Framework to Redesign Cognitive Presence in Accelerated Asynchronous Online Courses in STEM: Case Study

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Abstract

This research brief presents a single, fully analyzed case study drawn from a larger, ongoing research project exploring evidence-based instructional design in graduate STEM courses.

Accelerated eight-week online graduate STEM courses are increasingly common, yet many are created by compressing 15-week designs without intentional redesign of early cognitive learning supports. In technically demanding courses such as database systems, this often increases cognitive load and contributes to early disengagement. These challenges are further intensified in the era of Generative Artificial Intelligence (GenAI), where students may rely on AI tools without sufficient instructional scaffolding for responsible use.

This research brief reports examines the redesign of the first two weeks of an online graduate database course across two existing course iterations (n = 25 per semester). Guided by the Community of Inquiry framework and theories of self- and co-regulation, the redesign introduced reflective activities supporting responsible GenAI engagement, low-stakes formative "Learning Quests," and collaborative error-analysis assignments.

Data sources included standard end-of-semester course evaluation ratings, student learning artifacts, early assessment outcomes, and instructor debrief reflections. Results showed observable increases in early peer interaction, improved student perception ratings (overall mean 4.13 → 4.75), and stronger early comprehension compared to the prior iteration. Based on these preliminary findings, the paper proposes a Cognitive Learning Redesign Framework for Early Course Weeks to support cognitive presence and metacognitive regulation in accelerated graduate STEM courses.

Introduction

Graduate STEM education is undergoing rapid transformation as students increasingly seek flexible, accelerated, and fully online programs that accommodate professional responsibilities while maintaining academic rigor. Eight-week course formats are now common; however, instructional designs often lag behind these structural changes. Many accelerated courses are created by compressing semester-long designs without reconsidering cognitive load, increasing the risk of overload, disengagement, and uneven early performance [1], [2].

The emergence of Generative Artificial Intelligence (GenAI) introduces an additional challenge. While AI tools may support learning, accelerated courses require explicit scaffolding so that students engage in responsible and effective use rather than substituting AI output for understanding.

Prior research on cognitive presence within the Community of Inquiry (CoI) framework has largely emphasized higher-order phases such as integration and resolution. Comparatively little attention has been given to how instructional design can support the early phases, such as triggering events and exploration, particularly in accelerated graduate STEM contexts.

To address this gap, this case study examines a redesign of the first two weeks of an online graduate database course. The goal was not to reduce rigor, but to restructure early learning experiences to support cognitive presence, metacognitive regulation, and responsible GenAI engagement. As a primary contribution, this study proposes a Cognitive Learning Redesign Framework for Early Course Weeks that offers transferable design principles for accelerated graduate STEM learning environments in the AI era.

Theoretical framework

This redesign is grounded in the CoI framework, with emphasis on early cognitive presence [3], as well as theories of self-regulation and co-regulation [4], [5]. Cognitive presence refers to the extent to which learners construct meaning through sustained discourse in a purposeful learning community. Cognitive presence develops through four phases: triggering events, exploration, integration, and resolution. In accelerated graduate courses, early learning often stalls at the triggering phase, leaving students overwhelmed and uncertain about how to proceed.

Metacognition is a critical cognitive ability for deep and meaningful learning in complex domains. Self-regulation refers to learners' awareness and control of their own cognitive processes and beliefs about capability and agency [4], [6], while co-regulation extends these processes through peer interaction and shared monitoring [5], [7]. Research suggests that collaborative learning environments that make thinking visible can reduce isolation, normalize confusion, and support more effective learning strategies in graduate STEM contexts [8]. Accordingly, the redesign intentionally integrated opportunities for both self- and co-regulation during the opening weeks of the course.

Together, these perspectives guided the redesign of early course experiences to support cognitive presence, metacognitive regulation, and responsible GenAI use.

Research questions

This study addressed the following research questions:

- RQ1: Did students' engagement patterns during Weeks 1–2 differ from those observed in the prior course design?
- RQ2: What were students' perceptions of the redesigned assignments and overall course experience?
- RQ3: Were there observable differences in early content comprehension and performance compared to the previous iteration?

Methods

This study follows an exploratory case study approach within a broader design-based instructional research effort. The goal was to examine how targeted redesign of early learning activities influences engagement and comprehension in an authentic accelerated graduate course setting. The redesigned offering was compared to a prior iteration of the same course.

Participants included 50 graduate students across two semesters (n = 25 per semester), ranging in age from early 20s to mid-50s, with diverse professional and technical backgrounds. The course served as a foundational graduate database course emphasizing relational theory, entity–relationship modeling, and SQL fundamentals.

Data were drawn from multiple existing instructional sources:

- Standard end-of-semester course evaluation ratings (5-point scale)
- Student learning artifacts from Weeks 1–2 (diagram analyses, reflections)
- Early assessment outcomes (Test 1, Part 1)
- Instructor debrief notes and observational reflections

No new data were collected specifically for research purposes. Analyses are therefore descriptive and intended to provide preliminary evidence to inform accelerated course redesign rather than causal claims. In addition to survey comparisons, student learning artifacts were reviewed to identify common misconceptions, evidence of conceptual progression, and patterns of co-regulated reasoning. Instructor debrief notes were used to contextualize observed engagement behaviors and triangulate emerging themes across the two course iterations.

Instructional redesign (Weeks 1–2)

The redesign targeted early cognitive presence and metacognitive regulation through three integrated strategies.

First, a structured assignment in Module 1 emphasized ethical and responsible uses of GenAI through a short, research-based writing task. Students completed a brief inquiry paper examining how GenAI tools are shaping contemporary educational practices, including both potential benefits (e.g., personalized support, explanation generation) and emerging concerns (e.g., overreliance, authorship ambiguity, equity, and academic integrity). As part of the assignment, students used ChatGPT selectively for idea refinement, feedback, and clarification while critically evaluating AI-generated output rather than accepting it uncritically. Students were required to articulate independent positions supported by course readings and credible sources, and to reflect on the limitations of AI assistance in learning. This activity framed GenAI as a reflective learning partner that can support metacognitive awareness and responsible engagement, rather than as a shortcut to bypass conceptual understanding.

Second, traditional quizzes were replaced with low-stakes Learning Quests, designed as formative exploration activities rather than performance-based evaluations. In this format, Quests functioned primarily as a learning tool rather than a testing tool, allowing students to practice, reflect, and build understanding without the pressure of high-stakes grading. Key features included unlimited attempts, immediate automated feedback, and flexible pacing to reduce anxiety and support self-regulation. Importantly, the Quests encouraged students to engage with concepts through multiple complementary learning resources each of which may present the same idea in different ways. This structure was intended to help students connect ideas across representations, synthesize foundational knowledge, and develop a more coherent conceptual understanding during the accelerated early weeks of the course. By emphasizing iterative sensemaking over correctness on the first attempt, Learning Quests supported learner confidence while promoting deeper cognitive engagement.

Individual practice problems were redesigned as structured collaborative assignments to promote co-regulated metacognitive engagement during the earliest stages of the course. Students worked in small teams using a shared diagramming workspace to analyze two entity–relationship diagrams: one correct and one intentionally flawed. This design encouraged collective reasoning, peer explanation, and discussion of misconceptions, supporting early cognitive presence through exploration and shared sensemaking. Together, these collaborative diagramming activities served as an early bridge between triggering events and exploration within the CoI framework, helping students move from initial exposure and uncertainty toward shared inquiry, sensemaking, and conceptual grounding during the accelerated early weeks of the course.

During the first week, teams analyzed a correct entity–relationship diagram to develop a shared understanding of what a well-formed conceptual solution looks like. Students identified entities, attributes, and relationships, examined alignment with stated business rules, and compared alternative interpretations through peer discussion. This activity was intentionally designed to support initial understanding allowing students to build confidence and establish a common conceptual reference point before engaging in more complex analytical tasks.

In the second week, teams examined a faulty diagram containing embedded errors, omissions, and structural inconsistencies. Students were required to apply previously established principles to identify, explain, and collaboratively correct design flaws. This shift from guided analysis of an accurate model to group-based diagnosis of errors prompted deeper conceptual processing, as students moved from recognizing diagram structures to actively applying modeling criteria, justifying decisions, and reasoning through alternatives. Peer dialogue and reflection were central components of both activities, making thinking visible and normalizing confusion as part of learning.

Following each assignment, students submitted brief reflective summaries synthesizing their own insights, remaining questions, and peer feedback. Overall, this progression from guided recognition to collaborative error detection was designed to reduce extraneous cognitive load while supporting deeper conceptual understanding, stronger co-regulation, and improved readiness for subsequent individual assessment tasks.

Results

RQ1: Engagement patterns

Compared to the prior course design, the redesigned semester showed observable increases in early engagement behaviors. Instructor debrief notes documented more frequent student-initiated communication and peer interaction during Weeks 1–2. Students actively used discussion boards and email communication to coordinate collaborative work and clarify misconceptions. While platform-level learning analytics were not formally analyzed in this brief, engagement indicators increased during the collaborative diagramming activities, where students sustained peer exchange focused on conceptual clarification. These findings are preliminary and descriptive, and future work will incorporate deeper engagement analytics to strengthen these observations.

RQ2: Student perceptions

Student perceptions improved relative to the prior iteration. Overall course effectiveness ratings increased from M = 4.13 to M = 4.75 (5-point scale). Previously lower-rated items showed notable gains, including:

- Contribution to class activities: 3.27 → 4.50
- Perceived learning due to instructional methods: 3.89 → 4.73

Qualitative feedback reflected reduced anxiety, appreciation for collaborative learning, and increased recognition of AI as a support tool rather than a replacement for learning. One student noted, "I was worried I was the only one confused… then I realized we were all learning together."

Responsible GenAI use was explicitly scaffolded through reflection and critique rather than answer generation. Students reported using ChatGPT to request alternative explanations, compare AI interpretations against course materials, and identify weaknesses in their own reasoning before submitting reflections.

RQ3: Early comprehension and performance

Students demonstrated stronger early content comprehension following the instructional redesign, as reflected in instructor-observed performance patterns on Test 1, Part 1. This assessment is specifically designed to evaluate how students apply the fundamental concepts introduced during the first three weeks of the course, with primary emphasis on the foundational material from Weeks 1–2. In Part 1, students are presented with a realistic, real-world database scenario that requires them to analyze business requirements and develop an appropriate conceptual solution in the form of an entity–relationship diagram (ERD).

Importantly, this task aligns directly with the redesigned Week 1–2 instructional sequence, in which students first collaboratively analyzed a well-formed ERD to establish a shared conceptual reference point, and then engaged in structured error analysis of a flawed diagram to identify misconceptions and reasoning gaps. This progression from guided recognition to collaborative diagnosis was intended to strengthen early exploration and conceptual grounding before individual performance was required.

Compared to the prior course iteration, students in the redesigned semester appeared better prepared to interpret problem constraints, identify entities and relationships, and justify modeling decisions. As this study is exploratory and based on secondary instructional evidence, these observations are reported descriptively rather than as a formal statistical comparison.

Discussion and proposed framework

Findings suggest that early cognitive presence can be intentionally scaffolded through formative exploration, collaborative sensemaking, and reflective GenAI engagement. Triggering events were facilitated through peer discussion that normalized confusion and reduced isolation, while exploration was supported through low-stakes practice and error-based examples.

Based on these preliminary outcomes, this paper proposes a Cognitive Learning Redesign Framework for Early Course Weeks, integrating:

1. Early scaffolding of triggering events and exploration
2. Low-stakes formative assessment supporting self-regulation
3. Collaborative error analysis supporting co-regulation
4. Intentional and responsible GenAI use as reflective support

Table 1 synthesizes the proposed framework by aligning early cognitive presence phases with metacognitive supports and corresponding instructional activities.

Table 1. Cognitive Learning Redesign Framework for Early Weeks

Cognitive Presence (CP) Metacognition (M)	**Learning Domain**	**Activities**
W1: Triggering Events (CP)	Emotional	Practice and reflect Example: Ethical Consideration of AI in Education
W2: Exploration (CP)	Cognitive	Brainstorm and search information; trial and errors Example: Correct and Error-Based Diagram Groupwork
W1-2: Self-Regulation (M)	Psychomotor	Organize and plan learning Examples: Learning Quests, other assignments
W1-2: Co-Regulation (M)	Psychomotor	Observe and compare Example: Diagrams, forums

Limitations and future work

This study is limited by its exploratory single-case design and reliance on descriptive evidence drawn from existing instructional sources, including instructor observations and student artifacts from two course offerings. While findings suggest promising early patterns, deeper learning analytics, systematic artifact coding, and multi-course comparisons are needed to strengthen the evidence base.

Future work will extend the framework to programming-intensive modules such as SQL, incorporating AI-supported debugging and collaborative coding challenges, as well as examining how prior experience moderates outcomes in accelerated graduate STEM learning environments.

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