

## RETHINKING ONLINE STEM "BEST PRACTICES": EVIDENCE FROM A HISPANIC-SERVING INSTITUTION

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### Abstract

Despite rapid growth in online higher education, evidence-based guidance for online STEM instruction remains fragmented, especially in Hispanic-Serving Institutions (HSIs). This article synthesizes findings from a National Science Foundation-funded mixed-methods project at a public Hispanic Serving Institution in the U.S. Southwest. Guided by a theoretical lens that foregrounds social presence, cognitive presence, and student readiness, the evidence base combines a cleaned Spring 2023 student survey dataset (N = 1,256 overall), 58 usable faculty surveys, descriptive project analyses, 12 faculty interviews, 12 student focus groups, and the peer-reviewed articles that emerged from the grant. Because the published papers used different inclusion rules and theme-specific subsamples, analytic Ns vary across individual findings. Across sources, three conclusions were consistent. First, STEM students valued structured and content-linked practice more than generic interactivity. Second, disciplinary differences were large enough that one-size-fits-all guidance was unreliable. Third, equity-oriented design depended less on lowering expectations than on increasing transparency, instructional presence, and coherent practice opportunities. Students did not favour minimizing lecture altogether; rather, they preferred substantial weekly lecture time when content was clearly organized and segmented. They also rated instructor-designed rehearsal, such as study guides, practice quizzes, and automatically graded practice problems, more highly than optional or loosely connected engagement tasks. Online testing was viewed as less anxiety-producing than in-person testing, but its credibility still depended on alignment among question design, timing, rehearsal, and feedback. Online labs showed promise, especially in hybrid or carefully targeted formats, but remained more context-sensitive than lectures or rehearsal. The article concludes with implications for faculty development, course design, and future implementation research, with lessons relevant both within and beyond U.S. HSI settings.

**Keywords:** *Online education, STEM education, active learning, Hispanic-Serving Institutions, equity in higher education.*

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### 1. Introduction

Online education is now a mainstream part of higher education, yet much advice about digital course design still treats disciplines as interchangeable. That assumption is especially risky in science, technology, engineering, and mathematics (STEM), where conceptual density, rehearsal, testing, and laboratory work often operate differently than in many non-laboratory subjects. It is also risky in institutional contexts, such as the Hispanic Serving Institutions (HSIs) in the United States, where students are more likely to combine study with paid work, family responsibilities, commuting, or uneven access to quiet study space and technology. Although broad reviews often find that online and face-to-face teaching can produce comparable learning outcomes under appropriate conditions, discipline-specific guidance for online STEM education remains relatively limited (Bernard et al., 2004; Nguyen, 2015; Kefalis & Drigas, 2019).

Although HSI is a U.S. policy label, the broader issue examined here is internationally relevant: whether widely promoted online best practices travel well across institutional contexts, student populations, and disciplinary traditions. This article examines that question through evidence from the NSF-funded pilot project – Improving Online STEM Education for Undergraduate Students at HSIs – at California State University, San Bernardino (CSUSB), a public university in the U.S. Southwest. Rather than assuming that generic online practices automatically transfer into STEM, the project asked a more targeted question: which practices remain effective in online STEM courses, which require modification, and which depend strongly on local context?

## 2. Theoretical grounding

As outlined in the original project statement, the inquiry is guided by three interconnected constructs: social presence (e.g., Garrison, Anderson, & Archer, 2023; Kehrwald, 2008), cognitive presence (e.g., Eom, Wen, & Ashill, 2006), and student readiness (e.g., Sieber, 2025). Within this framework, social presence in STEM is not simply about interaction for its own sake, but about purposeful peer engagement that enables rehearsal, protocol practice, and collaborative problem-solving. Cognitive presence addresses whether online instruction sustains intellectual rigor and conveys disciplinary enthusiasm, particularly in explanation-intensive fields. Student readiness underscores that course quality is also contingent on learners' ability to manage pacing, structure, and self-regulation in online environments.

In an HSI context, this perspective draws attention to students who are often balancing employment, family responsibilities, commuting, and uneven access to technology. Taken together, these theoretical lenses allow the project to examine not only where dominant online “best practices” hold, but also where they fall short in online STEM contexts.

## 3. Method

This article is a synthesis paper rather than a new standalone empirical study. It draws on three linked source types produced under NSF Award No. 2225206: (1) the cleaned Spring 2023 CSUSB student and faculty survey datasets; (2) internal project analyses and year-two qualitative follow-up materials; and (3) the peer-reviewed articles generated from the grant. The project ran from October 2022 through September 2025.

The quantitative phase produced 1,256 cleaned student responses overall and 58 usable faculty responses. The most detailed cross-disciplinary analyses centred on four focal disciplines: computer science and engineering, information and decision sciences, mathematics, and psychology. An additional comparison set from geography and environmental studies was collected but was not central to the main disciplinary analyses. Because individual papers applied different inclusion criteria and item-level exclusions, analytic sample sizes vary across published outputs; for that reason, the results below report patterns that were consistent across the project rather than treating a single N as applicable to every analysis.

The qualitative phase extended the survey findings through 12 faculty interviews and 12 student focus groups across the four focal disciplines. Across the project, five themes structured the inquiry: lecture strategies, rehearsal strategies, testing practices, laboratory design, and inclusion/belonging. The present article synthesizes the grant record together with the peer-reviewed papers that emerged from the project, including publications on changing student perceptions over time, online computing labs, rehearsal and testing, virtual avoidance, and active learning in online STEM courses (Hou, Ghasemkhani, Aldirawi, McIntyre, & Van Wart, 2024a; Hou et al., 2024b; Liu, Zhang, McIntyre, Seferoglu, & Van Wart, 2025; McIntyre, Cui, & Hou, 2025; Van Wart et al., 2025).

## 4. Major findings

Three cross-cutting patterns appeared repeatedly across themes. First, students valued structure and content-connected activity more than generic interactivity. Second, disciplinary variation was substantial enough to make universal prescriptions unreliable. Third, equity-oriented online design worked best when it increased clarity, pacing, and instructor presence rather than when it diluted academic expectations.

**Lectures.** The project did not support a simple microlecture rule. Students did not appear to want lecture minimized; rather, they favored substantial weekly lecture time when it was clearly organized, broken into manageable segments, and supported by good audio quality, instructor enthusiasm, and responsiveness. Embedded questions and polling were viewed more positively than breakout-room activities during lectures. In other words, students wanted explanation plus purposeful interaction, not interaction detached from disciplinary mastery.

**Rehearsal and formative assessment.** This was the most consistent finding across project outputs. Students repeatedly rated instructor-created study guides, practice quizzes, and automatically graded practice problems as among the most helpful supports for learning. Required, low-stakes rehearsal was perceived as more helpful than optional rehearsal, and project analyses consistently showed a notable gap between the perceived value of structured practice and the consistency with which courses actually provided it. The active-learning paper reinforced this pattern: most active learning supports were viewed positively, but the highest-ranked ones were instructor-designed and closely linked to assessment rather than generic participation tasks (Van Wart et al., 2025).

Testing. Students generally preferred online exams and reported less anxiety online than in face-to-face testing. At the same time, the project did not suggest that online testing problems had disappeared. Faculty were more skeptical than students about fairness, integrity, and the degree to which online exams reflected learning. The clearest lesson was that assessment quality depended less on surveillance alone than on alignment: realistic time limits, appropriate question design, structured preparation, and timely feedback. The rehearsal-and-testing study reached a similar conclusion, especially in relation to the value of structured preparation before exams (Liu, Zhang, McIntyre, Seferoğlu, & Van Wart, 2025).

Labs. Laboratory instruction showed the clearest boundary conditions. Students were open to online labs, but not without qualification. Online lab formats were most credible when they were used for clearly defined learning goals, supported by recorded demonstrations or tutorials, and backed by visible instructor or teaching assistant support. Hybrid models were often more convincing than fully online substitutes for activities that depended heavily on equipment, tacit demonstration, or rapid troubleshooting. The online computing lab study likewise concluded that post-pandemic online lab design had improved but still required better targeting and stronger support structures (Hou et al., 2024b).

Inclusion and belonging. Most students reported generally positive online classroom climates, and the overall picture was stronger than deficit-based assumptions might predict. Even so, the evidence was not uniformly positive. A substantial minority reported weaker belonging, and about one in ten students reported feeling minimized in online classes. The project's equity implication was therefore not to reduce rigor, but to reduce avoidable ambiguity. Clear expectations, accessible support, visible presence, and predictable opportunities for practice appeared more central to equitable online STEM learning than symbolic appeals to inclusion alone.

Taken together, the findings suggest that STEM students do not reject active learning in principle. They reject forms of activity that feel weakly connected to mastery. Across the project, the most valued supports were those that helped students understand what they needed to learn, practice it in a structured way, and prepare for formal assessment.

## 5. Discussion and implications

The project's main contribution is both conceptual and practical. Much conventional guidance on online teaching treats more interaction as inherently better and often assumes that shorter videos, more discussion, and more breakout-room time will reliably improve outcomes. The evidence synthesized here suggests a more conditional view. In online STEM settings, students wanted active learning, but they preferred forms of active learning that were explicitly connected to content mastery, rehearsal, and assessment.

This finding matters beyond the U.S. HSI context. The specific policy label HSI is U.S.-specific, but the underlying conditions are not. Many institutions around the world serve large numbers of commuter students, working students, first-generation university students, and students with uneven access to study space or technology. In such environments, instructional structure is not the opposite of equity. It is often one of the main ways equity is enacted in practice.

Several implications follow. First, faculty development for online STEM teaching should be discipline-sensitive rather than built around universal slogans. Second, course design should not assume that the best solution is always to reduce lecture time aggressively; a better goal is to provide substantial explanation in a form that is well segmented, navigable, and responsive to student questions. Third, low-stakes, instructor-designed rehearsal should be treated as core course architecture rather than as optional enrichment. Fourth, online labs should be approached as a design challenge, not a binary question of whether they are possible. Some learning outcomes are well served by hybrid models, whereas others can be achieved online only when goals, materials, and support structures are carefully aligned. Finally, institutions seeking more equitable online STEM environments should prioritize transparency, pacing, presence, and coherent practice opportunities.

A further implication concerns evidence use itself. The project suggests that broad online best practices should not simply be imported from non-STEM contexts without testing whether they fit the cognitive and practical demands of STEM subjects. Context-sensitive adaptation is not a retreat from evidence-based teaching; it is a condition of applying evidence well.

## 6. Limitations and future research

Several limitations should temper interpretation. This article synthesizes results from one institution, even though that institution is large and demographically diverse. The published papers also draw on overlapping but not identical subsamples, meaning that theme-specific *N*s vary. In addition, much

of the evidence concerns perceptions of helpfulness, fairness, belonging, or preparedness rather than direct measures of achievement or longer-term progression. These are important outcomes in their own right, but they do not answer every question about performance.

Future research should therefore move in three directions. First, the design principles identified here should be tested through implementation studies of model courses across different institution types, including HSIs, community colleges, and research-intensive universities. Second, future work should connect perception data more directly to achievement, retention, and progression in gateway STEM courses. Third, additional research is needed on discipline-specific lab design, belonging among first-generation and historically underrepresented students, and the opportunities and risks created by AI-enabled feedback tools in practice-heavy courses.

## 7. Conclusion

This project shows that online STEM instruction can be rigorous, inclusive, and effective when course design matches disciplinary demands and student realities. The most defensible conclusion is not that online STEM has a single best model. Rather, the project points to a set of stronger design principles: substantial but well-organized explanation, meaningful structured practice, assessment aligned with preparation, and deliberate instructional presence. Those principles travel better than generic formulas, both within HSIs and in other institutions serving students whose success depends on clarity, flexibility, and coherent academic support.

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