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Comparing Online and Face-to-Face Instruction in Engineering Economy: Impact on Student Learning Outcomes

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Abstract

This study examines the impact of instructional modality on student performance in an undergraduate Engineering Economy course required for Civil and Construction Engineering majors at The Citadel. Engineering Economy provides students with essential tools for addressing financial challenges and is critical for professional success due to its real-world relevance. The course was delivered in two formats: face-to-face (Summers 2023-2024, n = 42) and asynchronous online (Summer 2025, n = 32). Both formats were taught by the same instructor using identical materials, learning objectives, and assessments. The face-to-face section was based on constructivist principles, while the online section applied the Community of Inquiry (CoI) framework with multiple engagement strategies emphasizing interaction with content, peers, and the instructor. Student achievement was measured through midterm and final exams, weekly quizzes, peer teaching activities, and a semester-long assignment. Statistical analysis showed that online students scored higher on midterms, quizzes, and peer teaching but slightly lower on the semester-long assignment and final exam. Preliminary findings indicate that when asynchronous online courses are grounded in established learning theories and intentionally designed to foster engagement, they can yield outcomes comparable to traditional classroom instruction.

Background

Online education has expanded rapidly in higher education as institutions search for scalable and cost-effective approaches to meeting student demand. National reports indicate that nearly one-third of U.S. college students enroll in at least one online course annually, highlighting the importance of evaluating the quality and effectiveness of online learning environments [1]. Early research comparing online and face-to-face modalities often focused on broad performance comparisons and yielded mixed findings. Some studies reported comparable or superior performance in online courses due to increased flexibility and learner control [2], while others suggested lower performance associated with reduced interaction or insufficient instructional support [3], [4].

A common limitation in prior modality-comparison studies is the presence of confounding variables such as differing instructors, inconsistent course materials, or unequal assessments. Tallent-Runnels et al. emphasized that variability in instructional design and instructor characteristics often obscures true differences between modalities [5]. More recent research has stressed the importance of grounding online course design in sound learning theory rather than treating modality as the primary determinant of student success. Means et al. found that online courses designed with intentional engagement strategies often match or outperform traditional courses, particularly when aligned with established pedagogical frameworks [1].

Two frameworks frequently applied in education research are constructivism and the Community of Inquiry (CoI) framework. Constructivist teaching emphasizes active learning, learner-centered instruction, and social knowledge construction, principles shown to improve engagement and conceptual understanding in engineering education [6], [7]. In contrast, the CoI framework explains learning effectiveness as the interplay of three dimensions; cognitive presence, social presence, and teaching presence; which collectively support meaningful educational experiences [8]. Studies applying CoI principles have demonstrated enhanced interaction, deeper reflection, and increased learner satisfaction in asynchronous environments [9], [10].

Despite the extensive literature on online learning, relatively few studies examine differences in performance across specific assessment types such as quizzes, midterms, peer teaching tasks, and semester-long projects. Prior work indicates that asynchronous environments support improved performance on frequent, low-stakes assessments due to flexible pacing and repeated access to content [11], whereas cumulative exams or long-term projects may be more sensitive to differences in self-regulation, motivation, and opportunities for instructor feedback [12], [13]. In engineering education specifically, several studies have found that well-designed online environments can match face-to-face instruction when learning activities are aligned with course objectives and incorporate mechanisms for active engagement [14], [15]. However, hands-on or integrative tasks may still present challenges in asynchronous settings without sufficient support structures [16].

Given these gaps, this study contributes to the literature by comparing two instructional modalities, face-to-face and asynchronous online, within an Engineering Economy course taught by the same instructor using identical assessments. This study differs from much of the existing literature in several important ways: (1) many comparative modality studies suffer from instructor effect or variations in course design. This study controls these confounds by using the same instructor, identical learning materials, and the same assessments in both modalities. This strengthens internal validity and allows performance differences to be attributed more confidently to modality and engagement design rather than instructor or curriculum differences. (2) Much of the in-person vs. online literature simply compares outcomes without clearly grounding courses in theoretical frameworks. This study intentionally applies Constructivism in the in-person section, and the CoI framework in the online section. This allows the study to evaluate not just modality, but how theoretical design choices influence learning outcomes. (3) A substantial portion of prior research compares in-person to synchronous or blended modalities. Fully asynchronous courses remain less studied, especially when designed with robust engagement strategies that mirror social, cognitive, and teaching presence. (4) Most modality comparison research is centered on STEM or general education courses. Very few studies directly examine Engineering Economy, a course with mathematical reasoning, economic decision-making, and multi-step problem-solving, tasks that may respond differently to modality. (5) Prior work often focuses purely on exam scores. This study evaluates performance across midterm; final exam; weekly quizzes; peer teaching activities; semester-long assignment. This allows for a more insightful observation of how modality affects different types of learning tasks.

Study Method

Research Question: Is there a significant difference in assessment scores (assignments, quizzes, midterm, final exam, and peer teaching) between online and in-person sections of an Engineering Economy course?

Course Context: Civil, Construction, and Electrical Engineering majors at The Citadel must complete a two-credit engineering economy course in their junior year. Offered in fall and summer semesters, the course covers principles of engineering economy applied to cost analysis for construction and operation of engineering projects.

Learning Objectives: Students will learn to:

1. Apply economic factors to engineering problems.
2. Calculate nominal and effective interest rates.
3. Determine capitalized cost and equivalent uniform annual worth.
4. Perform rate of return and benefit-cost ratio analyses.
5. Compute depreciation using straight-line, double-declining balance, and MACRS methods.

Course Design: To ensure consistency, all sections follow a structured approach in design, delivery, and assessment. In summer 2025, course was redesigned for a fully online, asynchronous format using the CoI framework to promote deep, meaningful learning. The assignments, peer teaching, assessments, Generative AI statement, and the design of each section are described below.

Assignments

Instead of traditional textbook problems, the instructor redesigned assignments into six weekly problem-based learning tasks in both formats. Each task was set in a realistic context, included extraneous information, and required decision-making. Students in both in-person and online sections submitted a weekly deliverable with qualitative and quantitative components. Assignments were available in Canvas throughout the week and due by Sunday at midnight. This approach, framed within a professional context, encouraged critical analysis, integration of course concepts, and evidence-based solutions, promoting higher levels of cognitive presence.

Peer Teaching

Reciprocal Peer Teaching approach [17] involved students taking turns teaching topics such as applications of time value of money, capitalized cost, present worth analysis, annual worth analysis, future worth analysis, benefit-cost ratio, and depreciation. Each student led a 15-20-minute lesson with learning objectives, problem solving activities, and summaries. The instructor collaborated closely with peer teachers, discussing content, and providing insights and clarifications. This approach enabled students to deepen their understanding of economic topics, develop leadership skills, and overcome challenges in mastering and explaining concepts to struggling peers.

Exams and Weekly Quizzes

Students in both in-person and online sections completed the same quizzes, midterms, and final exams. In-person exams were held during the scheduled evening class period and proctored by the instructor within a 2.5-hour window. Online assessments were delivered through LockDown Browser with Respondus Monitor in Canvas, which restricted printing, copying, accessing other websites or applications, and exiting the quiz before submission. Respondus Monitor also provided automated webcam-based proctoring. After each assessment, the instructor reviewed quiz details and monitored recorded videos.

Generative AI Statement

Following is the Generative AI statement as it appears in course syllabus: This course specifically forbids the use of ChatGPT, Google Gemini, Microsoft CoPilot, Grammarly GenAI tools, or any other generative artificial intelligence tools at all stages of the work process, including preliminary ones. This includes brainstorming, outlining, drafting, revising, or polishing your assignments. Violations of this policy will be considered plagiarism.

CoI Framework in Online Section

The instructor demonstrated teaching presence through deliberate course design, facilitation of discourse, and direct instruction. During the design and organization phase, the instructor followed the best practices in structure and navigation. Each lesson maintained a consistent format that included a reflective question, introduction, learning objectives, and an activity outline. Learning materials were presented in multiple formats to accommodate diverse learning preferences, and assignments were scaffolded to promote progressive knowledge building. Active learning opportunities were intentionally aligned with course outcomes to ensure coherence and relevance. Detailed grading rubrics and clear instructions guided students in completing activities and using required technologies. The instructor facilitated discourse by actively engaging in discussions, providing explicit participation guidelines regarding length, content, netiquette, and timeliness, and responding to students' "muddiest points" [18] to address emerging misconceptions. Finally, the instructor provided direct instruction through timely, supportive, and detailed feedback. Additional individualized feedback and optional Zoom meetings supported deeper understanding of complex topics. Feedback emphasized strengths, offered actionable suggestions, and linked comments to grading criteria and learning goals.

The instructor established a strong social presence through an online orientation with a video walkthrough introducing the course and key topics. Before students gained access, he shared a personal introduction, teaching philosophy, course overview, expectations, and netiquette guidelines. Weekly check-in videos recapped key concepts and previewed upcoming material, and frequent reminders reinforced participation and deadlines. Reciprocal Peer Teaching further enhanced social presence, as students took turns teaching an assigned topic.

The instructor fostered cognitive presence using discussion forums designed to engage students in the exploration, integration, and resolution phases of inquiry. For example, a case-based discussion prompt asked students to assume the role of a consulting team hired by the State Department of Transportation to evaluate two alternative highway construction methods for a 20-year project. Students applied the Annual Worth and Present Worth methods to compare the alternatives at a minimum attractive rate of return of 8% and an analysis period of 20 years and recommended the more economically viable option.

Constructivist Principles in In-Person Section

In the in-person section, the instructor used just-in-time and case-based teaching methods, starting with questions or case studies for analysis. To encourage preparation, students completed web-based pre-class reading responses [19], answering one or two open-ended questions (e.g., "What is the difference between APR and APY?"). Before each lesson, the instructor reviewed these responses and designed activities based on students' needs. Each lesson ended with a One-

Minute Paper [18], where students summarized key concepts, created an exam question, or answered a big-picture question in 60 seconds.

Case-based examples:

1. Students evaluated whether Uncle Mort should rent a house for $2,000 per month or buy it for five years, performing present-worth analysis, creating cash-flow diagrams, stating assumptions, and writing a brief recommendation letter.
2. Students identified an energy-wasting location at home and assessed whether an economic project could reduce waste. They analyzed current processes, proposed improvements, estimated costs, and risks, then submitted a recommendation letter with supporting analysis.

Data collection

Data were collected from three sections of an engineering economy course offered during summers 2023–2025: two in-person sections (2023 and 2024) and one online section (2025). The online section included 32 students, while the two in-person sections had a combined total of 42 students. Variables of interest were the mean scores for midterm and final exams, assignments, peer teaching, and quizzes. The grading weights were midterm (20%), final exam (20%), quizzes (15%), assignments (15%), and peer teaching (8%). The remaining 22% of the grade, allocated to discussions, cases, and reflective assignments, was excluded from this study.

Uncontrolled Variables

To control uncontrolled variables, the instructor collected baseline data before instruction. A five-question pre-test, aligned with course learning objectives, was administered at the start of the semester to assess students' prior knowledge of engineering economy. The pre-test did not count toward the course grade. The standardized mean difference in scores between the in-person and online sections was less than 0.2, indicating no significant preexisting differences. Results show that students entered the course with minimal prior knowledge, which is expected given their limited exposure to these concepts before taking engineering economy.

Analysis and Findings

Online and in-person students completed identical assignments, peer teaching activities, exams, and quizzes. The same instructor taught and graded both sections using standardized solutions and rubrics to ensure consistent evaluation of the learning objectives.

Figure 1 presents the mean scores and standard errors for each section. The in-person sections (assignments: 91.8; Quizzes 95.4; final: 91.6) outperformed the online section (assignments: 91.5; quizzes: 91.6; final: 88) by approximately 0.2–4%. However, the on-line section (peer teachings: 92; and midterm exams: 92.9) outperformed the in-person sections (peer teaching: 90; and midterm exams: 90.9) by approximately 2%.

Results from two sample *t*-tests indicated no statistically significant differences between the sections (midterm 1: $p = 0.30$; midterm 2: $p = 0.35$; final exam: $p = 0.15$).

For each component, mean and standard deviation scores were calculated, and differences between groups were tested using independent t-tests (Table 1).

- **Assignments:** Six deliverables were submitted by both groups. The p-value of 0.90 indicates no significant difference in mean assignment scores.
- **Peer Teaching:** Both groups taught identical engineering economy topics. The p-value of 0.75 shows no significant difference in peer teaching scores.
- **Exams:** Midterm and final exams were identical. P-values of 0.35 (midterm) and 0.15 (final) indicate no significant differences between groups.
- **Quizzes:** Seven identical quizzes were administered. The p-value of 0.03 indicates a statistically significant difference in mean quiz scores between online and in-person students.

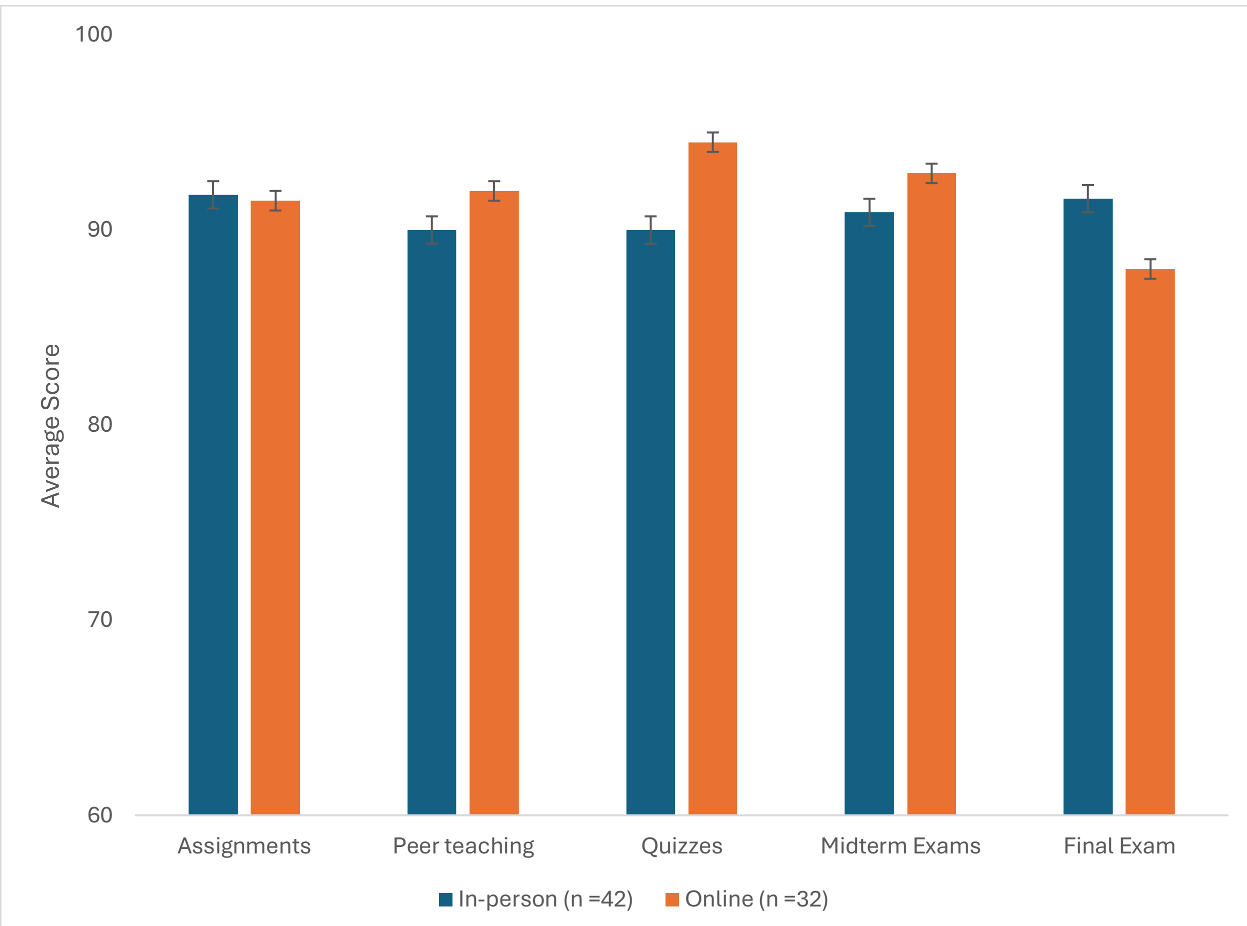

Figure 1. Mean score and standard error associated with each assessment

Table 1. Results of statistical analysis.

Assessment	In-person Mean (n =42)	Online Mean (n =32)	p-value
Assignments	91.8	91.5	0.9
Peer teaching	90	92	0.75
Quizzes	91.6	95.4	0.03
Midterm Exams	90.9	92.9	0.35
Final Exam	91.6	88	0.15

The observed pattern: higher online performance in midterms, quizzes, and peer teaching, but slightly lower in assignments and the final exam, can be explained by several factors. Online students often have more control over pacing and the ability to revisit materials, which supports comprehension and procedural tasks like quizzes and midterms. CoI-based online activities, such as discussion boards and video responses, may have made peer teaching more structured and reflective, leading to deeper processing and better outcomes. In contrast, semester-long assignments and final exams require synthesis, long-term planning, and integrative problem-solving, which can be more challenging for online learners without synchronous prompts. Asynchronous learning also places greater demands on time management, persistence, and help-seeking behaviors; students lacking strong self-regulation may struggle with cumulative assessments. Meanwhile, in-person students benefit from spontaneous, informal interactions such as asking questions during class or overhearing peer explanations, which can support success on large projects and final exams.

CoI's structured engagement strategies (discussion prompts, guided reflections, instructor presence through announcements and videos) likely improved performance on frequent, lower-stakes tasks such as quizzes and peer teaching. In contrast, the constructivist in-person format provided richer real-time social cues, which may have better supported the complex reasoning required for the final exam and the semester-long assignment.

Online students may have started strong (boosting midterm scores) but faced declining engagement, higher cognitive load, and end-of-term burnout, impacting semester-long assignment completion and final exam performance more than weekly assessments. In-person students benefited from immediate help during class or office hours, aiding major assignments and cumulative exams, whereas online students relied on delayed feedback cycles, hindering mastery of advanced topics.

The semester-long assignment required iterative feedback. In-person students likely experienced richer interaction and feedback loops, while online students worked more independently, potentially affecting quality.

Conclusions and future Studies

This study compares in-person and online instructional delivery. Findings indicate that online delivery can be as effective as in-person, provided courses are properly designed.

Due to the small sample size, no conclusive recommendations can be made, and results from the 2023–2025 academic years should not be generalized. Additional data collection across multiple course offerings is needed for more robust conclusions.

Furthermore, withdrawal rates were not tracked in this study, though they may influence effectiveness comparisons. Future research will include withdrawal rates for both delivery modes.

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