence of physical cues. According to Jean, this modeling helped students feel more comfortable opening up, asking questions, and connecting with one another. She elaborated:

> You have to be very deliberate in the online environment. Things that you naturally do like when you walk into a classroom and you smile, right, it makes connections organically, you don't have to think about should I smile, right? In the online environment, they can't see you smile. So, I use lots of emojis.

Similarly, Alfred incorporated comics as part of his humor strategy and viewed discussion forums as a platform for students to come out of their shells, interact with others, express feelings, and share personal information. In contrast, Sasha used light humor occasionally but did not actively encourage personal sharing or emotional expression among

students, attributing this to his identity as an engineer, noting, “I do not use emojis, if I do, it’s, you know, very light humor, but not very often. I don’t know maybe because we’re engineers, but there’s not a whole lot of personal information sharing.”

To further support affective expression, instructors provided structures that encouraged emotional sharing. Welcome forums and introductory videos were used to invite students to share personal interests and concerns. Carolina reported responding empathetically to students who expressed anxiety about taking their first online course, modeling emotional openness and validating their feelings. She also encouraged them to share visuals in the Q&A forums, such as pictures of their work or anything they found challenging to understand and noted that students often included respectful emojis in their email communication.

Listening to and acknowledging students’ emotions was another way instructors supported affective expression. Alfred described scheduling one-on-one meetings when students expressed distress, while Jean encouraged students to openly share when they were confused or lost. By reinforcing that no question was “dumb” and validating students’ emotional reactions, these instructors aimed to encourage students to openly share their feelings, assuring them that there will be no judgment. Jean shared:

> You gotta tell me what that look on your face is, right? Is it that you’re bored, or did I say something, and have no idea what I’m saying? I try to help them overcome that because once they feel like they can ask questions without fear of judgment, they tend to be much more forthcoming.

However, some instructors encountered challenges in supporting affective expression due to the nature of their course content or the limitations of asynchronous delivery. Albert, for example noted that the highly technical nature of his course, characterized by numbers and codes, left limited room for emotional interaction. Similarly, Willie described difficulty fostering emotional connections in his asynchronous course, observing that students interacted infrequently with him and other students. This indicates that, while some instructors do not prioritize affective expression due to the technical nature of the course content and the challenges associated with an asynchronous format, others employ various methods to encourage students to express their feelings.

Open Communication

To establish open communication and a risk-free learning environment, some instructors added a netiquette section to their syllabi to encourage respectful behavior among students. Willie shared his practice of using the statement provided by his institution to create a safe online environment. He emphasized that, given the absence of interactions between students in his course, there is little opportunity for bullying or an unsafe environment to develop. In line with Willie’s approach, Albert explained that the absence of online discussions also eliminated the opportunity for any unsafe environment to arise. On the other hand, John used his institution’s netiquette and developed an orientation module for his students. This module instructs them on how to behave in an online class and how to conduct themselves appropriately.

Group Cohesion

Students do not engage in collaborative and interactive assignments in six of the courses examined in this study. Although instructors encourage collaboration, the prevailing expectation

is that students complete and submit assignments individually. For instance, John mentioned that he provides a disclaimer that allows students to collaborate with others on assignments, but they must independently write up their solutions. This tendency may arise from instructors' challenges in assessing whether all team members contribute equally to collaborative projects. Likewise, Sasha mentioned that he used to include a group project in his course before QM certification. However, in the certified course, he eliminated it to ensure that all students are actively learning. He explained, "If students work together, I have no problem with that. What I don't want is one student doing the work and the other ones, just kind of watching. I want the learning process to occur for everybody."

The nature of the course and its content also influenced whether instructors incorporate collaboration. John explained that his course follows an individual learning approach, with students tackling problems that typically have a single answer. While he desires to introduce a more team-based approach, he has not yet found a way to implement it. Alfred noted that he assigns group projects to students in regular semesters, but in his summer class, time constraints make it more challenging to integrate such projects. These examples underscore that factors such as course content, concerns about the balanced distribution of work in team projects, and the course duration impact instructors' decisions regarding collaboration.

Jean was the only instructor who had her students work together to learn the course material, including having students work on a real-world project in teams and interact through discussion boards. She believes designing such group projects in an asynchronous environment is more challenging for instructors. Students tend to favor multiple-choice assessments over group work because they find them easier. However, Jean sees value in student collaboration. Addressing the concern about students not contributing equally in teams, as discussed earlier, Jean mentioned that she has each team member evaluate the performance and contributions of their peers and assigns points accordingly. Furthermore, to foster a sense of community in her course, Jean has students introduce themselves at the beginning of the semester. This practice helps students get to know their classmates better and allows for personal connections between Jean and her students when she responds to their posts.

Beyond collaboration, instructors also emphasized the importance of inclusive learning environments. Sasha, recognizing the diverse nature of his student body, added an equity, diversity, and inclusion statement to his syllabus. He also proactively monitored student responses and behavior to ensure that inappropriate language or behavior is addressed promptly. Similarly, Alfred and Albert expressed their commitment to maintaining a safe learning environment. They mentioned that they are prepared to intervene if they ever notice interactions going in the wrong direction, although such situations have not arisen thus far.

Jean places great emphasis on empowering students to find their voice in her class. She achieves this by asking students about their preferred names and hobbies, addressing them by their chosen names. Jean assures her students that there are no "dumb" questions in her class and encourages them to ask questions without fear of judgment. Like Jean, Alfred further emphasized the importance of allowing students to express themselves freely and respecting their choices regarding how they wish to be addressed.

In summary, we found various practices instructors use in online classes to establish social presence. Of the three components of social presence, collaborative and interactive assignments received the least emphasis from instructors.

Teaching Presence

Design and Organization

Instructors adopted similar approaches regarding the design of the online learning environment and course activities. These included maintaining a consistent course structure and availability for student inquiries through multiple channels, welcoming students to the online course, and sending weekly "to do" emails. All instructors highlighted the importance of maintaining a uniform structure throughout the course, ensuring consistency in the layout for each module. For instance, John shared that he outlines course-level and module-level learning outcomes on the course site, arranging all course materials into groups for enhanced student navigation. Willie specified his approach, stating, "There's a set of pre-lecture review questions. Uh, there is the lecture itself and then there's some post lecture review problems. And then there's labs that will validate everything will also be unit tests. And a final exam." All instructors adopted a similar method to Willie, maintaining a standardized module structure for a cohesive learning experience.

Several instructors emphasized accessibility considerations. This involved incorporating features such as alt text for images, captions for lecture videos, and the use of suitable colors. Many admitted that they had not given much thought to these aspects, and integrating accessibility requirements was a learning curve during the course design process. While instructors are expected to follow a consistent course structure and address accessibility due to QM certification requirements, it is noteworthy that they also gained new insights during this process. This learning experience suggests that instructors actively expanded their understanding beyond merely adding materials to their LMS, a knowledge gain they are likely to apply in future online course designs.

Five instructors emphasized the significance of their availability to students, providing various communication channels to address questions and offer assistance. They encouraged students to arrange online or in-person meetings, including virtual office hours. In addition to accessibility, these instructors underscored the importance of responding promptly to student inquiries. Sasha, for instance, expressed his commitment to quick responses as follows:

> I tend to respond rather quickly because many of my students will work because we're a computer school and they'll be doing homework like on a Saturday. If I respond to them on Tuesday who cares by that time. So, I think trying to respond to their questions in extremely timely manner is a huge advantage.

Welcoming students to the online course, either through synchronous meetings or introductory videos recorded by instructors, emerged as a common method to enhance the organization of the course. Sasha, for example, incorporates synchronous meetings at the beginning of the semester along with a welcome video on the LMS to discuss course expectations and orient students. He also holds synchronous review sessions to actively engage with students, address their concerns, and clarify expectations. Similarly, John values the opportunity to have live sessions with students, considering it a chance to be present as an instructor.

Five instructors—Carolina, Willie, John, Jean, and Alfred—indicated that they regularly send weekly emails to students, typically at the start of a new module. These emails

communicate reminders, highlight upcoming assignments, and outline upcoming week expectations. John, for example, emphasized that his emails aim not only to remind students of upcoming assignments but to establish a sense that "there is someone behind the screen," fostering support for students. Similarly, Jean stated:

> My announcement starts out with happy Monday, and then I use something personal, but not like super personal, like, what happened over the weekend, and then I tell them a little bit about what they can expect for the week and then a reminder again, of, I'm always here to help.

Facilitation

Instructors acknowledged the increased difficulty of facilitating the learning environment in an online setting compared to face-to-face interactions. To address this challenge, they employed various strategies, including monitoring the learning environment and fostering student participation and a positive learning atmosphere.

Willie, John, Alfred, and Carolina shared their practices of regularly checking the learning environment, specifically discussion forums and the grade center, to track student participation and assignment submissions. In cases where they identified students who had not submitted assignments or showed inactivity, they reached out via email to inquire about their well-being and offer assistance. Despite the constraints of handling a considerable number of students and additional teaching responsibilities, they acknowledged their commitment to monitoring student interactions and providing responses, recognizing the importance of staying engaged with the online learning community.

Albert and Alfred acknowledged the varied pace at which students progress in online courses, citing instances of some students completing all course materials ahead of their peers. They emphasized recognizing and accommodating these differing learning paces in monitoring student learning. Alfred specifically addressed the challenge of detecting cheating in an online course. When identifying instances of cheating, Alfred engages in conversations with the students involved as part of addressing the issue.

Jean and John emphasized the importance of fostering a positive learning environment, acknowledging the complexity of the subject matter and the potential challenges students may face in understanding it. Jean was the only instructor whose course included collaborative activities and assignments. She ensures equal opportunities for all students to contribute during these interactive sessions by actively facilitating the learning environment. When certain students dominate discussions, Jean expresses gratitude for their input while actively encouraging less participating students to become part of the conversation.

Direct Instruction

To check student understanding and offer feedback and guidance, all instructors engaged in two key practices: (1) evaluating student progress and (2) providing feedback. Grading assignments emerged as an important tool for understanding student advancement and their grasp of the material. Carolina, for instance, takes a personalized feedback approach, focusing on highlighting areas of improvement rather than simply categorizing answers as right or wrong. She encourages students to schedule online meetings to discuss the feedback further and address any questions they may have. Jean employs detailed rubrics for discussion forums and

assignments to ensure precise feedback. Many instructors use multiple-choice questions for assessing learning, using automated grading within their LMS. For those incorporating open-ended questions, they make it more personalized. Jean follows a "feedback sandwich" model, beginning with positive feedback, providing constructive critique, and concluding with additional positive feedback. Overall, assessing student learning and providing feedback were the two major methods instructors used to enhance direct instruction.

In summary, we observed similar approaches to course design, likely influenced by the expectations of the QM certification process. Instructors recognized facilitation as a challenge in online courses. This was accomplished by ensuring their availability to students, promoting active participation, and actively monitoring the learning environment. To check student understanding, they concentrated on assignments and assessments, delivering constructive feedback.

Discussion

This study examined the teaching practices of online engineering instructors to establish cognitive, social, and teaching presence in their QM-certified online courses. The identified strategies for establishing teaching presence, such as sending weekly emails, being available, maintaining a consistent course structure, assessing progress and providing feedback, were consistent across all instructors. This shared approach can be attributed to the assistance provided by instructional designers and the expectations to adhere to QM guidelines and rubrics during course design.

However, fewer instructors employed facilitation strategies, often citing the difficulty of doing so in an online setting. This may be due to disciplinary norms, as facilitation is generally less emphasized in hard disciplines like engineering, where knowledge transmission from the content expert is prioritized over free-ranging nature of knowledge development (Arbaugh et al., 2010). Yet, facilitation plays a critical role in engineering education, particularly in problem-based learning environments, by guiding the problem-solving process and modeling effective problem solving approaches for students (Arena et al., 2021). Facilitation has been shown to positively impact key aspects of the engineering design process, such as enhancing psychological safety and reducing perceived task load during idea generation (Murphy et al., 2023). When facilitation is absent or weak in science classes, both social and cognitive presence suffer (d'Alessio et al., 2019). Given the hands-on nature of STEM disciplines, which often involve not only facilitating online classrooms but also managing online labs, it is essential to prepare STEM educators for the challenges of facilitating in virtual environments.

To foster cognitive presence, instructors used diverse methods to enhance course engagement and relate course materials to real-world applications. These efforts primarily targeted the early phases of cognitive presence, triggering events and exploration, aligning with prior research that found these two dimensions particularly common in STEM courses (Faulconer & Chamberlain, 2022). Contrary to earlier work suggesting that resolution is rarely achieved, especially in shorter courses or when students are new to the subject matter (Moore & Miller, 2022), our findings indicate that some instructors did incorporate resolution practices.

One area of cognitive presence that received the least attention was the integration of externally sourced knowledge. Most instructors, while supplementing their courses with additional resources within the LMS, believed the provided textbook and their generated

materials were sufficient. Such decisions may stem from the technical nature of the engineering courses, which typically do not necessitate reliance on external information. This finding is consistent with prior research suggesting that integration and resolution may be less prominent in hard applied disciplines because these fields often emphasize the acquisition of knowledge and expert-delivered solutions rather than open-ended exploration and constructive nature of knowledge building (Arbaugh et al., 2010). However, other studies have shown that integrating external resources in engineering courses can enhance learning outcomes (Maclaren, 2018).

In this study, three instructors employed strategies to encourage integration, while four did not. Because participants taught different engineering courses, these variations may have influenced their instructional decisions. This echoes previous findings of variation in cognitive presence across different STEM disciplines (Olesova et al., 2024). Additionally, two of the instructors who promoted integration had 10 and 20 years of online teaching experience, while another had significant industry experience. This supports prior findings that STEM instructors with industry backgrounds tend to incorporate more examples of industrial applications to formulate course structure and that their industry background influences their teaching practices (Hu et al., 2019), which may encourage students to seek and apply external knowledge. Still, further research is needed to better understand the impact of teaching and industry experience on how instructors foster cognitive presence in online engineering education.

Limited student interaction in six of the courses, along with a reliance on multiple-choice assessments, may also have contributed to the limited emphasis on resolution and particularly integration. Prior research has shown that collaborative activities and reflective assessments are important for supporting higher levels of cognitive development within the CoI framework (Garrison et al., 2000; Kanuka & Garrison, 2004). Most instructors cited the practicality of using multiple-choice formats due to large class sizes, which may have influenced their assessment choices and reduced opportunities for deeper forms of cognitive engagement.

A notable finding from the study is the limited emphasis on social presence, particularly in terms of group cohesion. In six of the seven courses, collaborative activities were minimal and often limited to introductory posts or optional interactions in help forums. This finding aligns with Gorsky et al. (2010), who reported that group cohesion tends to be lower in the sciences, while open communication is more common compared to the humanities. Participants in this study may have encountered difficulties in monitoring and facilitating group work, possibly due to concerns about unequal student contributions or challenges in assessing individual performance within teams, as some instructors noted. These concerns echo those reported by Richardson et al. (2024), who found that engineering instructors often worry about academic dishonesty and view their courses as offering limited opportunities for collaboration.

In this study, several instructors placed limited emphasis on social presence in their courses, which may help explain the lower levels of social presence reported among engineering students in previous research (Lim & Richardson, 2022). When instructors do not intentionally foster practices that promote social connection, such as collaborative activities or affective expression, students may not perceive these elements as important to their learning. Instructors' beliefs about engineering, along with how they were taught as students, may also have influenced their teaching practices, including the extent to which they emphasized social presence (Kim et al., 2013; Tekmen-Araci & Mann, 2019).

The limited emphasis on student collaboration may also stem from broader challenges inherent in teaching engineering online. Engineering faculty often have limited experience or training in facilitating and assessing teamwork, and supporting effective collaboration in virtual environments requires significant time and effort (Lingard & Barkataki, 2011). This underscores the need for greater faculty support in guiding team-building activities and in fostering communication among students (Belanger et al., 2021).

Similarly, affective expression, including sharing feelings and personal information, emerged as another aspect of social presence receiving less attention, echoing the findings of Faculconer and Chamberlain (2022), who noted that affective expressions are particularly uncommon in STEM. Science classes are often viewed as emotionally neutral spaces that prioritize objectivity, logic, and detachment over emotional expression (Pierson et al., 2023). However, emotional expression in engineering education has been shown to play a vital role in advancing social justice, problem-solving, student development and retention, ethics, and diversity and inclusion (Lönngren et al., 2023). The limited attention to emotional expression observed among participants may be attributed to the technical nature of their courses, which often focus on numerical analysis, coding, and single-solution problems. Additionally, engineers typically perceive their work as rational, beyond emotion, scientific, and focused on technical solutions for real-world issues (Cech, 2018). These disciplinary norms and the instructors' own identities as engineers may have contributed to the observed underemphasis on this aspect of social presence.

Implications for Practice

This study offers practical implications for online instructors in engineering and other STEM fields. One key implication is the need to support the higher phases of cognitive presence, especially integration and resolution. Instructors can foster integration by designing prompts and assignments that require students to connect ideas across modules or apply concepts in course contexts. Encouraging resolution can involve incorporating real-world problems or project-based learning tasks where students can apply what they have explored to problem-solving or decision-making activities.

Findings also suggest that instructors benefit from collaboration with instructional designers, especially in designing well-structured online courses. Departments and online learning centers should continue providing instructional design support during course development, regardless of whether the course is pursuing QM certification. Instructors reported that they learned valuable practices, such as adding alternative text, designing for accessibility, and organizing course content more effectively, through working with instructional designers. This emphasizes the broader benefit of such support beyond formal certification process.

The study further highlights that instructors often face challenges in facilitating online environments and tend to avoid collaborative assignments due to concerns about unequal participation or course logistics. To address this, professional development opportunities could be designed to help instructors build strategies for effective facilitation. Likewise, sharing models of successful collaborative activities could encourage more instructors to integrate peer interaction into their course designs, which could strengthen social presence.

Finally, modeling affective expression, creating spaces such as welcome forums and reflective check-ins can enhance social presence and engagement. Instructors can enhance

students' affective expression by intentionally modeling emotional openness, such as using humor, personal stories, emojis, or visual communication and by creating opportunities for students to share their own experiences and concerns.

Overall, the findings emphasize the need for professional development that goes beyond instructional design to include facilitation techniques, strategies for fostering higher levels of cognitive presence, promoting collaboration among students, and encouraging emotional expression. This is particularly important for faculty from traditionally lecture-driven disciplines such as engineering, where these practices may not be emphasized in standard instructional practices.

Limitations

This study was limited to seven engineering instructors, which does not fully capture the diversity of practices across different institutions, disciplines, and courses. While the multiple case study design provides rich, contextualized insights into online teaching practices in engineering education, the findings are not generalizable but instead offer in-depth insights from a specific group of instructors. The comparison of commonalities and differences across instructors may have been constrained by variations in institutional contexts, teaching styles, or course content and format, which could limit the ability to draw broad conclusions. Participants were selected based on their experience with QM-certified courses, which may have led to a sample of instructors who are more familiar with course design standards than typical faculty. Additionally, the study relied on self-reported data through interviews, which may reflect personal bias. While the CoI framework provided a useful lens for analyzing teaching practices, it is also important to note that instructors were not trained in or asked about the CoI framework, and their practices were interpreted through this lens by the researchers.

Recommendations For Future Research

Future research should explore online teaching approaches among engineering instructors in a broader range of contexts to gain a more comprehensive understanding of effective practices. Expanding the sample to include a more diverse group of instructors can provide deeper insights into how quality online engineering courses are designed and delivered. In addition, incorporating student perspectives on the effectiveness of these courses and measuring learning outcomes can further enhance our understanding of effective online teaching strategies in engineering education. Research should also examine how instructors approach online teaching across different delivery formats, such as synchronous and blended environments.

As the Community of Inquiry (CoI) framework continues to evolve with the inclusion of elements such as learner presence and emotional presence (Honig & Salmon, 2021; Majeski et al., 2018), future research can benefit from incorporating these additional dimensions to enhance our understanding of online teaching practices in engineering education. Additionally, exploring alternative frameworks for assessing the quality of online teaching may offer valuable insights into identifying effective online teaching methods in engineering education.

Conclusion

This study examined how engineering instructors design and deliver quality online courses and implement cognitive, social, and teaching presence, if applicable. We conclude that

certain elements of social presence receive comparatively less attention in online engineering courses. The use of the CoI framework has been relatively new in engineering education, and its adoption to explore instructor approaches to online teaching remains limited. Thus, this study contributes to the field by using the CoI framework to investigate engineering instructors' educational practices and methods in quality online courses.

Declarations

The authors declare no competing interests with respect to the research, authorship, and/or publication of this article.

The study was conducted in accordance with the ethical standards and received approval from the university's Institutional Review Board.

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