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# Community of Inquiry and Cognitive Load in Online STEM: Transferability Plan

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# Community of Inquiry and Cognitive Load in Online STEM: Transferability Plan

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This document presents evidence in support of the Community of Inquiry and Cognitive Load Framework (supported by NSF #204430), with guidance on translating this framework to additional contexts within the studied institution and beyond.

## The Framework

Our goal was to positively impact persistence, performance, and perspectives of students engaging in their STEM degrees in fully online programs by promoting Community of Inquiry (CoI) while mitigating extraneous cognitive load (CL). We designed and tested a pilot program for improved asynchronous course discussions through both course design efforts and through faculty professional development to improve facilitation of the courses. Full details on the intervention, measures, and data analysis are presented in a series of research papers. A summary of key findings and citation details can be found in our Research Summary Document.

The course redesign efforts used evidence-based methods to address the CoI presences and CL by redesigning the discussion prompts, instructions, and rubrics, as well as attention to the general design of discussions (e.g., group size). The instructor professional development was executed through a 10-week asynchronous training program with faculty spending about 5-6 hours in total. The training introduced instructors to evidence-based ideas for facilitating discussions to improve CoI and reduce extraneous CL. The training focused on cultivating a growth mindset both about student abilities to succeed in STEM discussions and the instructor's self-perceived teaching abilities. The efficacy of the instructor's efforts based on this training were explored using the college's peer observation program.

## Modeling the CoI-CL Framework

The simplistic model we hypothesized at the start of the project is presented in Figure 1 while the result of SEM modeling is shown in Figure 2. Several Structural Equation Modeling (SEM) models were developed to analyze the relationship between Community of Inquiry presences (social, teaching, and cognitive), Cognitive Load subscales (understanding expectations, initial post, reading posts, replying to posts, and integrating feedback), grades (both for discussions and final course grade), and demographics (gender, race, ethnicity, GPA, etc.). Brief top-level statistical relationships:

- Negative relationship between Cognitive Load and Grades (as Cognitive Load goes up, Grades go down).
- No relationship between Grades with Social or Teaching Presence, but a positive relationship between Cognitive Presence and Final Grade in course (as Cognitive Presence goes up, Final Grade in Course goes up).
- No relationship between overall Community of Inquiry presence and Cognitive Load, suggesting these are two distinct mental constructs.

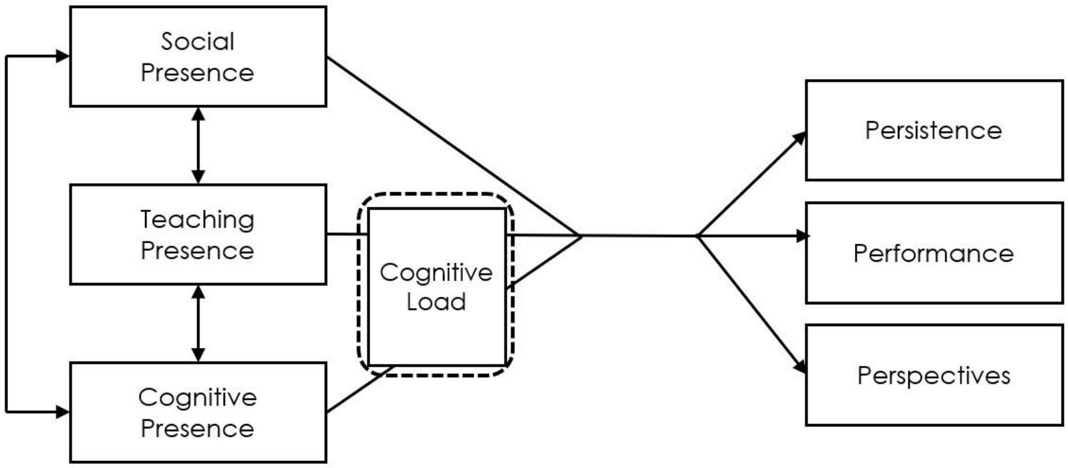


**Figure 1** ***Hypothesized Model of Community of Inquiry and Cognitive Load Framework***

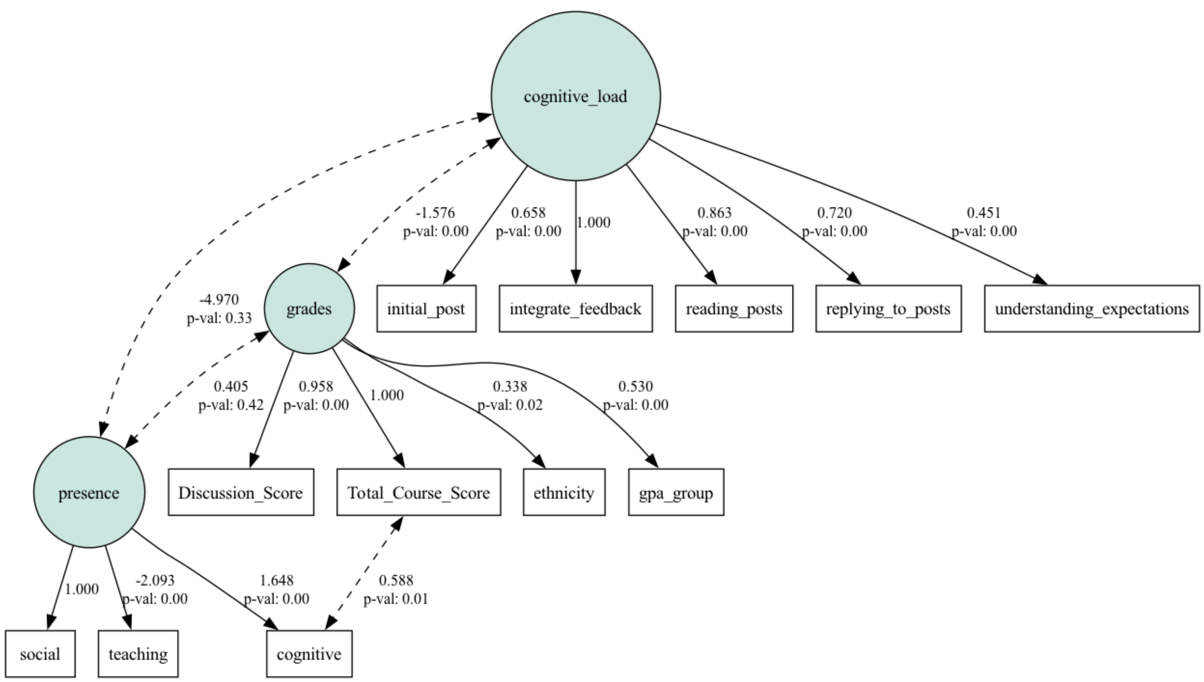


**Figure 2** ***SEM Modeling of CoI-CL Framework***

## Project Evaluation

The impact of the framework was evaluated based on the efficacy of improving CoI, reducing extraneous CL, and achieving the intended impacts on students' persistence, performance, and perspectives.

| Measure | Goal | Outcome |
|---|---|---|
| Social Presence | Strong student-reported social presence | 75% of responses to social presence were positive (4 or 5 on 5-point Likert scale)<br><br>**Statistically significant increase from pre-intervention (p-value=0.0026).** |
| | Strong direct measure of social presence (measured as social presence density) | **Students:**<br>• Math: Cohesive SPD +75%, Interactive SPD +41%<br>• Phys: Cohesive SPD +11%, Interactive SPD +32%<br><br>**Instructors:**<br>• Math: Cohesive SPD +150%, Interactive SPD –42%.<br>• Phys: Cohesive SPD –25%, Interactive SPD +50%.<br><br>**Both courses showed statistically significant increases in SPD for students and teachers when using the CoI-CL Framework** |
| Teaching Presence | Strong student-reported teaching presence | 67% of responses to teaching presence were positive (4 or 5 on 5-point Likert scale).<br><br>**No statistically significant increase from pre-intervention (p-value=0.7748).** |
| | Strong direct measure of teaching presence | Math: Design TPD –26%, Instruction TPD –11%<br><br>Phys: Facilitating TPD –64%, Design TPD –21%, Instruction TPD –16%<br><br>**Reduction in Facilitating TPD and Design TPD may be due to improved instructions from intervention since student perception did not change from pre-intervention.** |
| Cognitive Presence | More high-level cognitive presence (student-reported) | 84% of responses were positive (4 or 5 on 5-point Likert scale)<br><br>**Statistically significant increase from pre-intervention (p-value=0.0000).** |
| | More high-level cognitive presence (direct measure) | Math: Triggering CPD –23%, Integration CPD –55%<br><br>Phys: Triggering CPD +108%, Exploration CPD +28%, Integration CPD –39%<br><br>**Decrease in CPD for math but increase in lower-tier CPD in phys likely due to design intervention and increase in social component of math discussions.** |

| | | |
|---|---|---|
| Cognitive Load | Lower student-reported cognitive load (comparing Instructional Efficiency pre/post) | Reduced frustration for understanding expectations, initial post, and integrating instructor feedback, suggesting **reduction in extraneous load**<br><br>Increased cognitive load in reading and replying to posts, suggesting **increase in cognitive presence increased germane load**<br><br>In Framework, more effort in replying to other students and less effort in replying to instructor, suggesting **increase in student-to-student engagement** |
| Persistence | Increased persistence | W Rate: 4.4% (pre) vs 3.1% (post)<br><br>**Statistically significant decrease in W rate (p-value=0.0153), suggesting Framework increased persistence** |
| | Reduced withdrawals in "Institutional Factors" | Data quality prevented analysis[1]. Addressed in *Gathering Nuanced Data for Understanding Student Withdrawals.* |
| Performance | Increased pass rate | Math ABC Pass Rate –5.7% (p-value=0.0001); Phys ABC Pass Rate +2.6% (p-value=0.0348)<br><br>**Statistically significant decrease in Math ABC pass rate to 79% and increase in Phys ABC pass rate to 91%. Both above national averages.** |
| | Left-skewed grade distribution | MATH showed statistically significant shift from left-skew to bi-modal distribution (SKEW -0.56 to -0.23). PHYS showed statistically significant shift from left-skew to more left-skew (SKEW –0.69 to –0.83).<br><br>**Inconsistent shift in grade distribution in STEM disciplines** |
| STEM attitudes | More positive STEM attitudes | Statistically significant increase in positive STEM Intention (p-value=0.0614), Control Beliefs (p-value=0.0522), and Normative Beliefs (p-value=0.0882).<br><br>**Increase in STEM beliefs (control and normative) led to increased STEM intention. Overall increase in STEM attitudes.** |

## Transferability

When adopting or adapting the CoI-CL Framework, it is important to consider specific criteria, such as those listed below, to ensure successful implementation.

[1] Impact of the Framework on course persistence was unable to be evaluated. Existing institutional structures for processing a withdrawal depend on a webform with a dropdown list to select a reason and an optional comment box to provide further information. The list insufficiently provides withdrawal reasons identified in research literature. Many comment boxes were blank or referenced attachments (not available to researchers). Working with the Advising Office, more comments materialized for the first year; however, the following year returned to the high rate of blank explanations, being uncodable.

**Internal Transferability**

***Relevance to Course Format.*** Most online courses at ERAU's Worldwide Campus contain a discussion forum, whether hosted in Canvas or third-party platforms like Yellowdig and Harmonize. Only certain in-person courses at ERAU's Daytona Beach and Prescott Campuses utilize online discussion forums, thus limiting the potential transferability of this Framework to their traditional in-person modality.

***Relevance to Discussion Goals.*** Discussions in asynchronous online courses can have a variety of goals, including knowledge construction, critical thinking development, peer learning and collaboration, communication skills enhancement, reflection and metacognition, active engagement, community building, and feedback and assessment. While the CoI framework includes cognitive presence as a central component that is highly relevant to the goals of knowledge construction and critical thinking, other goals of asynchronous online discussions may not necessarily align with this framework. It is important to consider the purpose and function of the discussion activity in the course to evaluate the adoption (or adaptation) of the Framework.

***Adaptation Needs.*** Prior to implementation of the Framework in new settings and context, there should be careful consideration of customizations based on the course content, learner demographics and needs, and technological infrastructure (e.g., discussion platform used).

***Faculty Readiness and Support.*** Because the framework involves a faculty professional development component, the readiness of faculty (buy-in) and impacts to workload should be considered. Also, because the professional development includes collaboration, support mechanisms and the availability of a facilitator is an important consideration.

Additionally, the support of course developers and the instructional design team is needed to implement the changes in the course discussion design, including instructions, prompts, and rubrics. Ideally, the course development activities could occur in a cohort approach as was implemented in this Framework, allowing for collaboration and peer feedback.

***Alignment with Priorities.*** The Framework has direct alignment with ERAU's values. Specifically, ERAU is committed to providing a climate that facilitates the highest standards of academic achievement. The alignment of this Framework with institutional strategic initiatives as well as the strategic goals of campus, college, and departmental entities should be considered.

***Data Needs.*** The need for data collection to evaluate the effectiveness of the adoption or adaptation of the framework should be considered so that proper data collection protocols can be put in place, including Institutional Review Board approval or exemption. It is important to identify all appropriate metrics, determine collection methods, and determine analysis methods in order to support an evaluation. Evaluation needs will vary.

***Stakeholder Engagement.*** Open communication channels should be established and maintained to engage relevant stakeholders to garner support, cooperation, and collaboration where needed. This includes administrators, instructional designers, faculty, and students.

**External Transferability**

Like internal transferability, adoption and adaptation of this Framework by external entities should consider key criteria, including:

1) relevance to course format and educational context across diverse institutional settings,
2) alignment with discussion goals and institutional priorities,
3) faculty readiness, support, and professional development,
4) collaboration and stakeholder engagement to open communication, share best practices, and facilitate knowledge exchange,
5) institutional support and sustainability to ensure long-term viability and scalability
6) cultural and contextual sensitivities to respect diverse educational philosophies, pedagogical traditions, languages, and cultural norms.

## Sustainability

**Assessment & Improvement**

As adoption and adaptation of the Framework occurs, the research team plans to assess the flexibility of the Framework to these different contexts, disciplines, and modalities. Given the validation of both Community of Inquiry and Cognitive Load survey instruments, the team can perform factor analysis to reduce the number of survey items to the bare minimum to target cognitive presence and cognitive load associated to frustration as these two mental constructs were the most predictive of student final grade in the course. These focused survey items can be added to End-of-Course Evaluation data to potentially analyze the relationships between cognitive presence, cognitive load, grades, and persistence in the course. Moreover, these same survey items can be administered mid-course as an early detection method for identifying at-risk students.

The team is committed to continuous improvement of the Framework and will engage in ongoing reflection and refinement based on feedback, data, and emerging best practices related to Community of Inquiry, Cognitive Load, and faculty professional development. The two courses in which our interventions were implemented reside in the same department where like-minded faculty are interested in this project's results. It is easily conceivable that the remaining mathematics, science, and technology courses will follow the lead in careful attention to Community of Inquiry and Cognitive Load. Continuing the assessment techniques used in this study will continue to bring insight into the department and its faculty. College colleagues have attended internal presentations, and some are eager to incorporate our learnings into other departments and disciplines. The addition of all these perspectives presents opportunity to test the Framework's applicability to expansion beyond the STEM courses we considered. In addition to expanding outside of the introductory physics and mathematics courses, additional lines of inquiry include an investigation of the impact of different technologies on the CoI-CL Framework.

We found evidence that the course redesign efforts alone provided prominent effects on students' social and cognitive presences, germane and extraneous cognitive load, and attitudes. By integrating the CoI-CL Framework into the course design process, students can be positively impacted without significantly increasing faculty workload. Moreover, the team is committed to developing a machine learning algorithm to classify student and instructor posts in discussion in real-time along the Community of Inquiry framework. This would allow instructors the opportunity to review students social and cognitive presences as they occur in a course and allow for a new metric to increase student engagement in discussions. Another potential avenue to increase teaching presence in particular is to develop a generative AI chatbot that provides real-time responses to facilitate discussions.

**Risk Management**

Curricular change always faces challenges from multiple directions, some easier than others to address. Resistance from instructional faculty may emerge from a real or perceived increase to their workload as well as varying experiences with previous course template revisions. While professional development to support community and cognitive load through the new discussion prompts can encourage a growth mindset for the instructors, the impact of professional development fades over time. Furthermore, technical limitations may exist within learning management systems or third-party platforms that extend discussion capabilities beyond them. The latter case was not part of our study but exists in the same department. Other third-party products used in courses could also enhance Community of Inquiry and address extraneous cognitive load.

Inclusion of instructional faculty in the revisions of course templates may generate buy-in and create a community for sharing ideas of efficiency with the new elements. These communities of instructors teaching the same revised courses can be a vector to remind faculty of the importance of reducing cognitive load for students while improving the Community of Inquiry presences. Departments, colleges, and other academic entities may offer annual awards to contingent faculty that can give preference to those remaining mindful of these two goals for teaching.

Educational technology is always evolving. It is important to take cognitive load into account at each technical update or when considering a new integration. Once technical change occurs, reminders of Community of Inquiry and cognitive load topics in a faculty community can adapt to the revised technology of course delivery if necessary.

## Conclusion

This Transferability Plan for the Community of Inquiry and Cognitive Load Framework represents a strategic roadmap for extending the impact of this innovative approach to online STEM education. By addressing both internal and external transferability considerations, we aim to maximize the reach and effectiveness of the Framework. Through a systematic evaluation, this Framework has been shown effective at improving students' cognitive presence in a course, both in reducing extraneous cognitive load and increasing germane cognitive load. Adoption and adaptation of this Framework across ERAU and at other academic institutions can be achieved through evaluation of key criteria including relevance, stakeholder engagement, and data management. The core team leading this project is committed to sharing best practices and embracing continuous improvement to further the impact of this Framework, enriching the learning experiences of students and empowering faculty in the digital learning environment.