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Assessing the Effectiveness of Virtual Workshops with Active Learning Approaches in Construction Education*

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Research suggests that online learning should be more engaging and collaborative to provide a compatible alternative to in-person learning. Many educators have implemented active learning in their in-person classrooms, while only a few assess how effective similar techniques are in virtual environments. The authors hypothesize that virtual learning, including active learning components, can improve student learning in virtual environments. Furthermore, the authors hypothesize that learning in virtual settings would be affected by students' gender, ability, and familiarity with the topic. The authors conducted a quasi-experimental study involving eighty-seven students from two institutions who participated in an online workshop covering fundamental concepts in construction scheduling. They were split into two groups: one group had no prominent active learning component, while the other was exposed to an active learning component. All participants completed pre and post-workshop surveys to assess their learning of the workshop outcomes and explore the effectiveness of virtual workshops and active learning components in online course delivery. The results of this study suggest that virtual workshops are effective in teaching construction scheduling, while active learning in the form of virtual pair-work does not have a significant positive impact on student learning. Furthermore, student performance in virtual workshops significantly differs based on gender, ability, and familiarity with the topic. Therefore, instructors need to be aware of significant student performance challenges, particularly for males and those with some familiarity with the topics covered in virtual workshops. Since this study was conducted during the COVID-19 pandemic, the authors present further challenges and recommendations for educators and institutions under similar emergency circumstances.

Keywords: active learning; virtual education; COVID-19 pandemic; construction scheduling; construction management

1. Introduction

The global COVID-19 pandemic brought significant changes and disruptions to the academic and professional community. Virtual teaching and learning became prevalent in early 2020 in light of the pandemic. Courses typically taught in a traditional face-to-face format were made virtual and delivered in synchronous or asynchronous modes. These virtual sessions can be enriching, but networking and engagement in virtual environments can be quite challenging [1].

In an effort to improve learning regardless of the mode of delivery, it is critical to identify approaches to engage students in the learning process. Active learning is one of the means to accomplish such engagement. "Active learning requires students to do meaningful learning activities and think about what they are doing" [2]. Students benefit from improved problem-solving and critical thinking skills when active learning is employed. Active learning approaches such as group work, think-pair-share, minute papers, and case studies also promote student engagement and facilitate collaboration in different educational fields, especially in Science, Technology, Engineering, and Mathematics (STEM) courses. These approaches have been more commonly used in face-to-face formats than online settings. A study that involved active learning showed improvements in examination performance that increased average grades by half a letter while failure rates increased by 55% when traditional approaches were used [3]. Haak et al. [4] also experienced the improved performance of students in an introductory biology course when they used a highly structured active learning approach. There are several approaches to active learning. One of the approaches is group work which can be considered a collaborative learning approach where students are broken into groups and given active learning tasks [5]. However, for collaborative learning to be successful, group work must be productive, and students should engage with the task together [6].

Research has shown that instructors need to be thoughtful and intentional when incorporating active learning into their instruction. For example, breakout rooms and group work should be structured intentionally with clear directions for students, specifying the time frame and how to share their findings [7]. Felder & Brent [8] revealed that students go through denial, shock and panic, frus-

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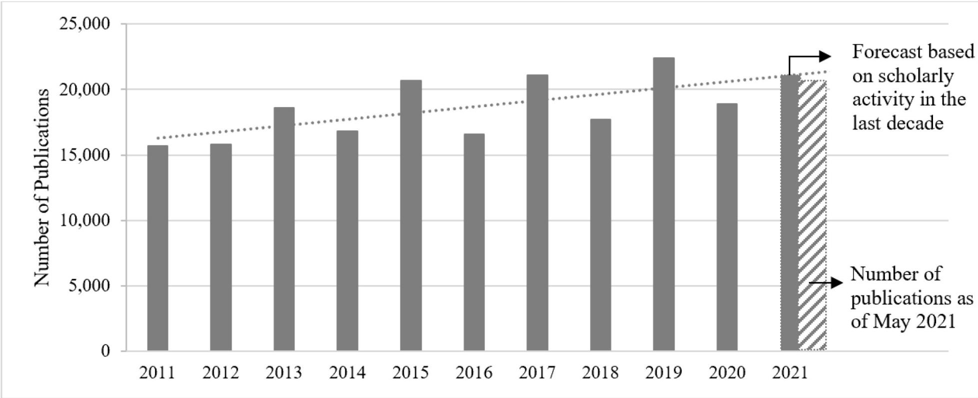

Fig. 1. Scholarly publications with a focus on "Virtual Learning" in the last decade.

tration, and acceptance when exposed to active learning for the first time. Navigating active learning in a virtual setting could have similar challenges. However, considering the success of active learning in face-to-face settings, more studies are needed to explore the effectiveness and potential challenges of these techniques in virtual settings.

This study investigates whether a virtual workshop can be effective in teaching construction scheduling and if certain demographics and the incorporation of active learning impact student learning online.

2. Background

2.1 Trends in Virtual Learning

Many governments worldwide have recognized the importance of computer technologies in education, especially in the last two decades. A significant number of students at various levels started gaining access to computers in the 1990s, particularly in developing economies. The increased access to computers and the Internet initiated a worldwide drive to use web and computer-based technologies to improve access to education. The Internet, along with increased access to the associated technologies, opened up opportunities for a global education marketplace [9]. Although virtual instructional technologies have been around for years, due to the recent pandemic, academic institutions were forced to adopt, which made virtual technologies widely available. Also, the number of professors who have experience in online teaching had been increasing even before the COVID-19 pandemic [10]. It is expected that the number will continue to grow, particularly after the mandatory virtual experiences due to the pandemic.

> "With exposure to existing virtual learning environments, many academics have begun to see the possibilities in the technology and to ask more of the system. Similarly, students have become accustomed to institution-wide use of systems to disseminate information, and to engage in dialogue with their peers and educators [11]."

In addition, the overall academic interest and access to virtual learning environments have been increasing steadily in the past number of years (Fig. 1). However, the COVID-19 pandemic in 2020 put such interest and access on an even faster pace as the world struggled to continue offering quality education while maintaining and complying with social distancing and other pandemic-related constraints. Nevertheless, it is expected that virtual learning is here to stay; thus, research on improving the quality of virtual learning is essential even more than ever before.

2.2 Active Learning in Virtual Environments

A national survey involving 1,008 students was completed during the shift from face-to-face to remote instruction due to the COVID-19 pandemic in early 2020 [12]. The survey results showed that students reported lower satisfaction levels in remote learning than face-to-face instruction [12]. Active learning, in general, is considered to be crucial to student learning. Through active learning techniques, students can be better engaged and widen their exposure, thus better assimilating the material being taught. Therefore, identifying active learning approaches that can be incorporated into online classrooms is essential to enhance students' interest in the topics taught while ensuring continuous engagement. Online instructional practices used in remote course instruction include meeting in breakout groups during a live class and using real-world examples to illustrate course content [12].

Students prefer active learning strategies to conventional passive teaching methodologies [13]. Studies have proven that active learning techniques are more impactful for education than traditional lectures only. When active learning occurs, the students change from passive to self-directed, taking responsibility for their learning. Students and teachers work together to solve problems which facilitates modeling, fosters creativity, and enhances active and collaborative learning.

In a study conducted by D'Youville School of Pharmacy, sixty PharmD students, 70% female and 30% male, were divided into Zoom breakout rooms consisting of five to six students each to complete an assignment based on the course material that had been taught [14]. Students were encouraged to actively engage through Zoom features like the chatbox and outside resources like Dropbox and Google Drive during these breakout sessions. Zoom breakout rooms allowed the instructor to move from one group to another efficiently and effectively to observe student and group progress and facilitate discussions. Overall the student's comments were positive, suggesting that the online class promoted student engagement [14].

In another example, due to the COVID-19 pandemic, the annual in-person collaborative asthma workshop for all second-year medicine and pharmacy students at Monash University was conducted through Zoom [15]. Compared to past experiences with virtual learning, Zoom allowed the students to engage with one another and the material faster than in the past. The facilitators believed this was because of the pre-distributed rosters, the perceived psychological safety provided by the webinar technology, the opportunity for interaction due to anxiety related to the pandemic, and the use of the chat function allowing clarification of any main learning points. It was found that the role of a facilitator is much more crucial when teaching virtually. The study concluded that learning is possible and workshop objectives can be met through collaborative practice using virtual means like Zoom [15].

On the other hand, another study found that the disadvantages exceed the main advantages of virtual classrooms via Zoom [16]. Video recording, cloud storage and sharing, and the ability to download and store virtual classes to a hard drive, are some of the main benefits. However, the disadvantages include reliance on the Internet connection and potential Zoom security breaches. Also, virtual environments make it more likely for students to be less engaged and not participate. Students also miss visual cues of non-verbal language. Interactions are less detailed in virtual settings than face-to-face, whether student-to-student or professor-to-student. Therefore, the study concluded that virtual classes would not replace in-person teaching once the pandemic is over [16].

2.3 Active Learning in Construction and Civil Engineering Courses

Active learning approaches have been implemented in various STEM fields, enhancing students' thinking and retention of material [2, 17]. In fact, studies show that student perception of learning and engagement increase when using active learning. A study at Auburn University showed sixty-eight percent (68%) of students believe an active learning environment enhanced their learning [12]. The same study revealed that eighty-two percent (82%) of the students felt their engagement was enhanced by the space, the teaching tactics incorporated, and shared engagement between students and professors[12].

Construction majors require a variety of skills and knowledge to work effectively in the industry. A few studies have discussed active learning in civil engineering, construction, and the built environment [18–20]. In a study conducted at Central Washington University, active learning methods were used to imitate construction industry practices [21]. In order to assess the difference between traditional book learning and active learning, the study used a combination of traditional lectures, readings, group work that involved active learning, and pre and post-lab quizzes. Two weeks after the workshop was completed, the students took a follow-up quiz. The students scored higher on the lab exercise questions than the questions covered in the traditional book learning section of the workshop. They mentioned that the active learning exercise helped them remember material better for the quiz, showing that active learning is more effective than traditional lectures [21]. A study conducted by Abraham [22] also showed that students reported increased confidence in carrying out tasks related to the intended course learning outcomes when more active learning components were introduced to a construction scheduling course.

2.4 Active Learning: The Impact of Group Work on Student Learning

Collaborative learning through group work is an active learning approach that allows students to engage with the tasks assigned to them together. Working in groups can enhance student learning because it improves their understanding of the course material. They also learn from each other and learn how to effectively work as a team [23]. Collaborative tools such as Miro, Overleaf, and Google Docs, enable cooperative group work in virtual settings. Virtual collaboration tools can solve many communication problems and be a huge benefit to teams within different organizations. Some of the benefits of virtual collaboration are lower overhead cost, higher scalability, high employee satisfaction, and higher efficiency [24].

Another benefit of working in groups is the ability of the group members to brainstorm. Brainstorming is a decision-making technique used to generate ideas by group members while allowing for open and free expression and discussion of ideas [25]. Group work may enhance collaboration and brainstorming, but it does not mean that it will always increase student learning. For example, in the study conducted by D'Youville School of Pharmacy, Zoom breakout rooms allowed students to work in groups and they used active learning to promote higher levels of cognitive learning [14]. However, the class averages for the assignments did not show any significant difference compared to those of previous years [14].

Group work provides the opportunity for both individual and peer feedback. However, not all group work benefits from both types of feedback. For example, a study by Storch [26] showed that group work is not as beneficial as working as an individual when working with complex grammatical items. The major drawbacks to virtual groups in work settings are lack of companionship, the risk to an organization's reputation and security, and a very high risk of confidentiality breaches since data is stored on remote platforms [24]. Similar to work settings, virtual group work in educational settings can often create a burden in managing life and learning requirements. Studies have highlighted the benefits and drawbacks of group work, but research is needed to study the impact of active learning through group work in virtual settings.

2.5 Impact of Background and Demographics on Student Learning

Multiple factors can impact learning effectiveness, whether online or in person. Based on evidence from existing literature, authors identified gender [27–29], student ability [30–32], and prior familiarity with the topic [33–35] as the most likely factors to have an impact on student learning in virtual environments. However, it is has been challenging to reach a consensus about the impact of gender on online versus face-to-face instruction. While Anderson [36] found that females prefer face-to-face communication, McSporran and Young [37] found that their online course favored females better than male students as they were more motivated and were better at communicating online. Based on a pilot study, Little-Wiles et al. [38] found no significant gender differences in course grades and the use of online tools like learning management systems.

3. Conceptual Framework

Cognitive Learning Theory was used to illustrate the significance of incorporating active learning into instructional design and delivery. A cognitive approach to learning considers how learners utilize their cognitive processes, knowledge, aptitudes, interests, and abilities to transform the instructional stimuli into meaningful information in memory [39]. In order to fully engage students in the learning process, instructors should organize, sequence and present in a manner that is meaningful to the learner [40]. Gagne et al. [41] introduced a model to describe a set of factors that influence learning and developed nine events of instruction to correlate to the conditions of learning. These events of instruction, as listed below, served as the basis for the virtual instruction structure used in this study:

- Gain attention.
- Inform the learner of the objective.
- Stimulate recall of prerequisite learning.
- Present the stimulus material.
- Provide learning guidance.
- Elicit the performance.
- Provide feedback about performance correctness.
- Assess the performance.
- Enhance retention and transfer.

These events and how they can shape the design of a virtual workshop are further discussed in the methodology section. Gagne et al.'s [41] model is also important as it illustrates how learning can be enhanced by incorporating active learning into the overall instructional design and delivery. Combined with the findings from previous research studies, this study seeks to uncover the influence of active learning, student background and demographics on learning, particularly in virtual settings.

Based on this framework, three hypotheses were defined to guide this study:

H1: Virtual workshops improve student learning.
H2: Active learning improves student learning in online settings.
H3: Learning in virtual settings are affected by students':
(a) gender;
(b) ability;
(c) familiarity with the topic.

4. Methodology

4.1 Research Design

This research involved a quasi-experimental design approach in which statistical analysis was conducted to analyze data from a virtual synchronous construction scheduling workshop administered to undergraduate students from construction-related fields at two institutions delivered through Zoom. The statistical analysis was conducted using tests administered before and after the workshop to determine the effectiveness of teaching a workshop on an online platform and identify how learning is affected when students are assigned to breakout groups to work collaboratively versus working individually. Furthermore, the authors explored demographic factors that may impact student learning, namely, gender, ability, and familiarity. The cumulative GPA of each student was collected as an indicator of their ability. Data about students' prior use of a construction schedule, exposure to scheduling, and construction experience were used as indicators of students' familiarity with the topic. Although there is evidence in the existing literature of other factors impacting student learning in virtual settings such as age [42, 43] and race [44, 45], authors excluded those factors due to homogeneity in such demographics among the subjects surveyed in this study.

4.2 Workshop Design

The workshop was conducted through Zoom and delivered by two graduate students under full-time faculty members' supervision, one from Rochester Institute of Technology and one from Roger Williams University. The workshop focused on introducing students to construction scheduling and testing their understanding of the Critical Path Method (CPM). The graduate students who delivered the workshop were trained virtually over 3.5 months by two full-time faculty from two different institutions offering courses in construction scheduling. The graduate students were intentionally kept as active contributors of the following components of the workshop:

- Develop workshop learning outcomes.
- Develop the workshop outline.
- Develop the content of the workshop, including the theoretical background and the associated practice problems and exercises.
- Develop a PowerPoint presentation to be used in the delivery of the workshop.
- Practice the breakout room option within Zoom as an active learning component.
- Set ground rules for lecture delivery.
- Rehearse multiple times for high-quality delivery and determination of appropriate timing while providing feedback for quality control and improvement.
- Discuss "what if" scenarios to ensure consistent delivery among multiple workshops with different students.

The authors used Gagne's [41] events of instruction as the basis of the workshop design, as illustrated in Table 1. Assessment of learning before and after instruction through pre and post-tests helped determine if there are any significant changes in the students' learning and understanding of the material taught [46, 47].

The program for the workshop and the duration of each activity are provided in Table 2. The learning outcomes of the workshop are as follows:

- Explain how the construction industry uses network diagrams to plan and control projects.
- Perform forward pass and backward pass calculations on a precedence diagram.
- Determine project duration from a precedence diagram.

Table 1. Gagne's event of instruction and corresponding workshop component

Gagne's Events of Instruction	Corresponding Workshop Component
Gain attention	• Introduced facilitators (faculty and graduate assistants). • Discussed details of the research study and how important students' participation is.
Inform the learner of the objective	• Reviewed all learning outcomes expected from the workshop. • Discussed how students' performance will be measured during and after the workshop.
Stimulate recall of prerequisite learning	• Administered a pre-workshop test that included questions about the topic and the student's prior experience.
Present the stimulus material	• Presented a PowerPoint presentation that included theoretical background as well as the technical instructions on how to solve CPM questions.
Provide learning guidance	• Provided multiple visuals, cases, and CPM exercises during the workshop presentation.
Elicit the performance	• Provided students a sample CPM problem and time to solve it. • A group of students was asked to work with a peer, while other students worked on the exercise individually.
Provide feedback about performance correctness	• Administered polls for students to report back their solutions for the CPM practice problem. • Reviewed the correct solution to the problem.
Assess the performance	• Administered a post-workshop test to compare results to the pre-workshop test.
Enhance retention and transfer	• Students continued to work on the same topic for the upcoming weeks as part of a scheduling course they were enrolled in.

Table 2. Planned duration vs. actual duration of the workshop

Planned Duration (minutes)	Actual Duration (minutes)				Activity
	Workshop 1	Workshop 2	Workshop 3	Workshop 4	
5:00	1:33	5:00 *	5:27	6:00	Introduction
8:00	11:09	9:00	8:47	11:00	Pre-workshop survey
2:00	0:43	0:25	0:41	1:00	Description of learning outcomes
18:00	19:20	20:20	18:10	18:00	Lecture and quick exercise by the instructor
10:00	11:01	13:44	10:40	12:00	Individual work/ breakout groups
0:00	3:56	3:03	3:31	2:00	Solutions to the exercise
12:00	11:44	15:00	14:00	12:00	Post-workshop survey
3:00	0:21	0:20	0:30	1:00	Question and answer session
2:00	2:12	1:00	0:50	2:00	Wrap up and review key points

* Estimated based on introduction durations of Workshop 3 and 4.

- Identify total floats of activities on a precedence diagram.
- Identify critical activities and the critical path(s) on a given schedule.

The workshop was split into two parts. The first part included a lecture with a sample exercise completed by the instructor, while the second part allowed the students to work on an exercise without help from the instructor. In order to ensure identical student experiences among four different workshops, students were told to save any questions they may have until after the workshop. For the exercise, the participants were either broken out into groups of two using the Zoom breakout room feature or asked to work on the exercise individually. The exercise was to complete a typical Critical Path Method exercise – a forward-pass and backward-pass on a simple network diagram to identify the project duration, early start, early finish, late start, late finish, and total float for each activity. The participants were also asked to determine the critical activities and the critical path. They were brought back together to the same Zoom session after about 10 minutes, and three poll questions were asked after the exercise. The three questions yielded the following results: 83.3% of the participants indicated that they completed the in-session exercise, 82.2% got the correct total duration, and 76.7% identified the critical path. The instructor then reviewed the correct solution to the exercise before proceeding to the post-workshop test. The participants were given the post-test, which featured the same questions as the pre-test (except the demographic questions) to assess the change in the participants' understanding of construction scheduling. The pre-test and post-test featured a partially complete network diagram (Fig. 2). Both

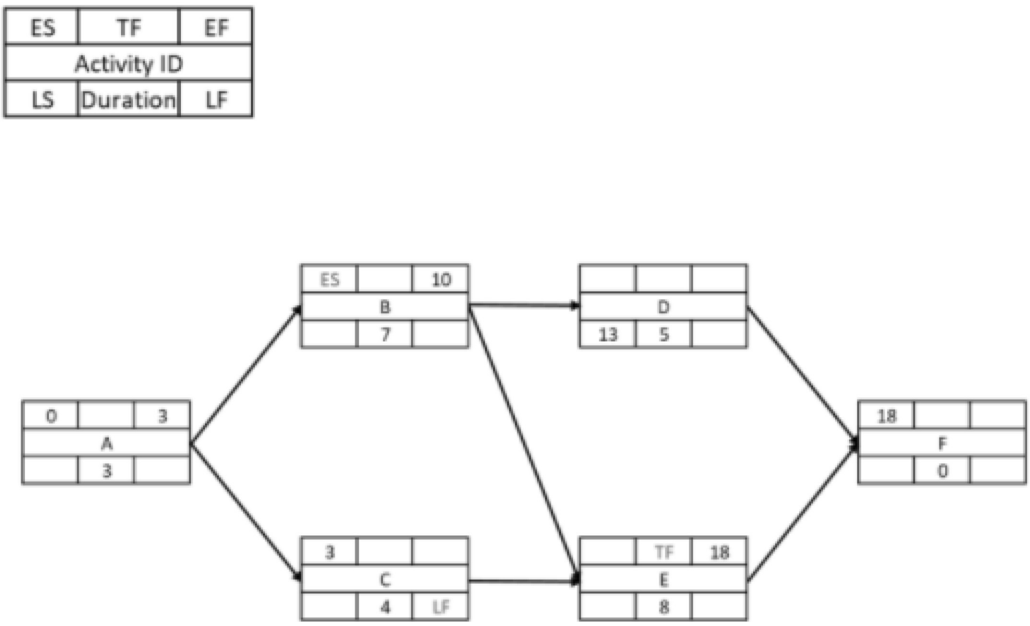

Fig. 2. Sample network diagram for questions in the pre and post-test.

tests were timed, but participants were allowed extra time to finish if needed. The entire workshop took just over one hour. Since the last three workshops were held as part of a regular classroom session, the professor, one of the authors of this study, introduced the last three sessions and took attendance. For this reason, workshops 2, 3, and 4 have longer introduction durations, as shown in Table 2.

4.3 Participants

Participants were from Rochester Institute of Technology and Roger Williams University, both private universities in the United States. The workshops were delivered in four sessions. The target group for the first session was first, second, and third-year civil engineering technology and construction management students, including students who had not taken a construction scheduling course before. They were sent email invitations, and fifteen students from two institutions volunteered to participate in the first workshop. They were invited to participate as long as they met the eligibility criteria of being in a construction-related program. Of the fifteen that participated in the first workshop, fourteen students completed the pre-workshop questionnaire, the workshop, and the post-workshop questionnaire. The three other workshop sessions included seventy-three students from Roger Williams University. The participants were registered in a lower-level construction scheduling course, and they represented first-year students to seniors, including one graduate student. The workshop was delivered as an introductory lecture for the Construction Estimating and Scheduling course they were enrolled in for the semester. The course is dual-listed as CNST 260 and ARCH 484 at Roger Williams University's Construction Management (CM) and Architecture programs. CNST 260/ARCH 484 is mandatory for all CM sophomores and an elective for Architecture students to introduce the basics of construction estimating and scheduling. Typically, students start the semester with an introduction to construction scheduling and spend the first half of the semester exploring basic scheduling concepts and methods, including Gantt charts, network diagrams, and CPM calculation. The second half of the semester focuses on the basics of construction estimating, including conceptual, square foot, and assembly types of estimates. All the students participated in the workshop except one were taking a scheduling course for the first time. One of the regular class sessions was utilized to conduct the workshops. These workshops were conducted intentionally at the beginning of the semester before students were exposed to scheduling concepts. Both institutions' institutional review boards approved the study, and all participants acknowledged the informed consent forms. The survey responses were anonymized before data analysis.

In total, eighty-seven students participated in all the workshops. An online pre-workshop (pre-test) survey was distributed to the participants at the start of the workshop before the lecture was delivered. The pre-workshop survey was conducted to screen and ensure that the participants were qualified to participate. The researchers also tested their knowledge of construction scheduling through the pre-workshop survey. The pre-workshop survey included eleven background and demographic questions and ten questions related to construction scheduling. The post-workshop test included the same construction scheduling questions from the pre-workshop test and no additional questions.

Approximately 70% of the participants are Construction Management students, 20.7% are Architecture students, 6.9% are Civil Engineering Technology students, 1.1% are Civil Engineering students, and 1.1% are in other majors (environmental science). Fig. 3 illustrates the different majors the participants are studying. Upon further review of the 87 responses, none of the students' pre and post-workshop performance appeared to be an outlier; thus, no responses were excluded from the analyses.

72.4% of all the attendees described their level of exposure to construction scheduling as minimal, while others had no exposure to construction scheduling. 64.4% of all the attendees stated that they had never used a schedule before. The participants had different levels of construction experience. 31% had no experience, while the majority (37%) had 1-12 months of experience (Fig. 4).

Approximately 21% of all workshop participants were female students, about 76% were male. In addition, 87.4% identified as Caucasian, while

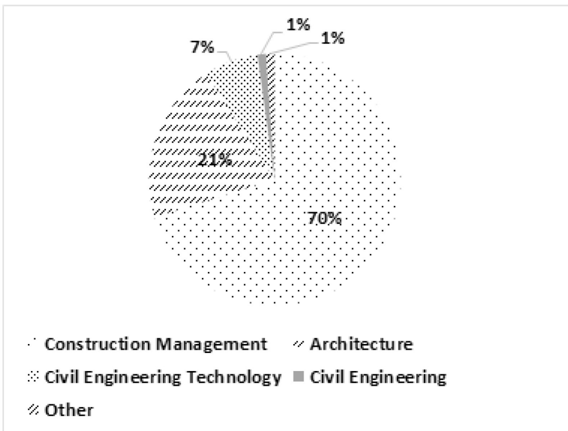

Fig. 3. Majors of students who attended the workshop.

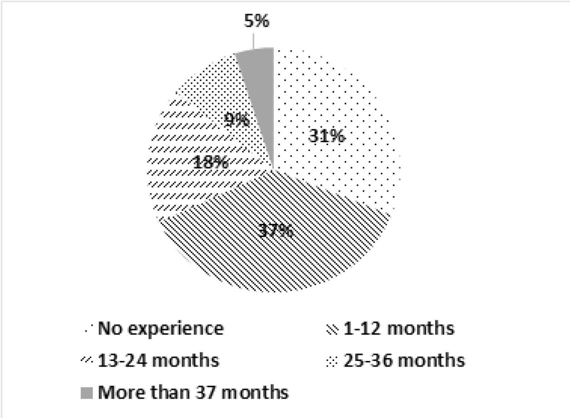

Fig. 4. Construction experience of the students who attended the workshop.

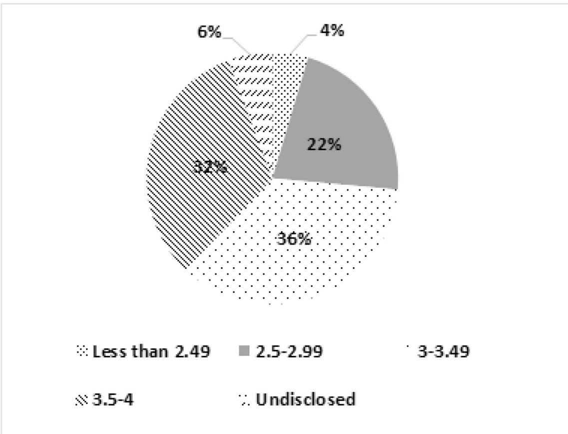

Fig. 5. Cumulative GPA distribution of workshop attendees.

others were African-American, Latino or Hispanic, Mixed Ethnicity, and Undisclosed. The student's raw cumulative GPAs were provided, the GPAs were then grouped (Fig. 5). 68% of the participants had a cumulative GPA greater than 3.00.

4.4 Data Analysis

The data was preprocessed and cleaned in Microsoft Excel and the statistical analysis was completed using SPSS version 26. Tests for normality were not completed since the sample size was greater than 30. Other statistical tests were completed to analyze selected variables as described in the results section. The authors conducted non-parametric statistical analyses using chi-square for mean comparison among binary variables while using t-tests to analyze the workshop's and the breakout room's impacts using pre and post-workshop scheduling test total scores. The authors used 95% as the confidence interval for the statistical analyses reported in this study.

5. Results and Discussion

5.1 Comparison of Overall Pre and Post-workshop Scores by Question

Table 3 illustrates the percentage of students who answered each question correctly in pre and post-workshop tests. Based on the t-tests conducted to compare the means of students' pre and post-workshop answers to each scheduling question, participants performed significantly better in every scheduling question administered after the workshop.

Results of a paired samples t-test confirmed that the total post-workshop test scores were significantly higher (M = 7.47, SD = 1.879) than the pre-workshop total test scores (M=3.07, SD = 1.758), $t(86) = -16.495$, $p = 0.000$). In other words, students did significantly better in all the post-test questions than the pre-test questions. These results support the hypothesis, H1 indicating that virtual workshops can improve student learning, which is consistent with studies that found that students benefited from virtual classrooms [48].

5.2 Comparison of Participants' Scores Based on Participation in Breakout Rooms

Some of the students were placed in breakout rooms to work on the exercise. Independent sam-

Table 3. Students' pre and post-workshop scores

Question Number	Pre-workshop Correct (%)	Post-workshop Correct (%)	Difference [Post-Pre workshop] (%)	Sig 2-tailed
Q1	49.40	93.10	43.70	0.000*
Q2	78.20	94.30	16.10	0.001*
Q3	19.50	79.30	59.80	0.000*
Q4	13.80	72.40	58.60	0.000*
Q5	26.40	64.40	38.00	0.000*
Q6	5.80	50.00	45.00	0.000*
Q7	46.00	97.70	51.70	0.000*
Q8	25.30	72.40	47.10	0.000*
Q9	6.90	74.70	67.80	0.000*
Q10	35.60	78.80	43.20	0.000*

* Significant at 95% confidence level.

Table 4. Differences in overall scores of those that attended a breakout room and those that did not

	Attended a Zoom breakout room?	Mean	Std. Dev.	Mean Diff.	Sig. (2-tailed)
Post-workshop overall test scores	No	7.81	1.61	–0.67	0.072
	Yes	7.14	1.85		
Improvement from pre to post-workshop	No	4.91	2.53	–1.00	0.061
	Yes	3.91	2.37		
Duration subjects took to answer the post-workshop test	No	379.07	171.36	21.16	0.560
	Yes	357.91	166.36		

Table 5. Differences in individual question scores of those that attended a breakout room and those that did not

Question Number	Attended breakout room?	Percent Correct	Percent Difference	Pearson Chi-Square
Q1	No	93.2%	–3.1%	0.414
	Yes	90.1%		
Q2	No	90.6%	7.1%	0.159
	Yes	97.7%		
Q3	**No**	**76.7%**	**–6.2%**	**0.039***
	Yes	**70.5%**		
Q4	No	81.4%	–17.7%	0.064
	Yes	63.7%		
Q5	No	69.8%	10.7%	0.299
	Yes	59.1%		
Q6	No	37.2%	–3.1%	0.761
	Yes	34.1%		
Q7	No	95.3%	4.7%	0.148
	Yes	100.0%		
Q8	**No**	**74.4%**	**–22.1%**	**0.032***
	Yes	**52.3%**		
Q9	No	74.4%	0.6%	0.950
	Yes	75.0%		
Q10	No	74.4%	–3.9%	0.679
	Yes	70.5%		

* Significant at 95% confidence level.

ples t-tests were conducted to identify the differences between means of each normally distributed non-binary variable between subjects who attended a breakout room during the workshop and those who did not. The t-tests show that the mean test scores of those who participated in a breakout room were lower than those who did not. There were no significant differences at or higher than the 95% confidence level (Table 4). However, it was interesting to note the relatively poor performance of students in breakout rooms. This result raises the question of which factors make breakout group sessions more effective. Examples of such factors may include providing a detailed structure with an outline of expectations for students working in breakout rooms. The authors further explored the data to understand students' performance on individual questions in relation to whether they were in a breakout room or they worked individually. Based on these results, for hypothesis H2, active learning components did not improve student learning in online settings. Another study that used breakout rooms did not find significant differences in class averages compared to students in previous years [14]. Although prior research has shown that active learning works, further research is needed to identify which active learning techniques and under what conditions they may be effective, particularly in virtual settings.

The percentage of correct answers to the post-workshop scheduling test grouped based on those who attended a breakout group during the workshop and those who worked entirely on their own during the workshop are given in Table 5. The table also shows the results of chi-square tests of independence that were performed to examine the relationship between students' performance in each scheduling question and their involvement in active learning (attending a breakout group during the workshop). Among the ten questions, two had significantly different results among those who participated in a breakout group and those who did not. In addition, the average Question 3 and 8 scores of those who participated in a breakout group were significantly less than the corresponding groups of those who worked individually.

The authors found no significant impact of the breakout session on the students' improvement scores when controlled for the cumulative GPA. The authors also conducted ANCOVA tests to identify differences between subjects who attended the breakout sessions and those who did not. There were no significant differences between these two groups' post-test scores when the comparison of means was controlled for the pre-test scores.

5.3 Comparison of Participants' Scores based on Gender

The students' performance based on their gender indicates that female students performed significantly lower (M = 2.11, SD = 1.711) than their male counterparts (M = 3.38, SD = 1.863, p = 0.011) in the pre-test. Although not statistically significant, the females (M = 7.83) did better than the males (M = 7.38) in the post-test. Female

Table 6. Comparison of gender and pre-test, post-test, and improvement

	Gender	N	Mean	Std. Deviation	Std. Error Mean	Significance
Pre-test Score	Male	66	3.38	1.863	0.229	0.011*
	Female	18	2.11	1.711	0.403	
Post-test Score	Male	66	7.38	1.734	0.213	0.359
	Female	18	7.83	1.855	0.437	
Improvement	Male	66	4.00	2.431	0.299	0.011*
	Female	18	5.72	2.372	0.559	

* Significant at 95% confidence level.

students improved significantly more (M = 5.72, SD = 2.373) than their male counterparts (M = 4.00, SD = 2.431, p = 0.011). Overall, female subjects benefited more from the workshop than the males (Table 6). However, ANCOVA tests showed no differences in the post-workshop scores of female and male students when controlled for their pre-test scores. Hypothesis H3a is supported by the results indicating that learning in virtual settings can be affected by students' gender which is supported by other studies [27–29].

5.4 Comparison of Participants' Scores based on Student Ability

The authors identified significant moderate positive correlations between subjects' ability as measured by their cumulative GPA scores and their pre to post-workshop improvement scores, r = 0.375, n = 82, p = 0.001. This means that the higher a student's ability as measured by cumulative GPA, the higher the improvement in their test performance after attending the workshop. The analysis also considered two groups of students cut off at a median GPA value of 3.3 (Table 7). One group included students with a cumulative GPA of less than 3.3, and the other group included students with a cumulative GPA of equal to or greater than 3.3. Although there were no significant differences in the pre-test performance of these two groups when it came to the post-test, students' with a GPA less than 3.3 performed significantly lower (M = 6.58, SD = 1.703) than those who had a GPA higher than or equal to 3.3 (M = 8.30, SD = 1.407, p < 0.001). Similarly, students with a GPA higher than or equal to 3.3 improved significantly more (M = 5.11, SD = 2.404) than their counterparts with a GPA less than 3.3 (M = 3.74, SD = 2.413, p = 0.012). These results support hypothesis H3b stating that learning in virtual settings be affected by students' ability which is consistent with findings from other studies [30–32].

5.5 Comparison of Participants' Scores based on Familiarity with the Topic

This study also looked at participants' familiarity with construction and construction scheduling by asking three questions. They were asked:

- if they had used a construction schedule before,
- what their level of exposure is to a construction schedule,
- if they had construction experience.

35.6% of the students had used a construction schedule before, while others had not. The pre-workshop score of students who had used a construction schedule before was higher than for those who had not, but students who had not used a construction schedule before had a higher improvement and better post-workshop scores than those who had used a schedule before (Table 8). Those who used a construction schedule before improved significantly less (M = 3.55, SD = 2.321) than those who did not have such prior exposure (M = 4.88, SD = 2.472), t(85) = –2.449, p = 0.016).

There were significant moderate positive correlations between subjects' pre-test scores and their

Table 7. Comparison of cumulative GPA and pre-test, post-test, and improvement scores

	Cumulative GPA less or greater than 3.3	N	Mean	Std. Deviation	Std. Error Mean	Sig.
Pre-test Score	<3.3	38	2.84	1.824	0.296	0.419
	≥3.3	44	3.18	1.944	0.293	
Post-test Score	<3.3	38	6.58	1.703	0.276	0.000*
	≥3.3	44	8.30	1.407	0.212	
Improvement	<3.3	38	3.74	2.413	0.391	0.012*
	≥3.3	44	5.11	2.404	0.362	

* Significant at 95% confidence level.

Table 8. Comparison of prior use of construction schedule and pre-test, post-test, and improvement scores

	Used Construction Schedule Before	N	Mean	Std. Deviation	Std. Error Mean	Sig.
Pre-test Score	Yes	31	3.71	1.811	0.325	0.017*
	No	56	2.71	1.836	0.245	
Post-test Score	Yes	31	7.26	1.788	0.321	0.403
	No	56	7.59	1.745	0.233	
Improvement	Yes	31	3.55	2.321	0.417	0.016*
	No	56	4.88	2.472	0.330	

* Significant at 95% confidence level.

level of prior exposure to construction scheduling, $r = 0.436$, $n = 87$, $p < 0.001$ (Table 9). Similarly, the authors identified a significant low positive correlation between the subjects' prior use of a construction schedule and their pre-test scores, $r = 0.255$, $n = 87$, $p = 0.017$.

In other words, as the construction scheduling and schedule use experience increased, so did the students' pre-test scores. However, the same correlation was not present regarding the post-test performance. In fact, those with some exposure to construction scheduling performed significantly less (M = 7.24, SD = 1.729) than those who did not have such prior exposure (M = 8.08, SD = 1.717), $t(85) = 2.041$, $p = 0.044$) when it came to their post-workshop performance. Similarly, those with some exposure to construction scheduling improved significantly less (M = 3.67, SD = 2.140) than those who did not have such prior exposure (M = 6.33, SD = 2.334), $t(85) = 5.066$, $p < 0.001$).

69% of the students had prior construction experience. The pre-workshop score of students who had construction experience was higher than those who did not (Table 10). Those with no construction experience improved significantly better (M = 5.74, SD = 2.795) compared to those who had some construction experience (M = 3.80, SD = 2.098, $t(85) = 3.222$, $p = 0.003$).

Students with exposure and experience with construction and construction scheduling did not seem to learn as much as those without such familiarity. This could be because students with familiarity with the topic may have felt more comfortable and confident and, in turn, may not have paid as much attention during the workshop. These results support hypothesis H3c, stating that learning in virtual settings can be affected by students' prior familiarity with the topic, which is consistent with findings from other studies [33–35].

Table 10. Comparison of prior construction experience and pre-test, post-test, and improvement scores

	Prior Construction Experience	N	Mean	Std. Deviation	Std. Error Mean	Sig.
Pre-test Score	Yes	60	3.50	1.790	0.231	0.001*
	No	27	2.11	1.739	0.335	
Post-test Score	Yes	60	7.30	1.700	0.220	0.194
	No	27	7.85	1.854	0.357	
Improvement	Yes	60	3.80	2.098	0.271	0.003*
	No	27	5.74	2.795	0.538	

* Significant at 95% confidence level.

Table 9. Comparison of level of exposure to construction scheduling and pre-test, post-test, and improvement scores

	Exposure to Scheduling	N	Mean	Std. Deviation	Std. Error Mean	Sig.
Pre-test Score	None	24	1.75	1.260	0.257	0.000*
	Minimal	63	3.57	1.838	0.232	
Post-test Score	None	24	8.08	1.717	0.351	0.044*
	Minimal	63	7.24	1.729	0.218	
Improvement	None	24	6.33	2.334	0.477	0.000*
	Minimal	63	3.67	2.140	0.270	

* Significant at 95% confidence level.

6. Implications

The main implications of this research for educational practice are discussed below. The findings support the initial hypothesis (H1) for this study that virtual workshops can be effective in teaching construction scheduling.

Our study did not support the hypothesis (H2) that active learning approaches would improve student learning in virtual environments. For the active learning portion of this study, students placed in the Zoom breakout rooms did not do as well as those that worked individually. It appears that pair work (at least virtually) does not have the expected effects of increasing student learning. In fact, the opposite effects on student learning are likely, particularly for virtual pair work. Since there is an overwhelming number of existing studies that illustrate the effectiveness of active learning strategies, it is critical for future researchers to further investigate which and how active learning approaches should be delivered in order to maximize their effectiveness, particularly in virtual settings. Also, student work in breakout rooms should be intentionally designed to ensure effective learning or group work [49].

The virtual workshops worked better for some factors associated with student demographics. Gender differences were also highlighted in the pre and post-workshop test results. Female participants scored lower in the pre-workshop test but higher in the post-workshop test. They seemed to have learned more than their male counterparts. Instructors should be aware of gender differences and their level of preparedness to learn, especially in STEM fields. Students' familiarity with the topic had significant and adverse effects on their learning in virtual environments. While the virtual workshops work very well for students with no prior exposure to the topic or experience, instructors may need to consider more creative strategies to engage those students with prior exposure to the topics covered during these sessions.

7. Other Challenges and Recommendations for Remote Learning during Emergency Situations

The authors of this study made some additional observations while conducting the workshops. Students did not always leave their cameras on, even when instructed to do so. This may be due to various reasons, including ones associated with the pandemic and the remote working conditions of individual students. Regardless, the instructors perceived that students who had their cameras turned off were distracting as it was challenging to confirm their engagement with the content. This is especially concerning during active learning, such as pairwork that requires students' full participation. Castelli and Sarvary [50] recommend that instructors should not require the use of cameras during synchronous meetings but encourage its use. They also recommend surveying students to understand their reasons for not turning their cameras on [50]. Another way to address the perceived reduction in student engagement may be to use additional active learning techniques, such as polling which was incorporated in our study [49].

Another observation was regarding the students' ability to ask questions during the workshop. In this study, the students were asked to leave their questions until the end to allow for replicability across the different offerings of the workshop and reduce disruptions. The impact of the inability to ask questions during the workshop was not assessed. However, instructors are encouraged to allow their students to ask questions to facilitate exchange while checking for understanding before continuing with the lecture [49].

It is also important to acknowledge that the COVID-19 pandemic brought about significant challenges to the methods of instruction at educational institutions as many had to switch to online learning approaches abruptly. Table 11 presents some of those challenges reported related to remote learning, particularly during the COVID-

Table 11. Challenges and recommendations for remote learning during the COVID-19 pandemic

Challenges	Recommendations
Lack of infrastructure support for remote learning [55]. Technical issues with internet connectivity [56, 57]. Technical issues related to video conferencing tools and personal devices [56, 57]. Students being disengaged online [56]. Deficient student and instructor computer skills [58, 59]. Students' perception of increased workload when learning remotely [58]. Decreased student motivation [56, 57]. Difficulty in teaching certain subjects virtually [57].	For synchronous sessions, make accommodations for participants in different time zones [49]. Check for availability of reliable internet connection for both students and the instructors [49]. Ensure that appropriate technology is selected for remote learning [54]. Ensure that an instructor or staff is available to monitor the chat and breakout rooms and to answer questions [49]. Be flexible and set reasonable expectations [49]. Provide training for faculty and staff to effectively support remote learning with the appropriate modality [60].

19 pandemic. However, some studies report an increase in student performance in remote learning environments [51, 52], especially when students and instructors have prior exposure to online learning tools and technology [53]. Nevertheless, it is crucial to note that effective remote learning goes beyond the use of technology, and the instructor plays a crucial role in ensuring effective learning regardless of the modality [54].

8. Conclusions

This study assumes that given the need to switch to virtual teaching and learning formats during the COVID-19 pandemic, most students would have been exposed to receiving virtual instruction and working in breakout rooms online. Results of this study illustrate that virtual construction scheduling workshops can significantly increase students' understanding of basic scheduling principles and CPM calculations. This study also showed that students' gender, ability, and familiarity with the topic impacted their learning in virtual environments. Furthermore, while other studies indicate that active learning techniques can improve students' performance, in this research, the overall performance of students placed in breakout rooms to work in pairs did not significantly differ from those that worked individually. More studies are needed, particularly with larger sample sizes and more structured active learning tasks, to confirm the performance of those who engage in active learning during virtual education. It is important to note that the workshops were conducted with different cohorts, which could potentially impact the results. In order to minimize such errors in the experiments, authors carefully designed and delivered each workshop to ensure consistent results across all the deliveries.

To sum up, more research is needed to investigate the appropriate delivery methodologies for active learning techniques in virtual environments. Prior exposure to technology, keeping cameras on, allowing time to practice before pairing, and allowing opportunities to share results of experience with active learning techniques are some of the factors to explore in future studies to reap similar benefits from active learning techniques in virtual environments when teaching construction scheduling. Our study shows that without such knowledge, active learning strategies may not improve student learning in virtual settings. Thus, the authors recommend that instructors explore different strategies to engage students, particularly before, during, and after virtual group work sessions. Future work for this study will involve an in-person version of the workshop to assess and compare the impact of the in-person versus an online workshop delivery on student learning.

With the emergence of new variants of the COVID-19 virus, institutions may need to build agility in adopting a variety of remote, in-person, and hybrid methods of instruction. As society learns about the new variants and the associated operational consequences, it is critical for educators to choose the most suitable format of instruction while abiding by guidelines set out by their institutions to ensure the health and safety of all participants. This requires educators and their institutions to become familiar with the advantages and disadvantages of different modalities to be more proactive in the future. Given the experience with the COVID-19 pandemic, partial closures, and selective quarantining requirements, hybrid instruction in which some students attend classes virtually while others attend in-person, is likely to play an essential role in the future of education. Consequently, research into how similar workshops can be delivered in hybrid setups should be conducted as such settings are expected to have their unique challenges.

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