2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #53374

Teaching at the Teachable Moment Using Asynchronous Videos Combined With Live Interactions

Angelica Solano Salgado, University of South Florida
Scott Jeffree Bartlett, University of South Florida
Anway S. Pimpalkar, Johns Hopkins University
Jeremy Brown
Prof. Kyle B Reed, University of South Florida

Kyle Reed is a Professor in the Department of Mechanical and Aerospace Engineering at the University of South Florida. He performs research on human-robot interaction, rehabilitation robotics, haptics, and engineering education.

Teaching at the Teachable Moment Using Asynchronous Videos Combined With Live Interactions

Abstract

Motivation: Online instruction often requires instructors and learners to trade flexibility for interaction. Asynchronous (watch on your own) video lectures support self-paced study but typically separate student questions and instructor feedback from the moment of conceptual difficulty, as is available in live classroom settings. This paper addresses this gap by supporting teaching at the teachable moment within asynchronous learning environments.

Platform Description: We present an interactive video platform, "Choose Your Own Lecture", that embeds optional, question-and-response supports directly within the lecture timeline. Students can view prerecorded lectures with standard playback controls (pause, rewind, skip, change playback speed) and access previously asked questions near relevant timestamps, or submit new questions tied to the current moment in the video via live or delayed response options. Instructor or teaching assistant responses are recorded and anchored to the lecture, forming an evolving repository of contextualized explanations that learners can choose to watch or skip without disrupting their learning flow.

Study Design: The approach was piloted in two engineering courses at two institutions over five academic semesters, spanning both hands-on and flipped classroom formats. Student perceptions were collected via externally administered surveys consisting of item-level Likert questions assessing the perceived value of core platform affordances (e.g., self-paced controls, asking questions at moments of confusion, and viewing prior questions and responses), as well as questions capturing overall usefulness and willingness to adopt this platform in other courses. Survey results are reported descriptively using item means and, where appropriate, percentages selecting endorsed response categories. In parallel, platform usage logs were analyzed to characterize engagement with self-paced controls and time-anchored response videos, with course-level engagement examined in relation to final course grades.

Key Findings: Survey results indicate positive perceived value of the platform across instructional contexts, with students in the hands-on course reporting higher perceived benefits and recommendation rates than those in the flipped classroom course. Across both contexts, students reported that self-paced viewing combined with access to time-anchored instructor responses supported learning and interaction with the instructor. Platform usage data show substantial use of self-pacing controls and engagement with shared responses, with interaction patterns varying by lecture and instructional context.

Implications: Together, these results support a teachable-moment hypothesis in which the most informative engagement signals occur within specific instructional episodes that introduce key concepts. The findings further suggest that time-anchored response interactions may provide a useful indicator of where learners benefit from additional scaffolding in asynchronous engineering instruction, particularly at points of conceptual difficulty that can guide targeted instructional refinement.

Keywords: asynchronous learning; self-paced learning; learning analytics; interactive video; formative feedback; just-in-time feedback; student engagement; video-based learning

Introduction

Online and hybrid instructional models are increasingly common in engineering education, offering flexibility and access for students with diverse schedules, backgrounds, and learning needs. Asynchronous video lectures have become a dominant mechanism for content delivery, particularly in large-scale online learning environments, due to their scalability and support for self-paced learning. However, this flexibility often comes at the cost of reduced interaction and delayed instructor feedback. In contrast, synchronous instruction enables real-time questioning and clarification but requires uniform pacing and scheduled attendance that may not align with how students process complex technical material. These tradeoffs are especially pronounced in engineering courses, where learning is cumulative, and misconceptions can compound quickly.

A central challenge in online engineering instruction is not merely providing access to content, but delivering instructional support at the moment it is most useful. Students frequently encounter confusion while engaging with technical material outside scheduled class time, yet opportunities for clarification are often delayed or disconnected from the instructional context. When feedback arrives too late, students may disengage or reinforce misconceptions, reducing the instructional value of interaction despite its quality.

Learning science research [1,2] highlights the importance of the teachable moment, when learners are actively grappling with challenging material and are most receptive to guidance. In engineering education, these moments commonly arise during derivations, diagram interpretation, or application of concepts to new problems. Traditional asynchronous video instruction, however, treats lectures as static artifacts and offers limited support for responding to these moments as they occur, while synchronous sessions impose a single pace that may not align with individual learning trajectories.

This paper presents an instructional architecture designed to support teaching at the teachable moment within asynchronous video-based learning environments. The approach integrates self-paced prerecorded lectures with optional, temporally aligned instructor-mediated interaction embedded directly within the learning trajectory. Students can access additional explanations precisely when confusion occurs without disrupting their progress or constraining the learning experience of others. Learning analytics are used to examine how students engage with this just-in-time instructional support, enabling instructors to identify patterns of difficulty across learners and informing refinement of instructional materials. The approach has been piloted across five semesters in two engineering courses at two institutions, spanning both flipped classroom and hands-on instructional contexts.

Background

The instructional architecture described in this paper is implemented through an interactive video platform designed to support teaching at the teachable moment while preserving the flexibility of asynchronous learning. Prior research has documented persistent tradeoffs between synchronous and asynchronous instructional modes, with synchronous environments supporting immediacy and interaction, and asynchronous formats providing learner control but often delaying feedback [3,4,5]. This “Choose Your Own Lecture” (CYOL) platform integrates these affordances by embedding temporally aligned instructor-mediated interaction directly within prerecorded lecture videos, allowing interaction to emerge organically from student engagement.

Lecture Viewing and Self-Paced Interaction

Figure 1 (left) illustrates the primary lecture-viewing interface. Students engage with prerecorded lectures using standard playback controls, including pause, rewind, skip, and variable playback speed. These controls support self-regulated learning by allowing students to adjust pacing based on prior knowledge, cognitive load, and learning preferences [3,6]. This flexibility is particularly important in engineering courses, where students often revisit derivations, diagrams, or worked examples.

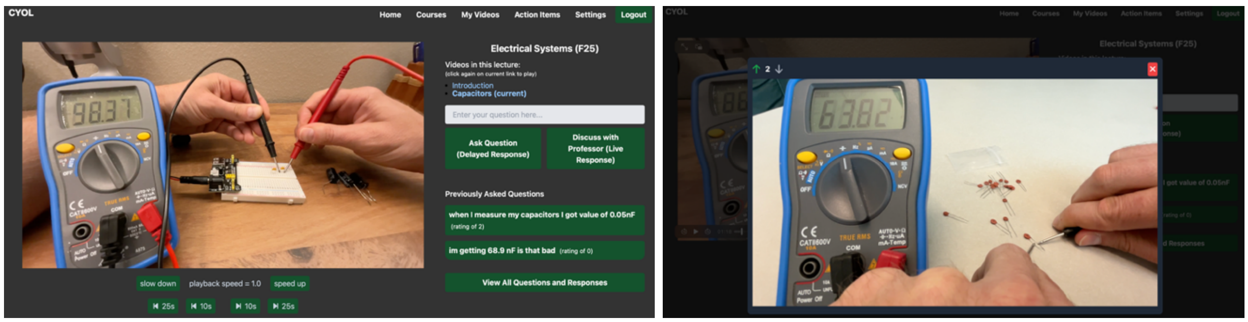

Figure 1. CYOL Interface While Watching the (left) Main Lecture and (right) Response Video

In addition to video playback, the interface displays previously asked questions associated with specific points in the lecture timeline. As students progress through the video, questions submitted by prior students at nearby timestamps become visible. Each question appears as an optional element, allowing students to engage with the associated response or continue watching uninterrupted. This design aligns with autonomy-supportive instructional practices that allow learners to control when and how they access additional instructional support [7,8].

Students may also submit new questions directly from the lecture interface at the moment confusion arises. Questions are tied to the current timestamp, preserving instructional context. To accommodate different instructional needs, questions can be submitted either through a Live Response option for immediate assistance during designated interaction periods or a Delayed Response option that allows asynchronous follow-up without disrupting the learning flow. Prior work suggests that learners often prefer asynchronous question submission while still valuing timely feedback [9,10]. The CYOL platform allows students to choose whether they need an immediate answer or if they can continue and receive an answer at a later time.

Instructor Responses and Time-Anchored Explanations

Once a question is addressed by the instructor or teaching assistant, the response video is anchored to the corresponding point in the lecture timeline. Selecting a question pauses the main lecture and presents a short response video answering the question. Figure 1 (right) shows the interface when a student selects a question and views the response.

Over time, these time-anchored responses form a growing repository of contextualized explanations accessible to current and future students, and students can rate the videos. Engagement with responses remains optional, enabling individualized learning pathways without requiring pre-scripted branching or algorithmic adaptation. This approach shares conceptual similarities with adaptive learning systems while avoiding the substantial upfront development costs often associated with such platforms [11,12,13].

Course-Level Navigation and Scalability

Beyond in-video access, students can view a summary list of all questions associated with a lecture or search across questions within a course. This functionality supports review and exam preparation and extends the instructional value of responses beyond the initial viewing session. The CYOL platform is designed to scale to larger enrollment courses while maintaining instructor moderation and student privacy; all responses are instructor-reviewed, and student identities are not publicly visible.

Methods

Participants

The instructional approach was examined at two universities across five academic semesters, encompassing multiple course formats. At the University of South Florida (USF), CYOL was integrated into an undergraduate "Electrical Systems for Mechanical Engineers" course over three semesters. In this setting, students worked with take-home electronics laboratory kits, and the platform's instructional videos provided guided, step-by-step support for circuit construction and analysis, functioning similarly to an at-home laboratory experience. At Johns Hopkins University (JHU), the platform was used over two semesters in a graduate Haptics course delivered in a flipped classroom format, where students engaged with conceptual and analytical content through the video-based system and class time was focused on answering questions.

Use of CYOL was a required component of each course and was independent of participation in the research study. Students were invited to participate in the study on a voluntary basis, and only data from those who provided signed informed consent were included in the analysis. All research procedures were reviewed and approved by the institutional review boards at both universities.

Data Collection

To evaluate student perceptions of the instructional approach, survey data were collected during each semester. Survey administration and data management were handled by an external evaluation firm, Magnolia Consulting, to maintain confidentiality and minimize potential instructor influence. Instructors were not aware of which students had agreed to participate in the study until after the semester had concluded. All survey responses were anonymized prior to analysis, and no identifying information was available to the instructional team during course delivery.

The CYOL platform records timestamped learner actions during video playback (e.g., pausing, skipping forward or backward) as well as interactions with the question-and-response layer (e.g., submitting questions and viewing response videos). These logs provide a record of how students regulate pacing and engage with instructor-mediated support during asynchronous learning.

Data Analysis

Each survey question was analyzed individually and pooled across semesters within the same course to descriptively summarize student perceptions, rather than to compare outcomes across semesters. Course-level aggregation was used to provide a robust view of engagement patterns that could be examined across instructional formats without assuming fine-grained alignment between specific lectures and assessments. Although results from the two courses are reported separately, no inferential statistical comparisons were conducted because the courses differ in institution, instructor, and instructional structure; instead, the analysis examines whether similar engagement patterns and perceived benefits emerge across distinct instructional contexts. Because the survey was designed to capture instructional perceptions rather than latent psychological constructs, items were interpreted individually and descriptively, with distributional summaries included to illustrate variability within contexts rather than to support cross-institutional statistical comparison.

To complement these perception-based measures, CYOL interaction logs were analyzed to characterize overall patterns of engagement with the platform. Interaction features were computed at the course level by aggregating logged events across all lectures for each consenting learner. These features included indicators of pacing regulation (pause and skip-backward rates), navigation behavior (skip-forward rate), engagement with the question-and-response layer (response interaction count and number of response videos viewed), and persistence through the lecture timeline (last-seen time).

Assessment outcomes included final course grades. CYOL interaction features were linked to assessment data using deidentified identifiers, and associations between course-level engagement features and final course grade were examined using bivariate correlation analyses. Course-level aggregation avoids assuming a direct mapping between specific lecture segments and individual assessment items, but it also constrains interpretation: summarized engagement features reflect broad study behaviors rather than concept-specific mastery and may be influenced by contextual factors such as course format, cohort composition, and assessment design. Correlation magnitudes are therefore interpreted as descriptive signals rather than evidence of causal effects or instructional impacts.

Results

Participants and Response Rates

At USF, 161 students across three semesters agreed to participate in the study; these students were predominantly in their third year, reflecting the typical timing of this course in the curriculum. Response rates were 95.4% (of 62 who agreed to participate), 95.8% (of 46), and 96.4% (of 53) for the first, second, and third semesters, respectively. At JHU, 65 students across two semesters agreed to participate in the study, with most students in their first year of a master’s program. Response rates were 91.7% (of 44) and 100% (of 21) of those who agreed to participate for the first and second semesters, respectively.

Lecture Style Differences

The survey asked students, “In what ways has having access to other students’ questions, which were similar to my own, helped in overcoming challenges in this course?” Overall, 76% (weighted average) of respondents indicated that access to a repository of previously asked questions supported their learning. Differences were observed across instructional formats: 64% of students in the flipped classroom course reported this benefit, compared to 84% of students in the hands-on course.

Student ratings of the content when using the CYOL platform compared to traditional lecture instruction are summarized in Figure 2. Generally, students reported a positive perception of course engagement (3.55/5) and content interest (3.56/5). However, there was a difference in perception between the two courses. Students in the hands-on format were more likely to report higher engagement with the content (3.79/5) and content interest (3.73/5) when using the platform than students in a flipped classroom course (2.96/5 and 3.16/5, respectively).

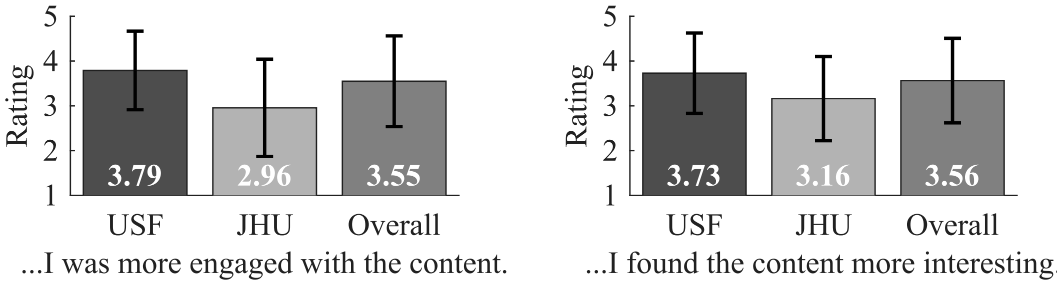

Figure 2. Survey: “Compared to a Traditional Lecture (not using CYOL), in this Course…” Likert Scale: 1 = Strongly Disagree … 5 = Strongly Agree. Error bars show standard deviation.

Figure 3 summarizes the students' ratings of the CYOL platform's features in terms of perceived helpfulness. The option to watch lecture videos at one’s own pace was the highest-rated feature overall (3.69/4), and the ability to ask questions for both immediate (3.24/4) and delayed response (3.13/4) was also highly rated. Among the students in the hands-on format, the rating for watching lectures at one’s own pace was higher (3.81/4) than for those in the flipped classroom format (3.40/4). Students in the hands-on format reported a higher rating for immediate (3.42/4) and delayed response (3.26/4) compared to the flipped classroom version (2.87/4 and 2.86/4, respectively), although all were on average viewed as helpful or very helpful.

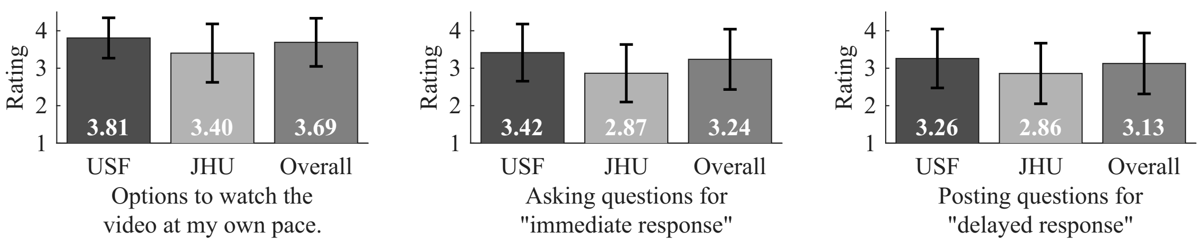

Figure 3. Survey: “How helpful were the following features of CYOL for your learning in this course?” Likert scale: 1=Not at all helpful … 4 = very helpful. Error bars show standard deviation.

Instructional Method Effectiveness

The survey asked students, “Would you recommend instructors in your other courses use CYOL?” Overall, 83% of respondents indicated that they would recommend the platform. Recommendation rates differed by instructional format, with 68% of students in the flipped classroom course indicating they would recommend the platform, compared to 92% of students in the hands-on course.

Student ratings of the effectiveness of different instructional methods in promoting student learning are summarized in Figure 4. Across all respondents, in-person instruction received the highest rating (3.33/4), followed closely by online instruction using the CYOL platform (3.23/4) and all other instructional methods had lower ratings. Differences emerged when comparing the two course formats. Students in the flipped classroom course rated in-person instruction higher (3.41/4) than students in the hands-on course (3.28/4), while rating online instruction with the platform lower (2.96/4). In contrast, students in the hands-on course rated online instruction with the platform higher than in-person instruction (3.34/4 vs. 3.28/4).

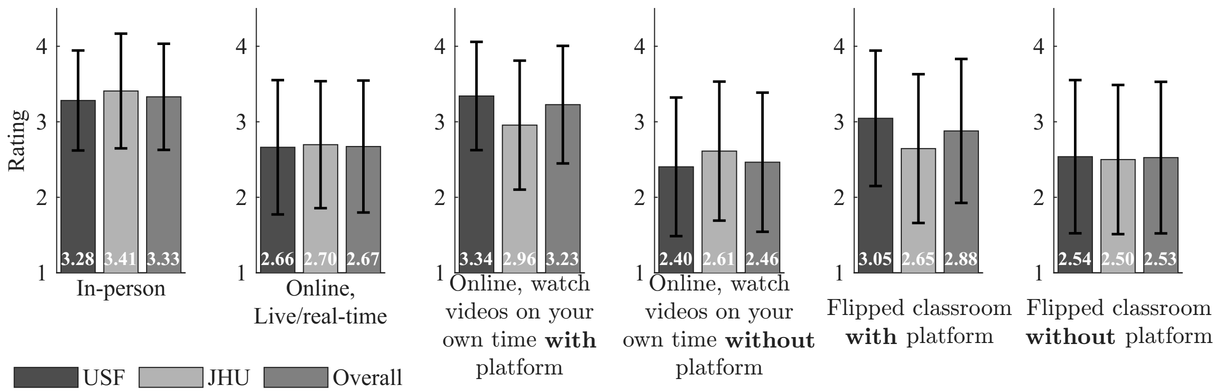

Figure 4. Survey: "How Effective do you think the following instructional methods would be in promoting student learning?" Error bars show standard deviation.

Learning Analytics and Performance Associations

To characterize how CYOL interaction traces relate to overall course performance, usage patterns were summarized across the two courses. USF employed a hands-on, project-based approach, whereas JHU used a flipped classroom format. Tables 1 and 3 report, for each semester within each university, the number of unique learners and total counts of pause, skip-forward, skip-backward, response-play events (total response videos played), and response users (number of students who watched at least one response video). Tables 2 and 4 present the corresponding per-learner rates (e.g., pauses per learner), where interaction counts are normalized by the number of unique learners and include all interactions with that lecture, including repeated visits over time. This normalization enables comparison across scopes with differing participation levels. USF included an additional homework-help scope (HW3), while JHU data reflect lecture scopes only.

Because response videos are anchored to specific lecture timestamps and persist across semesters, the size of the response repository differed across courses and offerings. In the USF circuits course, relevant response videos were carried forward between semesters, resulting in growth from 56 response videos in the first semester to 91 in the second and 120 in the third. Responses that were specific to transient or semester-dependent issues (e.g., logistics related to materials) were excluded from carryover to maintain instructional relevance. In contrast, at JHU, changes to the lecture content did not allow the response videos to be reused across semesters. As a result, the total number of response videos was smaller, with 8 response videos available in the first semester and 4 in the second. These differences in repository size provide important context for interpreting response-play events and response-user counts across institutions.

Table 1. Participation summary (USF). HW-homework; L-Lecture

Lecture	Students			Pauses			Skip forward			Skip backward			Response plays			Response users		
	F24	S25	F25	F24	S25	F25	F24	S25	F25	F24	S25	F25	F24	S25	F25	F24	S25	F25
HW3	47	43	42	1720	4016	3835	92	116	305	116	170	516	27	142	197	15	29	27
L05	62	46	53	3392	3282	5482	578	693	840	672	773	1650	83	104	204	24	31	33
L09	58	45	52	3233	3543	4638	898	1040	957	403	583	689	7	50	91	4	22	25
L11	41	37	40	1206	577	1155	483	285	454	167	193	223	24	5	9	12	4	6
L14	55	46	50	2729	2782	3447	870	658	545	657	660	865	19	125	161	10	29	29
L19	53	43	50	3941	3977	4408	1107	766	1646	811	740	1371	47	77	106	24	29	26
L23	51	43	50	3493	3242	4972	1019	793	1187	827	829	1375	24	53	88	13	21	27
average	**52**	**43**	**48**	**2816**	**3060**	**3991**	**721**	**622**	**848**	**522**	**564**	**956**	**33**	**79**	**122**	**15**	**24**	**25**

Table 2. Participation summary (USF). Activity per learner

Lecture	Pauses per learner	Skip forward per learner	Skip backward per learner	Response plays per response user
HW3	72.5	3.9	6.1	5.2
L05	75.5	13.1	19.2	4.4
L09	73.6	18.7	10.8	2.9
L11	24.9	10.4	4.9	1.7
L14	59.3	13.7	14.5	4.5
L19	84.4	24.1	20.0	2.9
L23	81.3	20.8	21.0	2.7
average	**67.4**	**15.0**	**13.8**	**3.7**

Table 3. Participation summary (JHU). L-Lecture

Lecture	Students		Pauses		Skip forward		Skip backward		Response plays		Response users	
	F24	F25	F24	F25	F24	F25	F24	F25	F24	F25	F24	F25
L05	44	21	762	556	28	62	43	26	58	2	17	2
L09	28	15	366	206	66	113	62	20	19	4	4	2
L13	16	7	152	114	0	187	12	23	0	0	0	0
L14	9	11	66	86	3	23	0	18	0	0	0	0
L15	12	12	102	117	1	44	6	7	0	0	0	0
average	**22**	**13**	**289**	**216**	**20**	**86**	**25**	**19**	**15**	**1**	**4**	**1**

Table 4. Participation summary (JHU). Activity per learner

Lecture	Pauses per learner	Skip forward per learner	Skip backward per learner	Response plays per response user
L05	20.3	1.4	1.1	3.3
L09	13.2	4.1	1.9	3.7
L13	11.7	8.2	1.6	-
L14	7.7	1.3	0.9	-
L15	9.1	1.9	0.6	-
average	**12.4**	**3.4**	**1.2**	**3.4**

Together, Tables 1–4 and Figure 5 provide descriptive summaries of how students interacted with CYOL across instructional formats. The hands-on course at USF exhibited higher overall volumes of interaction events, including pausing and skip-back navigation, compared to the flipped classroom course at JHU, which showed lower interaction volumes across all event types. Response-play events and response users capture participation in the time-anchored help layer and, when considered alongside pacing-related measures, differentiate general navigation activity from engagement with instructor-mediated responses.

To examine associations between aggregated interaction patterns and academic performance, course-level engagement features were assessed in relation to final course grade. Course-level behavior, aggregated across all lectures at USF, showed small associations with performance (Figure 5). Bivariate correlations indicated that the strongest association was observed for the retention proxy (last-seen time; $r = 0.207$). Response interaction count also showed a positive association ($r = 0.132$), while pause rate was lower ($r = 0.085$), and skip-forward and skip-backward rates were near zero ($r = -0.012$ and $r = -0.019$, respectively). These results describe the relationship between course-level CYOL engagement measures and final course grades without implying causal effects or concept-specific learning outcomes.

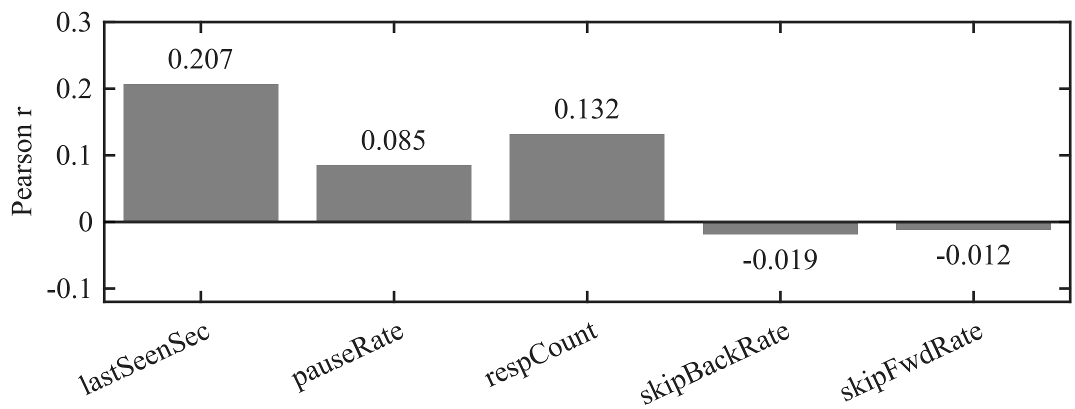

Figure 5. Global behavior associations with final course grade

Limitations

The findings reported here are descriptive and correlational and should not be interpreted as causal effects of CYOL use on academic performance. Final course grades reflect multiple factors beyond engagement with video-based instruction, including prior preparation, study behaviors outside the platform, assessment design, and other instructional activities.

Engagement analyses were conducted using aggregated, course-level interaction features derived from CYOL logs. As a result, these analyses do not isolate how interaction with specific lectures or concepts relates to individual assessments, nor do they capture learning activities that occurred outside the video environment. Because interaction features capture related aspects of learner behavior (e.g., pausing and rewatching), some degree of overlap among predictors is expected.

Discussion

Observed differences between the two deployments should be interpreted as differences between instructional contexts rather than as institutional effects. In this dataset, university, course format, course level, instructor, and assessment design are intertwined, limiting attribution to any single factor. Accordingly, the contrasts reported here are intended to characterize how the CYOL platform is used and perceived under two authentic implementations, and to motivate testable hypotheses about contextual moderators (e.g., task demands during viewing, pacing expectations, and the maturity of the reusable response repository) for future work.

A prominent observation from the CYOL usage data was the high volume of student interaction events in the circuits course at USF, particularly pausing behavior. Although the magnitude of these interactions was initially unexpected, verification of the CYOL interaction logs confirmed that they reflected valid student activity. Pause events occurred both when students rewatched specific lecture segments and when playback was stopped to view time-anchored response videos. The prevalence of pausing is consistent with the hands-on nature of the course, in which students constructed circuits alongside the instructional videos and frequently needed to stop playback to complete physical tasks before proceeding. Patterns of skipping behavior provide additional context: skip-forward events likely reflect encounters with familiar material, while skip-backward events likely indicate points where content was missed or required review. Together, these behaviors characterize active regulation of pacing rather than passive video consumption.

In contrast, the JHU course followed a flipped classroom format with fewer opportunities for application during video viewing. Correspondingly, interaction volumes were lower, with fewer response videos viewed and fewer question-related events recorded. Despite this reduced interaction, survey responses indicate that students still perceived value in the CYOL platform, though to a lesser extent than students in the hands-on course. This contrast suggests that while the platform provides benefits across instructional contexts, its perceived value is moderated by course structure and task demands. Courses in which learners benefit from pausing, revisiting explanations, or reflecting at different points (such as hands-on or problem-driven instruction) may therefore be especially well suited to time-anchored support. Because course structure, student population, and instructor practices differ across deployments, the present data do not support attributing these differences to "university" as an isolated factor.

An additional pattern emerged across semesters in the hands-on course at USF. Because response videos are anchored to specific lecture segments and persist across semesters, each subsequent offering of the course had access to an expanded repository of explanations. As this repository grew, response video viewing increased while the number of newly submitted questions declined. This pattern reflects a cumulative instructional process in which recurring or fringe questions are increasingly addressed through reusable explanations, improving instructional efficiency while expanding coverage of student needs over time. Accordingly, response video viewing and the fraction of response users should be interpreted in light of exposure (how many reusable responses were available and stable) in addition to students' willingness to use the feature. This pattern is consistent with increasing student benefit over time while reducing redundant instructor effort, but the instructor is still available as needed.

Perceived benefits of the CYOL platform varied across instructional formats. Students in the flipped classroom course reported lower, though still positive, perceived benefits than students in the hands-on course, reflecting differences in instructional goals, task demands, and how often learners need to pause, reflect, or seek clarification. When opportunities for application or problem-solving during viewing are limited, the immediate value of pausing and time-anchored clarification may be less apparent, even if the same functionality remains useful for later review and targeted just-in-time help. Prior work similarly suggests that the perceived usefulness of instructional technology depends on how directly it supports task demands [14]. Nevertheless, a majority of students in the flipped classroom course indicated that they would value access to this type of support in other courses, suggesting that the platform's benefits (timely, contextual clarification without leaving the instructional timeline) generalize across instructional settings and institutions [15,16].

A central contribution of the CYOL platform is that it produces a timestamped, lecture-anchored trace of how learners regulate pacing and seek help during asynchronous learning. These behaviors align with theoretical accounts of self-regulated learning, in which learners monitor understanding, allocate effort, and select strategies such as pausing, rewatching, or requesting assistance in response to perceived difficulty [17,18]. Because these behaviors are captured as fine-grained interaction events rather than coarse end-of-course measures, they provide a complementary lens on engagement that can inform both research and instructional decision-making. Prior learning analytics work similarly emphasizes that clickstream traces can serve as unobtrusive indicators of metacognitive and motivational processes when interpreted in context [19].

At the course level, aggregated engagement features (including pausing, skipping, and response interactions) showed small but interpretable associations with final course grades at USF. Throughout, "per learner" rates refer to event counts normalized by the number of unique consenting learners (and therefore include repeated interactions over time), rather than being normalized by the number of viewing sessions. This modest relationship is unsurprising in engineering courses, where grades aggregate multiple components such as homework, projects, exams, and independent study, many of which occur outside the video environment. In this context, course-level engagement summaries are best interpreted as indicators of general persistence and study habits rather than direct measures of concept mastery. A natural next step is to move from course-level aggregation to student-level and episode-level analyses (e.g., segment-specific engagement aligned to particular concepts or tasks), which would better separate individual learning trajectories from contextual differences across courses. Prior work likewise reports that aggregated behavioral traces can relate to performance, but with limited explanatory power when outcomes are broad and multiply determined [20,21,22].

The response interaction count merits particular attention because it directly indexes engagement with the question-and-response layer central to the teachable-moment design. In the CYOL logs, response interactions include viewing response videos and submitting delayed follow-up questions tied to specific lecture timestamps. Unlike pausing or skipping, which can reflect a range of behaviors such as note-taking or time management, response interactions more plausibly reflect deliberate support-seeking and clarification [23,24]. The observed association between response interactions and course performance is consistent with the interpretation that learners use anchored explanations to resolve confusion while remaining within the learning context, consistent with research on effective instructional video design emphasizing segmentation, active processing, and just-in-time guidance [25].

Taken together, these findings are consistent with the teachable-moment hypothesis motivating the platform design. When learners encounter confusion, instructional support is most effective when embedded within the ongoing activity and delivered at the moment of need [15]. The CYOL platform's time-anchored explanations function as reusable scaffolds by providing targeted assistance linked to specific content and instructional moments, benefiting both the original learner and peers encountering similar difficulties [16]. Although the analyses are correlational, they demonstrate that the platform's just-in-time support structure is behaviorally visible in how students regulate pacing and engage with instructional resources.

From an instructional standpoint, these engagement traces have practical value. Rather than relying solely on post-hoc assessments or end-of-course feedback, instructors can use CYOL logs to identify lectures or segments that consistently prompt increased pausing, rewatching, or support-seeking. This visibility supports targeted refinement of instructional materials and allows instructors to concentrate effort on recurring points of difficulty by producing reusable, time-anchored explanations instead of repeatedly addressing similar questions through email or office hours. In this way, the CYOL platform supports learner autonomy and instructor efficiency while preserving the flexibility that motivates asynchronous instruction.

Instructor-Facing Real-Time Analytics

This subsection presents an illustrative example of CYOL's instructor-facing analytics capabilities and is included to demonstrate potential instructional uses rather than to report additional statistical analyses. Figure 6 summarizes real-time engagement analytics for a single lecture in an undergraduate circuits course taught at USF in Fall 2024. In this 51.5-minute lecture, several segments have a concentration of pauses and skip backward events (largest between seconds 2190 and 2400), corresponding to segments with elevated student interaction. The instructor can click on the graph to bring the video (not shown here) to that time point to help understand what content was being discussed at those times and why the increased student engagement occurred at those time points. These analytics are presented as an illustrative capability, but the systematic study of how instructors act on these signals is an important direction for future work.

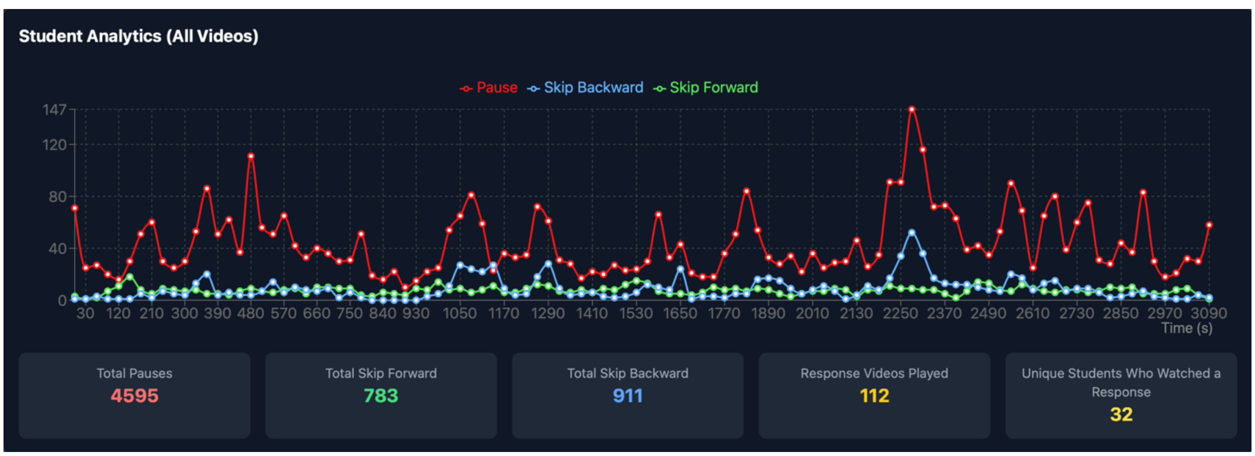

Figure 6. Real-Time Engagement Analytics for Fall 2024 Circuit Lecture at USF

Conclusions, Limitations, and Future Work

The evidence presented in this study suggests that, while perceptions of the CYOL platform's benefits differed across instructional formats, students across both hands-on and flipped classroom courses recognized the overall value of the platform relative to traditional lecture delivery without embedded support. Students reported that the ability to control pacing and access time-anchored instructor responses supported content engagement, interest, and their ability to overcome course challenges, indicating that the platform's core affordances are meaningful across instructional contexts.

In addition to these perception-based findings, course-level learning analytics indicate that aggregated interaction traces provide a complementary view of how students engage with asynchronous instruction. Although associations between overall engagement features and final course grade were modest, they suggest that learners who persist further through lecture timelines and engage more frequently with instructor responses tend to perform slightly better at the course level. At the same time, the limited explanatory power of course-level models reinforces that video engagement represents only one component of learning in engineering courses, which integrate multiple assessment and study modalities.

Unlike social annotation tools (e.g., text- or document-centered discussion platforms), the present CYOL platform is explicitly designed around time-anchored, instructor-mediated support within video-based instruction. Rather than emphasizing peer discussion layered onto static content, the architecture embeds reusable explanations directly within the lecture timeline, enabling clarification at the moment confusion arises without fragmenting attention or requiring learners to leave the instructional context. This design supports scalability by allowing instructor responses to persist across semesters and provides analytics that are tightly coupled to instructional episodes, offering instructors actionable insight into where and when learners struggle.

Taken together, these results support CYOL's underlying teachable-moment design by demonstrating that just-in-time, contextualized support is both behaviorally visible and valued by students. The platform enables learners to regulate pacing and seek clarification at moments of confusion while preserving the flexibility of asynchronous instruction. For instructors, the resulting engagement traces offer an interpretable signal of where students encounter difficulty, creating opportunities to refine instructional materials and produce reusable, time-anchored explanations that can support future learners.

Because the deployments differed in institution, instructor, course structure, and assessment design, we do not treat the two contexts as directly comparable experimental conditions. Consequently, we avoid direct cross-context inferential comparisons that could be misread as controlled institutional effects and instead emphasize descriptive contrasts appropriate for the study design and available data.

Future work will focus on expanding deployment to additional courses and institutions, refining interaction measures to better distinguish different forms of support-seeking, and examining how instructors can use engagement traces to guide iterative course improvements over time. These efforts aim to further develop the platform as a mechanism for delivering teachable-moment support and as a tool for informing data-informed instructional practice in online and hybrid engineering education.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. 2315353. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors thank Professor Autar Kaw of University of South Florida for his insights and advice on this project.

References

[1] K. VanLehn, "The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems," Educational Psychologist, vol. 46, no. 4, pp. 197–221, 2011.

[2] K. R. Koedinger, E. A. McLaughlin, J. Z. Jia, and N. L. Bier, "Is the doer effect a causal relationship? How can we tell and why it's important," in Proc. Learning Analytics and Knowledge Conf. (LAK), 2013.

[3] S. Hrastinski, "Asynchronous and synchronous e-learning," EDUCAUSE Quarterly, vol. 31, no. 4, pp. 51–55, 2008.

[4] A. F. AbuSeileek and K. Qatawneh, "Effects of synchronous and asynchronous computer-mediated communication (CMC) oral conversations on English language learners' discourse functions," Computers & Education, vol. 62, pp. 181–190, 2013.

[5] J. K. Cavanaugh and S. J. Jacquemin, "A large sample comparison of grade-based student learning outcomes in online vs. face-to-face courses," Online Learning, vol. 19, no. 2, p. n2, 2015.

[6] M. Merkt et al., "Pushing the button: Why do learners pause online videos?," Computers & Education, vol. 179, Art. no. 104414, 2022, doi: 10.1016/j.compedu.2021.104414.

[7] E. L. Deci and R. M. Ryan, Intrinsic Motivation and Self-Determination in Human Behavior. New York, NY, USA: Springer, 1985.

[8] J. P. Baker and A. K. Goodboy, "The choice is yours: The effects of autonomy-supportive instruction on students' learning and communication," Communication Education, vol. 68, no. 1, pp. 80–102, 2019.

[9] L. Li and J. P. Pitts, "Does it really matter? Using virtual office hours to enhance student–faculty interaction," Journal of Information Systems Education, vol. 20, no. 2, pp. 175–181, 2009.

[10] L. Li, J. Finley, J. Pitts, and R. Guo, "Which is a better choice for student–faculty interaction: Synchronous or asynchronous communication?," Journal of Technology Research, vol. 2, pp. 1–10, 2011.

[11] P. Kerr, "Adaptive learning," ELT Journal, vol. 70, no. 1, pp. 88–93, 2016.

[12] F. Martin, Y. Chen, R. L. Moore, and C. D. Westine, "Systematic review of adaptive learning research designs, context, strategies, and technologies from 2009 to 2018," Educational Technology Research and Development, vol. 68, no. 4, pp. 1903–1929, 2020.

[13] P. Moskal, D. Carter, and D. Johnson, "7 things you should know about adaptive learning," EDUCAUSE Learning Initiative, 2017. [Online]. Available: https://library.educause.edu/-/media/files/library/2017/1/eli7140.pdf

[14] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," MIS Quarterly, vol. 13, no. 3, pp. 319–340, Sep. 1989, doi: 10.2307/249008.

[15] L. S. Vygotsky, Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA, USA: Harvard Univ. Press, 1978.

[16] D. Wood, J. S. Bruner, and G. Ross, "The role of tutoring in problem solving," Journal of Child Psychology and Psychiatry, vol. 17, no. 2, pp. 89–100, 1976, doi: 10.1111/j.1469-7610.1976.tb00381.x.

[17] B. J. Zimmerman, "Becoming a self-regulated learner: An overview," Theory Into Practice, vol. 41, no. 2, pp. 64–70, 2002, doi: 10.1207/s15430421tip4102_2.

[18] P. H. Winne and A. F. Hadwin, "Studying as self-regulated learning," in Metacognition in Educational Theory and Practice, D. J. Hacker, J. Dunlosky, and A. C. Graesser, Eds. Mahwah, NJ, USA: Lawrence Erlbaum, 1998, pp. 277–304.

[19] P. H. Winne and R. S. Baker, “The potentials of educational data mining for researching metacognition, motivation and self-regulated learning,” Journal of Educational Data Mining, vol. 5, no. 1, pp. 1–8, 2013.

[20] R. F. Kizilcec, C. Piech, and E. Schneider, “Deconstructing disengagement: Analyzing learner subpopulations in massive open online courses,” in Proc. 3rd Int. Conf. Learning Analytics and Knowledge (LAK), pp. 170–179, 2013, doi: 10.1145/2460296.2460330.

[21] C. G. Brinton, S. Buccapatnam, M. Chiang, and H. V. Poor, “Mining MOOC clickstreams: Video-watching behavior vs. in-video quiz performance,” IEEE Transactions on Signal Processing, vol. 64, no. 14, pp. 3677–3692, Jul. 2016, doi: 10.1109/TSP.2016.2546228.

[22] O. R. Yürüm, T. Taşkaya-Temizel, and S. Yıldırım, “The use of video clickstream data to predict university students’ test performance: A comprehensive educational data mining approach,” Education and Information Technologies, vol. 28, no. 5, pp. 5209–5240, 2023, doi: 10.1007/s10639-022-11403-y.

[23] S. A. Karabenick and M. H. Dembo, “Understanding and facilitating self-regulated help seeking,” New Directions for Teaching and Learning, no. 126, pp. 33–43, 2011, doi: 10.1002/tl.442.

[24] I. Roll, V. Aleven, B. M. McLaren, and K. R. Koedinger, “Improving students’ help-seeking skills using metacognitive feedback in an intelligent tutoring system,” Learning and Instruction, vol. 21, no. 2, pp. 267–280, 2011, doi: 10.1016/j.learninstruc.2010.07.004.

[25] C. J. Brame, “Effective educational videos: Principles and guidelines for maximizing student learning from video content,” CBE—Life Sciences Education, vol. 15, no. 4, Art. no. es6, 2016, doi: 10.1187/cbe.16-03-0125.