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Evaluating Community of Inquiry's effectiveness in online Science Instruction

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ABSTRACT

The Community of Inquiry (CoI) framework has emerged as a pivotal model for online science instruction during the global shift to remote learning from 2020–2022. This meta-analysis evaluated its impact on academic achievement and students' behavior by systematically examining published articles (N=798) using Harzing's Publish or Perish© adhering to PRISMA© protocol. Effect sizes were calculated through Hedges' g and Random Effects Models, with heterogeneity evaluated using τ^2 and Q-statistics. The findings revealed a significant pooled random effect size (ES = 1.188, $p < .0001$), demonstrating a significant effect on academic achievement (ES = 2.026, $p = .097$) and a medium effect on students' behavior (ES = .611, $p = .0001$). CoI demonstrated significant potential in fostering meaningful academic and behavioral improvements in online learning, highlighting the need for targeted strategies to optimize its benefits and further explore its varied impact across diverse educational contexts.

Keywords: Community of inquiry, effect size, online Science instruction

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Introduction

Regarding online instruction, educators constantly examine their beliefs about what creates a successful and captivating learning environment (Yan et al., 2022). The Community of Inquiry (CoI) framework has been widely acknowledged as a valuable tool for cultivating such environments (Ling, 2022). Scholars have shown a growing fascination with CoI, as it possesses critical attributes that greatly enrich students' learning journey (Kim & Gurvitch, 2020; Yu & Li, 2022). The CoI framework significantly impacts teaching and learning realms. Research indicates that it contributes to achieving learning goals (Sun & Chen, 2016), enhances student satisfaction (Lee et al., 2021), improves academic performance (Shea et al., 2012), and fosters metacognition and self-regulation (Yu & Li, 2022).

Considering the extensive research conducted by ElSayad (2023), it is evident that there needs for more information regarding the efficacy of CoI in online science instruction amid the peak of online learning delivery. Dy et al. (2021) argued that a diverse approach has arisen to provide pertinent online classroom instruction during this time. In particular, the online learning environment posed substantial deficits due to decreased curricular material, insufficient student involvement, and comprehensive performance evaluation (Dizon & Errabo, 2022). It raises issues and concerns about the quality and equity of learning (Errabo et al., 2021). Likewise, this era also presented opportunities for online education, where students can gain knowledge and skills flexibly and conveniently (Briones et al., 2023).

Hence, it emphasizes the importance of solid instructional frameworks. This study addresses this void by comprehensively analyzing pertinent research articles in online science instruction during the pandemic. This analysis aims to delve into the random effect sizes, offering valuable and cross-sectional insights into the effectiveness of the CoI framework in this crucial context.

Theoretical Framework

In 1999, Garrison et al. introduced the CoI framework, which aims to promote profound learning by emphasizing social, cognitive, and teaching presence. CoI is the interdependence between critical community actors' interactivity, trust, expectations, values, and beliefs (Rovai, 2002). It highlights the intricate connections among individuals within a community (Garrison, 2013; Garrison, 2015; Garrison, 2017). It guides and seeks to establish how to successfully employ online learning standards to encourage students' critical thinking (Rourke et al., 1999) while supporting and guiding pedagogy and practices. The framework's fundamental tenet encourages online learners to create communities through which they can engage in meaningful conversations and activities (Hosler & Arend, 2013).

The first of the critical elements of the CoI framework is social presence. It entails the ability to present oneself in a digital setting genuinely. Shea et al. (2006) asserted that social presence emanates from cooperation and educational collaboration, relying on humans to create meaningful community connections. Promoting social interactions has been found to substantially influence learning outcomes, as supported by research conducted by Kreijns et al. (2022) and Zhao et al. (2014). It promotes cohesion within the group, facilitates efficient communication, and allows for individual self-expression.

Weidlich et al. (2022) describe it as the degree to which the learning environment promotes social interactions, shapes students' sense of being present, and encourages active participation.

Then, the cognitive presence is essential in evaluating the quality of a CoI. It plays a significant role in fostering social constructivist learning and encouraging collaborative participation, as Shea et al. (2022) highlighted. Students are encouraged to participate in thoughtful discussions and analyze information to develop and validate their understanding (Garrison et al., 1999). Cognitive presence entails progressive inquiry (Tolu & Evans, 2013, p.86) grounded on critical thinking (Garrison et al., 2001). Students' involvement in critical dialogue allows them to discern, create, and verify meaning in continuous reflective conversations (Garrison et al., 1999; Hosler & Arend, 2013).

Third, teaching presence is a crucial aspect of the CoI framework. It encompasses the planning, facilitating, and guiding of learning activities and delivering direct instruction. Several studies have highlighted the significance of teaching presence in online instruction (Anderson et al., 2001; Garrison et al., 2010; Zhang et al., 2016). Enhancing student-teacher relationships can have a positive impact on various aspects of learning. Research conducted by Wang (2022) suggests that when students and teachers have strong connections, it can lead to improved learning behaviors, and increased cognitive and enhanced emotional engagement. Additionally, it fosters a feeling of belonging and promotes general health and happiness (Arbaugh et al., 2008; Garrison & Arbaugh, 2007). A strong teaching presence requires educators to possess the necessary expertise in effectively managing of the learning environment and promoting student comprehension (Dunlap & Lowenthal, 2009; Vaughan, 2004).

Research Questions

This study aims to evaluate CoI's effectiveness in online science instruction. It seeks to address the following research question: What is the effect size of eligible studies when categorized based on academic achievement and students' behavior?

Methodology

This meta-analysis evaluated the effects of the CoI framework in online Science instruction. Meta-analysis is a method used to measure the effects between certain variables or evaluate the effectiveness of interventions (Gurevitch et al., 2018). It can evaluate conflicting theoretical assumptions and determine the impact of essential moderators (Aguinis et al., 2001; Bergh, 2016). The study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA, 2021) procedure for conducting a systematic review and reporting the findings.

Eligibility Criteria

The scope of our research encompassed science instruction across primary, secondary, and higher education levels, focusing on disciplines such as "General Science," "Physics," "Chemistry," and "Biology." We conducted a literature review on studies published in reputable journals indexed by Scopus or CrossRef from January 1, 2020, to December 31, 2022. Our review aimed to compare results throughout the peak online and remote learning period.

Information Sources

The data were extracted from the results of the included individual papers. Harzing's Publish and Perish© (PaP) technology facilitates a thorough exploration of electronic databases to locate published papers in English. The data analyzed were obtained directly from the individual studies' outcomes, explicitly focusing on academic performance and behavior.

Search Strategy

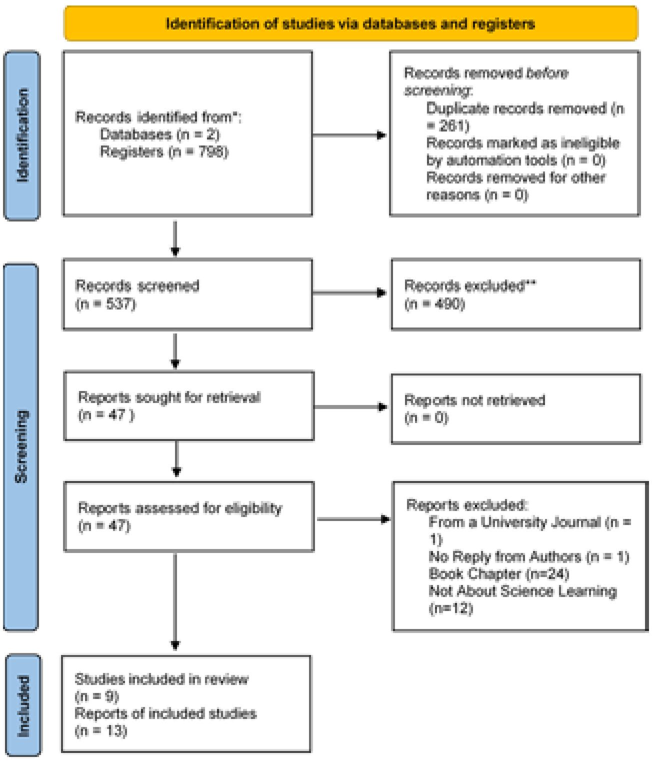
The PaP's advanced search feature accessed Scopus and Google Scholar databases. Keywords repeatedly used were 'Community of Inquiry', 'Biology', 'High School', 'Elementary', 'College', and 'Undergraduate'. For instance, the keyword 'Biology' was interchanged with 'Physics', 'General Science', or 'Chemistry'. During the search, PaP was gradually limited to one year search at a time. Then, a further search was implemented using the same set of keywords.

Study Selection

We began the investigation by conducting an initial database search, which yielded 798 articles. After removing 261 duplicates, 537 unique articles remained. Abstract screening refined the selection process, yielding 47 research publications that satisfied the essential criterion. Following full-text analysis, we discovered nine research papers, 13 of which included reports on using the CoI. Figure 1 illustrates the selection of the article of interest.

Figure 1

The Selection of the Research Articles



Selection Process

We modified the PRISMA flowchart (Page et al., 2021) into a four-stage review approach for selecting manuscripts and consistently applying eligibility criteria. We initially compiled Harzing's PaP statistics and loaded them into EndNote© for literature management. The second stage involved evaluating abstracts for relevance, focusing on phrases like "community of inquiry" in education. We thoroughly reviewed selected papers in the third stage and performed preliminary data extraction. Finally, the fourth stage covered the validation of the selected papers through rigorous data analysis, resulting in a comprehensive summary report.

The Scope and Characteristics of Eligible Studies

The studies were geographically diversified, focusing on affluent locations in the Middle and Southeast Asian regions. Most of the research concentrated on Physics and General Science, with participants primarily at the secondary school level. The study included 3,339 learner participants, separated into a control group (n=653) and a CoI inquiry group (n=1686). Table 1 presents eligible studies in this meta-analysis.

Table 1

Overview of Eligible Students using CoI in Online Science Instruction 2020-2022

Title	Authors	Year	Country	Subject	Level	Data Type
Using mobile devices to enhance inquiry-based learning processes	Becker et al.	2020	Germany	Physics	Secondary	Acad
The improvement of critical thinking skills of primary school students through guided inquiry learning models with integrated peer instructions	Ahhadin, Jatmiko, Supardi	2020	Malaysia	Physics	Elementary	Acad
The Effect of Teacher Evaluation and Self-Evaluation on Preservice Teachers' Inquiry-Based 5E Lesson Plan Design and Teaching Practice	Güngören, Hasançebi and Mesci	2020	Turkey	General Science	Undergrad	Bhv
Student-Led Argumentation: Effects on Knowledge Building	Yunting, Paderna	2021	Philippines	Biology	Secondary	Acad
Resource-based learning design thinking (RBLDT): A model to improve students' creative thinking skills, a concept gaining, and digital literacy	Rumahlatu et al.	2021	Indonesia	General Science	Secondary	Acad
Engagement and Satisfaction: Mixed-Method Analysis of Blended Learning in the Sciences	Lane et al.	2021	USA	General Science	Undergrad	Bhv
The Effect of Blended Learning on the Achievement in a Physics Course of Students of a Dentistry College: A Case Study at Ajman University	Alsalhi et al.	2021	UAE	Physics	Undergrad	Bhv
The effect of a cooperative argumentation model on listening and inquiry skills and argument level	Okumus	2021	Turkey	Biology	Undergrad	Acad
Examining the efficacy change of preservice science teachers: Does an inquiry-based laboratory instruction make a difference? A mixed-method study	Kiran	2022	Turkey	General Science	Undergrad	Bhv

Note: *Acad- academic achievement Bhv- students' behavoir*

Data Collection

The data from eligible papers were thoroughly reviewed based on each author's results and discussion. The acquired data was then carefully examined to guarantee accuracy and suitable categorization.

Data Items

The study collected exact data points such as p-values, difference test findings, and measures of central tendency and variability (such as mean and standard deviation). These datasets were critical for determining effect sizes. In addition, inquiries were made to the original authors to clarify and improve the interpretability of the reviewed results.

Coding Procedures

The researchers divided the data into three categories: (1) study groups for the control group, (2) CoI for the inquiry groups, and (3) pre-and post-tests for single-group investigations. 'Acad' represents academic achievement, while 'Bhv' indicates students' behavioral assessment research.

Effect Measures and Data Analysis

We analyzed the data using Comprehensive Meta-Analysis© version 4.0 software to calculate Hedges' g as the effect size metric. This measure is highly regarded for its ability to adjust for minor sample bias, allowing us to provide a standardized evaluation of the impact of the CoI framework across the included studies. We interpreted the effect sizes based on Cohen's guidelines (Lakens, 2013), categorizing them as small (0.2), medium (0.5), or large (0.8).

Given the considerable variability across the studies, which reflected differences in populations, methodologies, and the application of the CoI framework in science education, we employed the Random Effects Model. This model is well-suited for accommodating such variability by assuming that effect sizes are not fixed but rather influenced by study-specific factors, thus facilitating the aggregation of results from diverse contexts.

To determine heterogeneity, we employed Q-statistics, a chi-squared measure that tests whether random error accounts for the observed variance in effect sizes (Kulinskaya & Hoaglin, 2023). A significant Q-statistic indicates that the heterogeneity exceeds what chance alone would predict. Additionally, we calculated τ^2 (tau-squared) to estimate the variance between studies, allowing us to quantify the extent of heterogeneity (Kulinskaya & Hoaglin, 2023). These measures enabled us to effectively address variability and ensure the robustness of our meta-analytic estimates. Through these rigorous analytical methods, we systematically evaluated the effectiveness of the CoI framework in online Science instruction.

Findings and Discussion

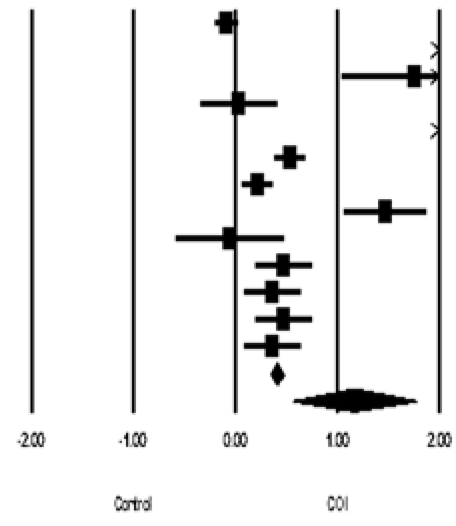
Table 2 shows the effect size of the individual using pooled fixed and random pooled effects approaches.

The data analysis uncovered a variety of effect sizes in the reports. Two reports indicated a small negative effect in favor of the control group under pooled fixed effects. However, it is essential to note that these findings did not reach statistical significance. One study found a small positive effect, while three others

Table 2

Effect Size using Pooled and Random Effects Approaches in Academic Achievement and Students' Behavior

Study Title	Study	Hedges' g	tandard Err	Variance	ower Lim	pper Lim	Z	p
Using mobile devices to enhance inquiry-based learning processes	1	-0.084	0.059	0.003	-0.199	0.032	-1.418	0.157
The improvemnet of critical thinking skills of primary school students	2	3.994	0.473	0.224	3.087	4.920	8.449	0.000
The effects of teacher evaluation and self-evaluation	3	1.758	0.366	0.134	1.040	2.478	4.799	0.000
Student led argumentation effects on knowledge building	4	0.038	0.194	0.038	-0.344	0.418	0.135	0.853
Resource based learning design thinking (RBLDT): A model to improve	5	6.294	0.219	0.048	5.864	6.724	28.881	0.000
Engagement and Satisfaction on Mixed Method Analysis of Blended Learning in the Sciences 1	6	0.538	0.079	0.006	0.382	0.891	8.804	0.000
Engagement and Satisfaction on Mixed Method Analysis of Blended Learning in the Sciences 2	7	0.221	0.077	0.006	0.071	0.371	2.882	0.004
The effect of Blended Learning on the Achievement in a Physics…	8	1.475	0.208	0.043	1.087	1.883	7.079	0.000
The effect of a cooperative argumentation model on listening and inquiry skills and argument lev	9	-0.053	0.271	0.073	-0.585	0.478	-0.197	0.844
Examining the efficacy change of preservice science teachers 1	10	0.477	0.144	0.021	0.194	0.780	3.303	0.001
Examining the efficacy change of preservice science teachers 2	11	0.388	0.141	0.020	0.089	0.842	2.588	0.010
Examining the efficacy change of preservice science teachers 3	12	0.477	0.144	0.021	0.194	0.780	3.303	0.001
Examining the efficacy change of preservice science teachers 4	13	0.388	0.141	0.020	0.089	0.842	2.588	0.010
Pooled	Fixed	0.418	0.033	0.001	0.351	0.431	12.539	0.000
Pooled	Rando	1.178	0.309	0.095	0.573	1.733	3.818	0.000



revealed significant impact sizes. On the other hand, nine reports indicated notably small effect sizes, while one demonstrated a significantly moderate effect size.

When comparing effect sizes, we observed that the pooled fixed effect size was relatively small (.417, $p<.0001$), while the pooled random effect size showed a more significant effect size (1.188, $p<.0001$). The Q-statistics (216.993, $df=26$, $p<.0001$) revealed a notable level of heterogeneity, with I^2 accounting for 88.015% ($\tau^2=1.191$) of the variation under the Random Effects Model.

Although the average effect size of CoI was relatively small, it had noteworthy effects on behavior and achievement in certain circumstances. The pooled and random effect size analysis revealed significant variations in smaller impact sizes, indicating a consistent pattern throughout our dataset.

Table 3 presents the moderator analysis of the achievement.

The examination of the reports (n=5) revealed a large but statistically non-significant random effect size (ES=2.026, $p=.097$), indicating a noticeable trend toward CoI learning without statistical significance. Furthermore, heterogeneity testing revealed a significant Q-value of 851.802 ($df=4$, $p<.0001$) among the reports, with an I^2 value of 99.530 ($\tau^2=7.377$), indicating significant variations in techniques and outcomes connected to CoI application in science education. We argue that this event was due to the limitation of the research article that satisfies the inclusion parameter of our study. Yet, it highlights the potential impact of CoI on academic achievement in science classes, supported by comprehensive educational approaches that combine planning, execution, and assessment across multiple intellectual and social domains (Anderson et al., 2001). Both the teaching and social presence play vital role in leveraging cognitive presence.

Teaching presence in the classroom plays a crucial role in improving student achievement by responding to students' needs and providing appropriate materials, regulating student workloads, and facilitating open lines of communication (Garrison et al., 2001). As a result, the teacher's involvement is vital during course design, method development, information transmission, and intellectual stimulation (Garrison & Arbaugh, 2007). Social presence boosts teaching presence by creating an environment that encourages group cohesion,

Table 3

The Moderator Analysis on Academic Achievement

Involved studies	Hedge's g	SE	σ^2	Z	p
Using mobile devices …	-.084	.059	.003	-1.416	.157
The improvement of critical …	3.994	.473	.223	8.449	.0001
Student-led argumentation …	.036	.194	.038	.185	.853
Resource-based...	6.924	.219	.048	28.681	.0001
The effect of a cooperative argument…	-.053	.271	.074	-0.197	.844
Random Pooled	**2.026**	**1.221**	**1.491**	**1.660**	**.097**

Table 4

The Moderator Analysis of Students' Behavior

Involved studies	Hedge's g	SE	σ^2	Z	p
The effect of teacher evaluation and self-…	1.758	0.366	0.134	4.799	.0001
Engagement and Satisfaction (F2F) …	0.536	0.079	0.006	6.804	.0001
Engagement and Satisfaction (Online) …	0.221	0.077	0.006	2.882	.004
The effect of Blended learning on the…	1.475	0.208	0.043	7.079	.0001
Examining the efficacy of preservice (TSES) …	0.477	0.144	0.021	3.303	.001
Examining the efficacy of preservice (SE) ...	0.366	0.141	0.020	2.588	.01
Examining the efficacy of preservice (IS) …	0.477	0.144	0.021	3.303	.001
Examining the efficacy of preservice (CM) …	0.366	0.141	0.020	2.588	.01
Random Pooled	**0.611**	**0.122**	**0.015**	**5.013**	**.0001**

communication, and expression in an effective way (Garrison &Arbaugh, 2007). It is a capacity to present oneself (Garrison et al., 1999;) in an online environment through a communication platform (Swan & Shih, 2005), which learning establishes social connections (Pallof & Pratt, 2011).

Table 4 presents the moderator analysis of students' behavior.

Our results showed that all calculated effect sizes were statistically significant. Two reports exhibited a significantly large effect size. At the same time, another, which focused on inquiry skills, engagement, and satisfaction in face-to-face classrooms, demonstrated a moderately significant effect size. The remaining effect sizes were minor but substantial.

The pooled random effect size analysis revealed a statistically significant medium effect size (ES=0.611, p=.0001) in favor of CoI, indicating that it significantly influences behavioral measures more than typical instructional contexts. This analysis revealed heterogeneity (Q=47.886, df=7, p<.001), with I^2 showing that 85.382% (τ^2=0.093) of the variability between studies can be attributable to causes other than chance.

CoI has a moderate effect in altering students' behavior in successful online science learning. It combines engagement elements with behavioral, cognitive, and affective dimensions (Coates, 2007; Hollister et al., 2022). Engagement promotes emotional attachment, allowing for active engagement and dedication to learning activities (Barlow et al., 2020). Student's behaviors use motivation to increase engagement and improve learning results. In the same way, students' engagement and regulation can predict better learning outcomes (Errabo et al., 2024). Likewise, Noor et al. (2022) discovered that learning behaviors improve student learning and motivation by boosting information acquisition and learning habits. As a behavioral feature, cognitive engagement indicates students' emotional interest in the learning process (Fredricks et al., 2004).

Conclusion and Implications

This meta-analysis highlights the effectiveness of the CoI framework as an instructional model for online science instruction. By synthesizing data from (N=798) studies that included (N=3,339) learners, primarily junior high school students, during the global shift to remote learning (2020–2022), the findings reveal a significant pooled random effect size. A large effect size was noted on academic performance, while student behavior exhibited a medium effect size. Notably, the lack of significant publication bias further substantiates the reliability and robustness of these results. This research contributes to growing theoretical insights into CoI as a model in online pedagogy and exploring its application in the Philippines and other countries in the Global South and the ASEAN regions, where educational systems face persistent challenges such as limited digital infrastructure and pedagogical inequities. Demonstrating its adaptability, the CoI framework emerges as a pivotal model for online science instruction, critical for fostering deeper learners' engagement and achieving improved academic outcomes within resource-constrained settings. Regionally, the study highlights CoI's potential to address disparities in educational quality and access, providing ASEAN nations and similar regions with a scalable, evidence-based model for enhancing online learning. On a global scale, it positions the CoI framework as a versatile and inclusive approach developed countries can adopt to optimize their online education systems, advancing equitable access to quality learning opportunities worldwide.

Limitations and Recommendations

Our cross-sectional study provides compelling evidence of the positive impact of the CoI on academic achievement. However, the limited scope of studies focusing specifically on online science classes constrains the broader generalization of these findings. This emphasizes the need for future research to expand the dataset, particularly in underrepresented contexts and disciplines within online education.

While our analysis revealed a medium effect on student behavior, the findings were not statistically significant, suggesting the influence of contextual factors such as instructional design, student engagement strategies, and cultural nuances. These factors merit further exploration to understand better how CoI shapes behavioral outcomes in diverse educational settings.

From a scholarly standpoint, our findings highlight the pressing need for targeted professional development to enhance cognitive, social, and teaching presences within the CoI framework. Educators can be empowered through actionable strategies, such as leveraging online discussion boards and collaborative projects to foster social presence, incorporating problem-based learning and virtual laboratories to bolster cognitive presence, and utilizing well-structured lesson plans alongside multimedia resources to strengthen teaching presence. For policymakers and educators, the study offers actionable recommendations for integrating CoI into online teaching practices and educational policies. Specific strategies include cultivating social presence, enhancing cognitive presence, and reinforcing teaching presence. Incorporating these strategies into professional development programs can equip educators with the skills to create equitable and high-quality online learning experiences.

By integrating CoI-focused training into professional development initiatives and encouraging interdisciplinary workshops, educators will be better equipped to implement these strategies effectively. These measures address the learning deficits observed during online education while ensuring equitable, high-quality learning experiences.

■ ■ ■

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5. **Ethical Approval:** We declared that our work is compliant with the highest ethical standards of our institution. We also sought approval for the use of the research article from the authors.

References

Anderson, T., Rourke, L., Garrison, D. R., & Archer, W. (2001). Assessing teaching presence in a computer conferencing context. *Journal of Asynchronous Learning Network, 5*(2), 1–17. https://auspace.athabascau.ca/bitstream/handle/2149/725/assess?sequnce=1

Aguinis, H., Boik, R. J., & Pierce, C. A. (2001). A generalized solution for approximating the power to detect effects of categorical moderator variables using multiple regression. *Organizational Research Methods, 4*(4), 291–323. https://doi.org/10.1177/109442810144001

Arbaugh, J. B., Cleveland-Innes, M., Diaz, S. R., Garrison, D. R., Ice, P., Richardson, J. C., & Swan, K. P. (2008). Developing a community of inquiry instrument: Testing a measure of the community of inquiry framework using a multi-institutional sample. *The Internet and Higher Education 11*(3), 133–136. https://doi.org/10.1016/j.iheduc.2008.06.003

Barlow, A., Brown, S., & Lutz, B. (2020). Development of the student course cognitive engagement instrument (SCCEI) for college engineering courses. *International Journal of STEM Education, 7*, Article 22.https://doi.org/10.1186/s40594-020-00220-9

Bergh, D. D., Aguinis, H., Heavey, C., Ketchen, D. J., Boyd, B. K., Su, P., Lau,C. L. L., & Joo, H. (2016). Using meta-analytic structural equation modeling to advance strategic management research: Guidelines and an empirical illustration via the strategic leadership-performance relationship. *Strategic Management Journal, 37*(3), 477–497. https://doi.org/10.1002/smj.2338

Briones, M. R., Prudente, M., & Errabo, D. D. (2023). Characteristics of Filipino online learners: A survey of science education students' engagement, self-regulation, and self-efficacy. *Education Sciences, 13*(11), Article 1131. https://doi.org/10.3390/educsci13111131

Coates, H. (2007). A model of online and general campus-based student engagement. *Assessment & Evaluation in Higher Education, 32*(2), 121–141. https://doi.org/10.1080/02602930600801878

Dizon, R. J. J., & Errabo, D. D. R. (2022). Compensating learning losses in online learning: Teachers and students' performance in virtual classrooms. In *Proceedings of the 2022 13th International Conference on E-Education, E-Business, E-Management, and E-Learning (IC4E '22)* (pp. 90–96). Association for Computing Machinery. https://doi.org/10.1145/3514262.3514317

Dunlap, J., & Lowenthal, P. (2009). Tweeting the night away: Using Twitter to enhance social presence. *Journal of Information Systems Education, 20*(2), 129–135. http://jise.org/Volume20/n2/JISEv20n2p129.pdf

Dy, E. H. L., Tan, A. J., & Errabo, D. D. (2021). Students' perceptions and anxieties towards e-assessment: Implications for online classroom delivery. In *2021 IEEE International Conference on Educational Technology (ICET)* (pp. 191–195). IEEE. https://doi.org/10.1109/ICET52293.2021.9563138

ElSayad, G. (2023). Can learning presence be the fourth community of inquiry presence? Examining the extended community of the inquiry framework in blended learning using confirmatory factor analysis. *Education and Information Technologies*. https://doi.org/10.1007/s10639-022-11480-z

Errabo, D. D., Berdan, M. C., Galapon, G. C., Bautista, R. P., & Arevalo, I. J. (2021). Impact of 7E inquiry segments in a mixed online learning environment. In *2021 3rd International Conference on Modern Educational Technology (ICMET 2021)* (pp. 136–141). Association for Computing Machinery. https://doi.org/10.1145/3468978.3469001

Errabo, D. D., Dela Rosa, A., & Gonzales, L. J. M. (2024). Optimizing differentiated podcasts to promote students' self-regulation and engagement, self-efficacy, and performance in asynchronous learning. *Journal of Research in Innovative Teaching & Learning*. Advance online publication. https://doi.org/10.1108/JRIT-02-2024-0039

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement:

Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59–109. https://doi.org/10.3102/00346543074001059

Garrison, D. R. (2013). Theoretical foundations and epistemological insights of the community of inquiry. In Z. Akyol & D. R. Garrison (Eds.), *Educational communities of inquiry: Theoretical framework, research and practice* (pp. 1–11). IGI Global. https://doi.org/10.4018/978-14666-2110-7.ch001

Garrison, D. R., Anderson, T., & Archer, W. (1999). Critical inquiry in a text based environment: Computer conferencing in higher education. *The Internet and Higher Education, 2*(2–3), 87–105. https://doi.org/10.1016/s1096-7516(00)00016-6

Garrison, D. R., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education, 15*(1), 7–23.

Garrison, D. R., & Arbaugh, J. B. (2007). Researching the community of inquiry framework: Review, issues, and future directions. *The Internet and Higher Education, 10*(3), 157–172. https://doi.org/10.1016/j.iheduc.2007.04.001

Garrison, D. R. (2015). *Thinking collaboratively: Learning in a community of inquiry*. Routledge. https://doi.org/10.4324/9781315740751

Garrison, D. R. (2017). *E-learning in the 21st century: A community of inquiry framework for research and practice* (3rd ed.). Routledge.

Garrison, D. R., Cleveland-Innes, M., & Fung, T. S. (2010). Exploring causal relationships among teaching, cognitive, and social presence: Student perceptions of the community of inquiry framework. *The Internet and Higher Education, 13*(1–2), 31–36. https://doi.org/10.1016/j.iheduc.2009.10.002

Gurevitch, J., Koricheva, J., & Nakagawa, S. (2018). Meta-analysis and the science of research synthesis. *Nature, 555*(7695), 175–182. https://doi.org/10.1038/nature25753

Hollister, B., Nair, P., Hill-Lindsay, S., & Chukoskie, L. (2022). Engagement in online learning: Student attitudes and behavior during COVID-19. *Frontiers in Education*. https://doi.org/10.3389/feduc.2022.851019

Hosler, K. A., & Arend, B. D. (2013). Strategies and principles to develop cognitive presence in online discussions. In Z. Akyol & D. R. Garrison (Eds.), *Educational communities of inquiry: Theoretical framework, research and practice* (pp. 148–167). IGI Global. https://doi.org/10.4018/978-1-4666-2110-7.ch009

Kim, G., & Gurvitch, R. (2020). Online education research adopting the community of inquiry framework: A systematic review. *Quest, 72*(4), 395–409. https://doi.org/10.1080/00336297.2020.1761843

Kreijns, K., Xu, K., & Weidlich, J. (2022). Social presence: Conceptualization and measurement. *Educational Psychology Review, 34*(1), 139–170. https://doi.org/10.1007/s10648-021-09623-8

Kulinskaya, E., & Hoaglin, D. C. (2023). On the Q statistic with constant weights in meta-analysis of binary outcomes. *BMC Medical Research Methodology, 23*(1), Article 146. https://doi.org/10.1186/s12874-023 01939-z

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology, 4*, Article 863. https://doi.org/10.3389/fpsyg.2013.00863

Lee, R., Hoe Looi, K., Faulkner, M., & Neale, L. (2021). The moderating influence of environmental factors in an extended community of inquiry e-learning model. *Asia Pacific Journal of Education, 41*(1), 1–15. https://doi.org/10.1080/02188791.2020.1758032

Ling, L. (2022). Teaching presence predicts cognitive presence in blended learning during COVID-19: The mediating chain role of social presence and sense of community. *Frontiers in Psychology, 13*. https://doi.org/10.3389/fpsyg.2022.950687

Noor, U., Younas, M., Saleh Aldayel, H., Menhas, R., & Qingyu, X. (2022). Learning behavior, digital platforms for learning, and their impact on university students' motivations and knowledge development. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2022.933974

Palloff, R. M., & Pratt, K. (2011). *The excellent online instructor: Strategies for professional development*. John Wiley & Sons.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71

Rourke, L., Anderson, T., Garrison, D. R., & Archer, W. (1999). Assessing social presence in asynchronous, text-based computer conferencing. *Journal of Distance Education, 14*(3), 51–70. http://auspace.athabascau.ca/bitstream/2149/732/1/Assessing%20Socil%20Presence%20In%20Asynchronous%20Textbased%20Computer%20Conferencing.pdf

Rovai, A. P. (2002). Development of an instrument to measure classroom community. *Internet and Higher Education, 5*(3), 197–211. https://doi.org/10.1016/s1096-7516(02)00102-1

Shea, P., Li, C. S., & Pickett, A. (2006). A study of teaching presence and student sense of learning community in fully online and web-enhanced college courses. *The Internet and Higher Education, 9*(3), 175–190. https://doi.org/10.1016/j.iheduc.2006.06.005

Shea, P., Richardson, J., & Swan, K. (2022). Building bridges to advance the Community of Inquiry framework for online learning. *Educational Psychologist, 57*(3), 148–161. https://doi.org/10.1080/00461520.2022.2089989

Shea, P., Hayes, S. K., Uzuner-Smith, S., Vickers, J., Bidjerano, T., Pickett, A., Gozza-Cohen, M., Wilde, J., & Jian, S. (2012). Learning presence: Additional research on a new conceptual element within the Community of Inquiry (CoI) framework. *Internet and Higher Education, 15*, 89–95. https://doi.org/10.24059/olj.v9i3.1788

Sun, A., & Chen, X. (2016). Online education and its effective practice: A research review. *Journal of Information Technology Education: Research, 15*, 157–190. https://doi.org/10.28945/3502

Swan, K., & Shih, L. F. (2005). On the nature and development of social presence in online course discussions. *Journal of Asynchronous Learning Networks, 9*(3), 115–136. https://doi.org/10.24059/olj.v9i3.1788

Tolu, A. T., & Evans, L. S. (2013). From distance education to communities of inquiry: A review of historical developments. In Z. Akyol & D. R. Garrison (Eds.), *Educational communities of inquiry: Theoretical framework, research and practice* (pp. 45–65). IGI Global. https://doi.org/10.4018/978-1-4666-2110-7.ch004

Vaughan, N. D. (2004). Technology in support of faculty learning communities. In M. D. Cox & L. Richlin (Eds.), *Building faculty learning communities: New directions for teaching and learning* (pp. 101–109). Jossey-Bass. https://doi.org/10.1002/tl.137

Wang, Y. (2022). Effects of teaching presence on learning engagement in online courses. *Distance Education, 43*(1), 139–156. https://doi.org/10.1080/01587919.2022.2029350

Weidlich, J., Göksün, D. O., & Kreijns, K. (2022). Extending social presence theory: Social presence divergence and interaction integration in online distance learning. *Journal of Computing in Higher Education*. https://doi.org/10.1007/s12528-022-09325-2

Yu, Z., & Li, M. (2022). A bibliometric analysis of Community of Inquiry in online learning contexts over twenty-five years. *Education and Information Technologies, 27*, 11669–11688. https://doi.org/10.1007/s10639-022-11081-w

Yan, Y., Vyas, L., Wu, A. M., & Rawat, S. (2022). Effective online education under COVID-19: Perspectives from teachers and students. *Journal of Public Affairs Education, 28*(4), 422–439. https://doi.org/10.1080/15236803.2022.2110749

Zhang, H., Lin, L., Zhan, Y., & Ren, Y. (2016). The impact of teaching presence on online engagement behaviors. *Journal of Educational Computing Research, 54*(7), 887–900. https://doi.org/10.1177/0735633116648171

Zhao, H., Sullivan, K. P. H., & Mellenius, I. (2014). Participation, interaction, and social presence: An exploratory study of collaboration in online peer review groups. *British Journal of Educational Technology, 45*(5), 807–819. https://doi.org/10.1111/bjet.12094

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