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The Effectiveness of Supplemental Instructional Videos in Construction Education

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Abstract

Instructional videos have become a prominent fixture in higher education. However, little empirical research has tested their direct impact on student performance, particularly in the context of construction education. As part of a broader investigation on the use of instructional videos in construction education, 46 students in a building construction course at a major university in the United States participated in a 12-week research study aimed at understanding the ability of supplemental instructional videos (SIVs) to improve student performance on reading quizzes. SIVs are a popular subcategory of instructional videos that have been promoted in the literature for being effective at improving student cognition and learning. The SIVs for the course were developed by the instructor in accordance with an interdisciplinary synthesis of best practices for video design. They were delivered online as complementary learning materials for course readings in a repeated-measures crossover experiment. ANOVAs and t-tests were used to compare average quiz scores. Contrary to much of the previous research, results from the experiment indicated no significant differences in performance between students who received SIVs and the control group. This outcome was the same regardless of student gender, number of years in college, final class grade, and the complexity of the learning topic. These results suggest that construction instructors who are considering using SIVs specifically to boost classroom performance should moderate their expectations. This study was underway when the COVID-19 pandemic abruptly moved all courses at the university online. At the completion of the study, in-person and online modalities were also compared, revealing that a statistically significant increase in student performance accompanied the online period of instruction, independent of SIV treatment.

Introduction

In 2002, H. Wayne Hodgins, who is credited with the conceptualization of digital learning objects and has been called “Mr. Metadata” for his contribution to the field of computer science [1], foresaw a future defined by internet-based learning. He envisioned placing the “control of content...into the hands of every individual...where everyone in need of a given skill or knowledge can be connected directly with those who have it… to have potentially billions of authors and publishers” [2, p. 81]. Years later, it is clear that this vision—to democratize education by empowering billions of people to reach and teach one another—has largely been fulfilled. To provide an example, YouTube EDU, a sub-site of YouTube, is devoted exclusively to publishing instructional videos and currently makes available hundreds of thousands of instructional videos produced by a variety of both well-known (e.g., PBS, TEDEd, and Khan Academy) and lesser-known authors [3].

Although instructional videos are now ubiquitous in higher education, due to the sustained emphasis on developing the technical infrastructure for video-based learning (i.e., video recording and editing hardware and software, video hosting platforms, distribution and streaming services, and viewing devices), research in this field has been disproportionately focused on the computer science side of instructional videos rather than pedagogy. A literature review by Jensen et al. [4] found that “only one [previous] systematic controlled comparison has been made between various pre-class content delivery methods to determine which is most effective for student learning” [4, p. 525]. Jensen et al. [4] concluded that while video appears to be superior to interactive tutorials or textbook-style readings for pre-class learning, additional research is needed before any conclusion can be drawn about the effectiveness of the medium. Thus, many open questions about the educational efficacy of instructional videos remain. Chief among them: Do instructional videos live up to their “most significant promise…to increase and improve the effectiveness of learning and human performance” [2, p. 76]? If so, how, for whom, and to what extent?

This paper reports on the outcome of an explanatory, experimental research study that tested the ability of instructional videos to support traditional, pre-class learning materials in an undergraduate construction course. As a result of the COVID-19 pandemic, the study also provides insight into differences in student performance between in-person instruction and exclusively online learning.

Literature Review

While many studies in construction education have evaluated students’ opinions of instructional videos, speculated about their impact, or documented the process of their design and development e.g., [5], [6], [7], [8], few have experimentally tested their effectiveness—their ability to objectively improve a student’s academic performance. The scant body of empirical research available (summarized below) at the intersection of construction education and instructional videos reports mostly positive results, but the studies are too dissimilar in scope and methodology to aggregate and generalize to the overall population of undergraduate construction students. Further, no previous experimental research could be found in which instructional videos were used to support pre-class readings rather than in-class lectures.

In 2011, Choudhury [9] explored the effectiveness of instructional videos among undergraduate students by comparing the performance of students in two different years of an environmental control systems course. In the study, students enrolled in the 2009 course were not provided any instructional videos while students in the 2010 course were “shown video clips related to the course [9, p. 5].” Choudhury [9] found that using instructional videos to supplement classroom lectures had a statistically significant positive effect on students’ test scores. However, the paper provides no information about the content, length, quality, or selection criteria for the video content used in the study, or the process for applying the videos in the lectures. Burgett [10] used the flipped classroom approach to test the effectiveness of video lectures in a course on heating, ventilation, and air conditioning (HVAC). The course was divided into two sections. One section was provided with a more traditional teaching experience in which in-person lectures were given during class time, while the other class section was given recorded video lectures to watch before class on the course website. Contrary to Choudry’s [9] findings, results on the final exam for both class sections were nearly identical. Additionally, students reported that they were reluctant to watch the recorded lectures and felt that they were a “poor choice” for teaching difficult concepts [9, p. 7]. Burgett concluded that instructional videos are best suited for introducing the basic concepts, while the more complex or difficult subjects should be taught in person. Lee, Salama, and Kim [11] similarly studied the effectiveness of instructional videos by comparing student performance in two sections of an upper-level estimating course. One section was taught in a traditional, lecture-based mode. The other section was taught using a flipped classroom model and utilized instructor-developed, lecture-based instructional videos. Pretest and posttest scores revealed that the flipped classroom produced greater positive changes in performance. Lee, Salama, and Kim [11] emphasized their belief that success in a flipped classroom is conditional on the design and execution of the videos. Hurtado, Kashiwagi, and Sullivan [12] researched the impact that video production techniques and implementation had on student performance. Drawing on best practice guidelines for instructional video design and development from the fields of educational technology and instructional design, their research team developed and tested a quality assessment tool for the effectiveness of instructional videos in a construction statistics course. While the quality and utility of instructional videos was the primary subject of evaluation, the study also assessed student performance. Over the course of three semesters, as the instructional videos received greater utilization in terms of minutes watched and number of views, student performance increased.

Research Questions & Expectations

Building on previous research, this study began with three research questions focused on the effectiveness of instructional videos as supplements to traditional, pre-class learning materials (readings). A fourth research question emerged with the onset of the COVID-19 pandemic and the subsequent transition of instruction to an exclusively online format.

- RQ1: *Does the use of instructional videos, as supplemental, educational tools for traditional learning materials (i.e., readings), improve objective measures of student performance?* Based on the research by Choudhury [9], Lee, Salama, and Kim [11], and Hurtado, Kashiwagi, and Sullivan [12], we expected that students who received instructional video supplementation of pre-class learning activities would have better learning outcomes (i.e., greater improvement in their scores) than students who did not receive instructional video supplementation.
- RQ2: *Which construction topics (e.g., plumbing, foundations, framing) are most conducive to using instructional videos?* Based on the research by Burgett [10], we expected that instructional videos would be associated with better learning outcomes (i.e., greater improvement in student scores) for the more basic topics.
- RQ3: *Which student groups, in terms of gender, age, years in school, and final grade in class benefit most from instructional videos?* Based on the research of Nasir and Bargstädt [8] who researched the best instruction methods for different construction professionals, we hypothesized that instructional videos would be more impactful for students who traditionally have less construction experience and expect to see greater improvement in their performance.
- RQ4: *What effect does the COVID-19 shutdown have on the performance of construction students?* Due to the original course design, which relied heavily on technology for the administration of the instructional videos, we hypothesized that the COVID-19 shutdown of all in-person instruction would have little effect on student performance.

Materials and Methods

Population and Sample

In the spring semester of 2020, all 46 undergraduate students in a course titled Residential Construction Technologies consented to participate in the research study on the pedagogical effectiveness of instructional videos. Prior to signing up, students in the class were given a short presentation and handout describing the research activities and objectives. All research activities were approved by and conducted in accordance with the [university redacted] Institutional Review Board (Protocol 19-853). The majority of the 46 students in the study were male (78%, n=36) and majoring in Building Construction (89%, n=41). Students were primarily in their second (n=10), third (n=17), or fourth (n=12) year of college, with few in their first (n=1) or fifth year (n=2). The college year of the remaining students was not clearly defined.

The Course: Residential Construction Technologies

Residential Construction Technologies was organized so that each week of the semester covered a different construction topic (e.g., foundation, framing, plumbing, interior floor finishes). Within each topic, students were introduced to two competing construction technologies: 1) a conventional technology and 2) a more technologically-advanced alternative, termed the ‘conventional-plus technology.’ The conventional-plus technologies were chosen based on their promise of improved efficiency in terms of cost, quality, time, safety, or sustainability. The main learning objective of the course was for students to effectively contrast the conventional-plus technologies with their conventional counterparts. To meet this objective, each week all students in the class were given readings covering both technologies (i.e., conventional and conventional-plus technologies) to prepare them for an in-class quiz to assess their mastery of the technologies. Each week, half of the class was randomly selected to individually watch a short, supplementary instructional video before completing the readings on the conventional-plus technologies. These instructional videos were the treatment in the experiment and served as the main independent variable of the research. To ensure equal treatment, by the end of the semester, all participants received the same number of instructional videos to supplement their readings (i.e., six). As an example of this process, in week seven, a standard 50-gallon storage-tank water heater was compared to a condensing storage water heater. All students were assigned readings covering both water heaters to be completed before the in-class quiz and group project work. Half of the students in the class were provided with an instructional video on condensing storage water heaters to be watched before completing the reading on that conventional-plus technology.

Supplemental Instructional Videos

Until very recently, many instructional videos were produced without informed guidance [12], falling short of student expectations on account of design or execution flaws and giving instructional videos a poor reputation [13]. One hindrance to better research on the effectiveness of instructional videos comes from uncontrolled variability in instructional video quality, length, pace, personalization, and level of engagement. Attending to the need for better guidance on the design and development of instructional videos, scholarship over the past few years has produced a wave of domain-specific, best-practice theories to guide researchers and practitioners as they attempt to produce effective instructional videos [13].

According to Kay [14], instructional videos fall into one of four categories: lecture-based, worked examples, enhanced, and supplementary. The last category, supplemental instructional videos (SIVs), was selected for this study due to its ability to provide "significantly more educational value" than other types [15, p. 317]. This is because SIVs prioritize transmitting information over garnering interest, entertaining, or motivating. They reinforce the main messages of the instruction by providing emphasis, focus, or clarity. And importantly, SIVs are frequently used to complement another teaching medium, such as readings [5].

For Residential Construction Technologies, the design and development of the SIVs was informed by an interdisciplinary synthesis of best practices for video design from the literature [16]. This meant that the SIVs needed to be: as short as necessary (i.e., less than 10 minutes, but closer to 5), scripted, segmented (i.e., focused on a single topic), high-quality in production, instructor-made, engaging, clear, connecting and personalized (i.e., first-person voice), interactive (i.e., accompanied by corresponding quiz questions to be answered while watching), and properly paced. Twelve SIVs were developed, one for each conventional-plus technology covered in the semester. The software used to produce the SIVs was a home license of TechSmith Camtasia 2018. Nearly all elemental content (i.e., images, graphics, videos, music, and sound effects) used during production came from license-free, attribution-free, creative commons, and public domain sources including Pixabay.com, the YouTube Audio Library, Google Images, Archive.org, and FreeSounds.org. Any content taken from outside of the public domain was attributed in the video and adhered to the fair use doctrine under the Copyright Act of 1976. A basic, standard outline was consistently applied to each SIV, including a routine introduction, complete with music and motion graphics. All SIVs went through a consistent pre-production, production, and review process to ensure that they were qualitatively similar.

Experimental Design

To evaluate the effectiveness of the SIVs, we applied a repeated measures experimental design (RMED), which is characterized by taking multiple measurements on individual participants. More specifically, we conducted a within-subject, withdrawal-of-treatment, crossover experiment. The crossover RMED was ideal for the study because the course content was siloed into weekly, non-accumulative sections that were identical in structure, but distinct in content; no instructional materials or corresponding work assignments were linked with previous or future course topics or materials. This format provided multiple opportunities for testing the effects of the independent variables (i.e., the SIVs) that were not biased by previous instruction from earlier in the course, and thus preserved statistical independence between measurements. Furthermore, the RMED is highly effective at neutralizing potentially confounding variables (e.g., intelligence, GPA, experience, year in school, gender, and age) because the participants in the treatment group are the same as those in the comparison group [17]. In a real classroom environment, controlling as many confounding variables as possible was imperative to preserve a functional and reliable, experimental setting.

Independent & Dependent Measures

The main independent variable, or focal variable used to answer RQ1, was the treatment of supplemental instructional videos (SIVs). SIVs were introduced to support the conventional-plus technology readings. For RQ2 and RQ3, gender, age, learning topic, and year in school were examined as qualitative moderator variables in order to explore which, if any, course topics and student demographics are most likely to be impacted by the treatment of SIVs. Student performance, measured as the difference in scores between a pretest and posttests, was the dependent variable, i.e. the target problem or main focus under observation.

Executing the Crossover RMED in Residential Construction Technologies

To control the research environment, all in-class instruction was taught by the same instructor who produced the instructional videos. Students were randomly assigned to the treatment group each week so each repeated measure consisted of a new, dynamic selection of participants from the sample pool. The course learning management system (LMS), Canvas, was used to administer all instructional videos exclusively to the treatment group each week, minimizing or eliminating the opportunity for diffusion to members of the control group. All course material presented in each repeated measure was considered to be “new knowledge” subject matter to establish independent measurements and eliminate existing knowledge biases. The research was designed so carryover effects and measurement sequencing could be statistically accounted for during analysis. The course did not allow for counterbalancing which, for this research, would manifest as distributing treatment topics (e.g., roof framing, plumbing, exterior finishes) to different students at different times throughout the course. Finally, to identify any unclear, ambiguous, redundant, or gameable questions, all pretest and posttest questions were piloted under real conditions by multiple undergraduate students in the same department who were not participants in the study.

Data collection

The pretest and posttest score data were collected from the university learning management system (LMS), Canvas. Demographic information needed to answer RQ3 was provided by the participants at the end of the study. Pretest and posttest questions covered material exclusively from the reading assignments, not the SIVs, so that students in the control groups each week were not being quizzed on the subject matter they had not been given. Each video had a corresponding quiz to report that the students were watching and understanding the SIVs. The pretest consisted of 84 multiple-choice questions (7 questions for each of the 12 conventional-plus topics) and was administered in two parts, divided over the first two class sessions of the semester. The pretest was administered electronically using Canvas. Students took the pretest in class, using their own devices. The goal of the pretest was to measure students’ existing knowledge about the spectrum of conventional-plus technology topics to be covered throughout the course and provide a baseline for measuring the impact of course instruction with and without SIVs. A single, comprehensive pretest, instead of weekly, topic-specific pretests, was used for convenience, time savings, and to reduce possible carryover effects including boredom and testing fatigue. Students did not have the ability to review their pretest scores or the questions after the pretest was submitted. For the posttests, in-class quizzes were administered each week throughout the semester covering that week's conventional-plus technology, which was described in pre-class reading assignments. Following previous studies [11], the posttest questions were identical in number (i.e., 7 per technology), content, and structure to the pretest questions for each of the 12 conventional-plus technologies, but they occasionally varied slightly in wording and answer option ordering. Like the pretest, the posttest quizzes were administered using Canvas, and students accessed and completed the quizzes on their own electronic devices. The scores and questions from these posttests were available for students to review and counted toward their final grades in the class. Nearly every week, a small number of students in the treatment group failed to complete their video assignment before taking the posttest, resulting in minor variations in the total number of posttests (N) that could be used in the analysis.

COVID-19 Adjustments to the Research

The COVID-19 pandemic, which required all instruction to be delivered online, did not impact the study treatment, since the pre-class SIVs were already being administered online. Likewise, the pretest, which had already been administered in aggregate during the first two class sessions of the course, remained unaffected. The primary disruption came at the point of classroom activities including mentored instruction, group work, and the posttests, which, for weeks 1-6 of the study, were administered in person. After the COVID-19 shutdown, these classroom activities continued but were conducted synchronously online rather than in person. Despite these disruptions, the study proceeded as initially planned, with the added goal to explore how the effectiveness of the SIVs would be affected by moving the class online (i.e., by moving the synchronous components of the course to an online setting with Zoom web conferencing). These adjustments to the study were approved by the [university redacted] Institutional Review Board (Protocol #).

Data Analysis

All statistical analyses were conducted in SPSS (version 25). We first conducted a mixed model ANOVA—a statistical test often used in studies in which data were collected by using repeated measures [18]—to account for sequencing and carryover effects. Based upon the mixed model ANOVA, no significant results were found for either sequences or carryover effects, indicating that first, the research was not statistically influenced by the random sequence of treatment topics ($p = 0.246$), and second, none of the previous weeks' treatments carried over to have an undue impact on subsequent trials ($p = 0.899$). Following the mixed model ANOVA, to answer RQ1, we used an independent t-test to evaluate the interaction effects between the main independent variable (i.e., the administration of the SIVs to the treatment group) and the dependent variable (i.e., the mean difference between all pretest scores and the average of all posttests scores). Next, for RQ2 and RQ3, we used a two-way, between-subjects ANOVA to evaluate differences in the treatment and control groups for the moderating variables (i.e., gender, year in school, age, topic, final grade in class, and course modality). Finally, we conducted post-hoc independent t-tests discriminately based on the significant results identified.

Results

Results of the Main Independent Variable (RQ1)

For RQ1, we found that, on average and across course topics, students in the treatment group who received SIVs to accompany pre-class readings scored 3.99 points higher (out of 7) on their posttests than on their pretests. Students in the control group, which received no SIV supplementation, had a mean increase in performance of 3.92. *An independent t-test indicated that this difference between the treatment group and the control group was not statistically significant* (p = 0.610) (Table 1).

Table 1. Results of the independent t-test for the SIV treatment. The "N" is the pooled number of posttest quizzes taken by all students across all 12 weeks. The "Mean Improvement Score" refers to the difference between the average of all pretest scores and the average of all posttest scores.

Group	N	Mean Improvement Score	Sig. (2-tailed)	Mean Difference	Standard Error Difference	Lower	Upper
SIV	242	3.99	0.610	0.073	0.143	-0.207	0.353
No SIV	259	3.92					

95% C.I.

Results of the Moderating Variables (RQ2 and RQ3)

For RQ2 and RQ3, a two-way ANOVA was applied to the moderator variables: gender, year in school, age, course topic, and final grade in the class, to explore whether those variables had any influence on the ability of the SIVs to improve student performance. *At the $p < .05$ level, no significant differences were identified between the treatment group and control group for any of these moderator variables*, however, some practically significant trends emerged. First, with SIV treatment, men improved more than women, on average. As shown in Table 2, between the pretest and posttest, men who received the SIV improved by an average of 0.07 points, while women's scores dropped by an average of 0.35 points. This is true despite women showing greater overall improvement from pretest to posttest than men. Second, students who were in their fourth and fifth year of college tended to have higher mean improvement scores when given SIVs than those in their first, second, and third years, as shown in Table 3. Third, students who received a C or an F as their final grade in the class (no students received a D) showed greater improvement between the pretest and posttest when given SIVs than students who received higher final grades in the class (Table 4).

Table 2. Results of the two-way ANOVA for the *Gender* variable. The "N" is the number of posttest quizzes taken across the 12 SIVs. The "Mean Improvement Score" refers to the difference between the average of all pretest scores and the average of all posttest scores when grouped by gender.

Gender	Group	N	Mean Improvement Score	Mean Difference	Standard Deviation	F	P-Value
Male	SIV	198	4.01	0.07	1.58	1.069	0.302
	No SIV	203	3.94		1.45		
Female	SIV	30	4.10	-0.35	1.40		
	No SIV	33	4.45		1.30		

95% C.I.

Table 3. Results of the two-way ANOVA for the *Year in School* variable. The "N" is the number of posttest quizzes taken across the 12 SIVs. The "Mean Improvement Score" refers to the difference between the average of all pretest scores and the average of all posttest scores when grouped by year in school.

Year in School	Group	N	Mean Improvement Score	Mean Difference	Standard Deviation	F	P-Value
First	SIV	6	4.17	-0.50	0.98	1.173	0.322
	No SIV	6	4.67		1.37		
Second	SIV	50	4.64	0.09	1.31		
	No SIV	49	4.55		0.98		
Third	SIV	87	3.99	-0.13	1.48		
	No SIV	94	4.12		1.39		
Fourth	SIV	62	3.84	0.51	1.48		
	No SIV	69	3.33		1.75		
Fifth	SIV	11	4.27	0.52	1.49		
	No SIV	12	3.75		1.60		

95% C.I.

Table 4. Results of the two-way ANOVA for the *Final Grade in Class* variable. The "N" is the number of posttest quizzes taken across the 12 SIVs. The "Mean Improvement Score" refers to the difference between the average of all pretest scores and the average of all posttest scores when grouped by the final grade in class.

Final Grade in Class	Group	N	Mean Improvement Score	Mean Difference	Standard Deviation	F	P-Value
A	SIV	68	4.22	-0.08	1.34	1.118	0.351
	No SIV	66	4.30		1.05		
A-	SIV	111	4.22	0.23	1.57		
	No SIV	120	3.99		1.60		
B+	SIV	22	3.64	-0.32	2.01		
	No SIV	28	3.96		1.71		
B	SIV	25	3.36	0.00	1.63		
	No SIV	22	3.36		1.40		
B-	SIV	7	3.00	-0.60	0.00		
	No SIV	10	3.60		1.43		
C	SIV	4	1.75	1.25	2.36		
	No SIV	6	0.50		2.17		
F	SIV	2	4.00	2.33	0.00		
	No SIV	3	1.67		2.89		

95% C.I.

Relevant to RQ2, at the $p < .10$ level, the *Course Topic* became a significant moderating variable in the ANOVA. Post-hoc independent t-tests indicated significant differences in student performance between the treatment and control groups in two of the twelve course topics. First, the treatment group significantly outperformed the control group in terms of their mean improvement in assessment scores for the week 9 topic, *Solar Shingles* ($p = 0.003$). Second, the control group significantly outperformed the treatment group in week 11 on the topic of *Insulated Vinyl Siding* ($p = 0.010$). In both cases, the boxplots for the control groups were heavily skewed, but in opposite directions. The boxplot for the control group in *Solar Shingles* had no scores in the lower quartile, even after initial outliers were removed, indicating a strong skew to the right. The boxplot of the control group scores for *Insulated Vinyl Siding* had no scores in the upper quartile range, indicating a strong skew to the left. No outliers were detected in the treatment group for either topic (Table 5).

Table 5. Significant results of the two-way ANOVA for the *Course Topic* variable. The "N" is the number of posttest quizzes taken across the 12 SIVs. The "Mean Improvement Score" refers to the difference between the average of all pretest scores and the average of all posttest scores when grouped by the course topic description.

Course Topic Description	Group	N	Mean Improvement Score	Sig. (2-tailed)	Mean Difference	Standard Error Difference	Lower	Upper
Solar Shingles	SIV	20	4.85	0.003	1.144	0.353	0.427	1.861
	No SIV	17	3.71					
Insulated Vinyl Siding	SIV	17	3.76	0.010	-1.235	0.455	-2.157	-0.313
	No SIV	23	5.00					

95% C.I.

As with the other moderating variables, a two-way ANOVA was used to test whether the transition to fully online learning due to the *COVID-19* shutdown had any significant impact on the effectiveness of SIVs. The test failed to detect any significant differences in student performance between the treatment and control groups before and after COVID-19 (p = 0.741), as shown in Table 6 below.

Table 6. Results of the two-way ANOVA for the *Student Performance* & *COVID-19* variables. The "N" is the number of posttest quizzes taken across the 12 SIVs. The "Mean Improvement Score" refers to the difference between the average of all pretest scores and the average of all posttest scores when grouped by course modality.

Course Modality	Group	N	Mean Improvement Score	Mean Difference	Standard Deviation	F	P-Value
In-person Instruction (First half of semester)	SIV	124	3.87	0.07	1.58	0.109	0.741
	No SIV	134	3.80		1.60		
Online Instruction (Second half of semester)	SIV	118	4.12	-0.02	1.64		
	No SIV	122	4.14		1.46		

95% C.I.

The ANOVA indicated that across all students, irrespective of SIV treatment and control groups, there were significant differences in student performance before and after the COVID-19 disruption (p = 0.037). In the first half of the semester, before moving instruction fully online, students had a mean performance increase of 3.83, compared to a mean performance increase of 4.13 across the weeks in which instruction was fully online (Table 7).

Table 7. Results of the two-way ANOVA for the *COVID-19* variable. The "N" is the number of posttest quizzes taken across the 12 SIVs. The "Mean Improvement Score" refers to the difference between the average of all pretest scores and the average of all posttest scores when grouped by course modality.

Course Modality	N	Mean Improvement Score	Standard Deviation	Mean Difference	F	P-Value
In-person Instruction (First half of semester)	258	3.83	1.59	0.30	4.354	0.037
Online Instruction (Second half of semester)	240	4.13	1.546			

95% C.I.

Discussion

The first research question (RQ1) focused on whether supplemental instructional videos (SIVs) that were administered to support pre-class readings had any impact on student performance in terms of improvement from the pretest to the posttest. Contrary to the results that Choudhury [9] and Lee, Salama, and Kim [11] reported, we found that, in aggregate, student performance was not significantly improved by the use of SIVs. This divergence between studies may be due to a number of factors. First, the environment and conditions in which the videos were administered could have an effect. Choudhury [9] showed the videos during class to magnify understanding of the lecture. Our SIVs, in contrast, were administered at home by the students themselves before completing the readings. In Choudhury's study, the instructor was likely able to provide additional explanations of video content and student questions could be answered immediately, which would result in the classroom supplementing the videos, in addition to the videos supplementing the lecture. Second, the qualitative aspects and magnitude of the intervention may be influential in the findings. Choudhury [9] used "video clips" to supplement the classroom lecture but offered little information about the number of videos shown, the duration of each video, or the frequency of the video treatment. From a close read, we assume that the videos were more generic, covering a broader range of topics, and were used more abundantly than the SIVs in our study. In our SIV research, a single video was provided for each pre-class reading assignment and, to stay in compliance with the latest literature, they were made intentionally short. The average duration of each SIV to support the assigned readings was just under three minutes.

The second research question (RQ2) focused on the complexity of the course topic. We expected that more complex topics would include those with many interconnected parts and complicated functions, such as solar shingles, condensing storage water heaters, and fiber optics. The topics assumed to be less complex included those with fewer assemblies and operating parts, such as three-pane windows and luxury vinyl plank flooring. Results from post-hoc, independent t-tests indicated that the treatment group in the *Solar Shingles* topic performed significantly better than the control group. Conversely, the control group in the topic of *Insulated Vinyl Siding* significantly outperformed the treatment group. Because the directions of these differences are inconsistent, no inferences about the effectiveness of SIV treatment for different topics could be made. As reported in the results, the data for the control groups were heavily skewed in both cases, and it is possible that the statistical tests were impacted by this non-normal distribution. Thus, unlike Burgett [10], we found that the level of difficulty or complexity of the topic had no bearing on the effectiveness of SIVs. It is possible that this surprising lack of difference stems from the additional time and effort that students may have exerted to understand the more complex topics.

The third research question (RQ3) focused on the impact of students' demographic characteristics (i.e., gender, age, year in school) and their final grade in the class on the effectiveness of SIVs. We found no statistically significant differences across student groups. However, in terms of practical significance, our findings show that, on average, men and students in their fourth and fifth years in college tended to perform better than their counterparts when given SIVs. Congruous with our own predictions, students who received a C or F as a final grade in the course also tended to show greater improvement between the pretest and posttest with SIVs. When these students did not have the SIVs to help with the readings, they did not improve nearly as much. This result is likely influenced in some way by the very low number of measurements ($n < 7$) in both of these final grade categories. Also, the only student who received an F was an international student who needed to return home early after the sixth week of class on account of the COVID-19 pandemic and thus did not participate in all weeks of the experiment.

Counter to our hypothesis in RQ4, we observed that the switch to exclusively online learning in response to the COVID-19 pandemic had a statistically significant positive impact on student performance. It is possible that online instruction itself could be the variable that triggered the improvement. However, this difference in student performance on quizzes could also be a result of the students being more familiar with the course structure in the latter half of the semester. The specific combination of topics in the first and second halves of the study may have also influenced this outcome. It is also true from our own observation that students sometimes take a greater interest in their grades toward the end of the semester. To better understand why the move to exclusively online instruction had a significantly positive impact on learning, more research would need to be conducted that counterbalances the order of treatment. For example, one section of students should receive online learning in the first half of the semester while the other section receives online learning in the second half. Whatever the reason for the improvement, this result seems to indicate that modern educational technology has the ability to rival certain aspects of in-person learning in circumstances in which classroom technology is already a substantial part of the experience. It is likely that even a decade ago, before the widespread adoption of many advances in educational technology, such as live classroom video streaming, high-quality recorded lectures, intuitive video editing software, and widespread and robust LMS technology, COVID-19 would have been far more disruptive and devastating to the learning experience.

Limitations

This study was limited in a few ways that could be addressed in future research. The first has to do with the real-world testing environment. The SIVs in this study were self-administered on Canvas by the students at home, alone, and before completing the readings. While controls were installed to improve the likelihood that these instructions were followed (e.g., corresponding quizzes to accompany each SIV to confirm the participants' viewing and understanding), the potential for minor inconsistencies across research participants still existed. For example, some students may have been sharing living or study space with classmates in the same course. Additionally, the type of device used to watch the video (e.g., a phone versus a computer) and the elapsed time between when a student watched the video, completed the reading, and took the posttest may have had an impact. Future research can address these limitations by conducting the study in a highly-controlled lab setting in which variability in the testing environment, viewing time, and viewing devices are all carefully controlled. A second limitation, as stated previously, was the COVID-19 pandemic, which precipitously shut down all in-person instruction after the sixth week of the study. For a course that already relied heavily on technology, this disruption was fortunately minimized, nevertheless, the switch from a more blended instruction to full, synchronous, online meetings should be taken into account.

Conclusion

Due to the work of Wayne Hodgins and other computer science visionaries, instructional videos have become a common and highly accessible medium for learning. They have allowed teachers to rethink the traditional classroom structure. Instruction that previously had to be delivered in class and in person can now be captured and delivered with video. However, despite these leaps forward in computer science, certain pedagogical questions about instructional videos have remained unanswered. Greatest of all, do instructional videos have the ability to improve student performance? We asked this question of supplemental instructional videos (SIVs) in a building construction context. While some useful, practically significant results and trends were detected in the experiment, our findings were generally contrary to previous empirical studies on instructional videos in construction education [9], [12], [11]. We found little statistically significant evidence that SIVs contributed to an improvement in student performance, despite accounting for moderating variability in age, year in school, gender, final grade in the class, and complexity of the learning topic. Thus, we conclude that construction educators should not expect large or significant changes in their students' performance from small SIV interventions. As discussed, in this study the SIVs were produced deliberately to be as short as necessary to comply with the literary guidelines for the design and development of instructional videos. Future work should consider magnifying the impact of SIVs by increasing the length or quantity of videos used or increasing students' interaction with the intervention, for example, through additional video quiz questions or real-time, online discussions about the videos. Finally, it is worth mentioning that the study demonstrated that instructors have the ability to tailor their own digital educational content quickly, skillfully, economically, in accordance with best practices, and using readily available equipment (e.g., cell phone cameras and personal computers) and technology (i.e., low-cost, highly intuitive video editing software that can be downloaded remotely).

References

[1] IEEE Computer Society, "H. Wayne Hodgins," *IEEE.org*. https://www.computer.org/profiles/wayne-hodgins (accessed Sep. 5, 2022)

[2] H. W. Hodgins, "The future of learning objects." *Proceedings of the 2002 eTEE Conference, 76-82 and Higher Education*, 2002. 33, 15–23. https://doi.org/10.1016/j.iheduc.2017.01.001

[3] "Teachers—YouTube," https://www.youtube.com/user/teachers/about (accessed Feb. 8, 2023)

[4] J. L. Jensen, E. A. Holt, J. B. Sowards, T. Heath Ogden, and R. E. West, "Investigating Strategies for Pre-Class Content Learning in a Flipped Classroom," *Journal of Science Education and Technology*, 27(6), 523–535. 2018. https://doi.org/10.1007/s10956-018-9740-6

[5] M. Hoxley and R. Rowsell, "Using Video in the Construction Technology Classroom: Encouraging Active Learning." *Architectural Engineering and Design Management*, 2(1–2), 115–122., 2006. https://doi.org/10.1080/17452007.2006.9684609

[6] J. H. Lee and B. G. McCullouch, "Lessons Learned from a Design Course Utilizing Object-Based Learning Method," *Construction Research Congress*, 2005, 1–10. https://doi.org/10.1061/40754(183)45

[7] R. Liu, and Y. Hatipkarasulu, "Introducing Building Information Modeling Course into a Newly Developed Construction Program with Various Student Backgrounds," *2014 ASEE Annual Conference & Exposition*, 2014. pp. 24-806.

[8] A. R. Nasir and H. J. Bargstädt, "An Approach to Develop Video Tutorials for Construction Tasks," *Procedia Engineering*, 2017. 196, 1088–1097. https://doi.org/10.1016/j.proeng.2017.08.066

[9] I. Choudhury, "The Effect of Watching Video Clips on Student Performance in a Construction Science Course at an Undergraduate Level," In *2011 ASEE Annual Conference & Exposition*, 2011. pp. 22-1450.

[10] J. M. Burgett, "Can 'Flipping the Classroom' Improve the Educational Experience in Construction Management Courses: A Case Study in Teaching," *HVAC Psychrometrics*, 2014. 8. http://ascpro0.ascweb.org/archives/cd/2014/paper/CEUE127002014.pdf

[11] N. Lee, T. Salama, and S. J. Kim, "Using the Flipped Classroom Model to Improve Construction Engineering and Management Education," *2016 ASEE Annual Conference & Exposition Proceedings*, 2016. 27168. https://doi.org/10.18260/p.27168

[12] K. C. Hurtado, D. T. Kashiwagi, and K. T. Sullivan, "An Assessment Tool for Using Videos and Rich Media in Construction Management Curriculum—A Case Study." *ASEE Annual Conference & Exposition, 2014. pp. 24-151,*

[13] E. Choe, "Optimizing Video for Learning: A Case Study-Based Primer of Informal, Educational, Digital Video Best Practices," *SSRN Electronic Journal*, 2017. https://doi.org/10.2139/ssrn.2909769

[14] R. H. Kay, "Developing a Framework for Creating Effective Instructional Video Podcasts," *International Journal of Emerging Technologies in Learning*, 9(1), 10. 2014.

[15] O. McGarr, "A review of podcasting in higher education: Its influence on the traditional lecture." *Australasian Journal of Educational Technology*, 2009. 25(3). https://doi.org/10.14742/ajet.1136

[16] A. F. Barnes, "Instructional Video Object-Based Learning in a Flipped Construction Management Classroom," Ph.D. dissertation, Dept. Building Construction, Virginia Tech, 2021.
[17] A. Minke, "Conducting Repeated Measures Analyses: Experimental Design Considerations," 1997.
[18] B. B. Frey, "The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation," *SAGE Publications, Inc.*, 2018. https://doi.org/10.4135/9781506326139