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Exploring the Impact of Virtual Office Hours on Engineering Students' Learning: A Case Study in Higher Education*

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Student-teacher interaction is a vital part of course design, for this reason many instructors in higher education have established office hours to further ensure this interconnection. However, office hours are often limited by time and physical space, creating a less than optimal learning environment for students who already have many other time commitments. For this reason, attendance rates are often low. A solution to these constraints was posed with the concept of virtual office hours. This low-stakes environment addresses the attendance issue and allows students the flexibility of experiencing meaningful learning from anywhere they choose. This study reports on the student experience of virtual office hours, as compared to the traditional face-to-face office hours, offered in three engineering courses. Students varying from sophomore to junior levels were enrolled in one of three semester-long courses, two mechanical engineering and one electrical engineering. 154 students between the two disciplines were enrolled in a course offering virtual office hours. The implementation logistics of these virtual office hours, key details on interactions during the sessions, and content presentation are discussed in this paper. Goals of this study were: to identify how virtual office hours impact engineering students' learning, ascertain whether the sessions were an efficient use of time for both students and instructors, and to determine the differences between virtual office hours and traditional face-to-face office hours. The students' perspectives were acquired through surveys administered at the end of the semester-long implementation of virtual office hours. Data analysis of the survey responses revealed that the implementation of virtual office hours within these courses was beneficial for both the students and instructors.

Keywords: office hours; virtual office hours; online learning; STEM learning; student perspective

1. Introduction

Student-teacher interactions are typically limited outside of the classroom, oftentimes being short, irregular, and only occurring within specific circumstances such as at conferences or presentations [1]. Office hours provide a convenient way for students and teachers alike to initiate the learning conversation outside of a formal learning scene. However, students are busy and in large classes, it is difficult to accommodate each person's availability for office hours. As such, a common complaint regarding traditional office hours is a lack of convenience and accessibility [2]. Virtual office hours (VOH) create an opportunity for this interaction to occur anywhere anytime, creating a convenient and accessible platform for student-teacher interaction.

2. Background

The student teacher connection. Personal contact between instructors and students is considered vital for optimal academic performance [2–4]. Studies as early as from the 1990s have shown that higher levels of contact with faculty, both formal and informal, are beneficial for students [5–7]. As noted in the literature, the era of technology is rapidly evolving, allowing for the frequency of student-teacher communication to increase and for mediation through technology [3, 7, 8]. VOH in particular create an additional time and space for students to connect and communicate with their instructors. A 2009 paper proposes that VOH are a form of cyberinfrastructure, and that they provide new avenues for enhancing student–faculty interaction [9]. Additionally, a 2017 publication reports student feedback from an asynchronous course which utilized synchronous VOH. Interestingly,

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students here responded that their number one reason for attendance was to get to know their instructor better [10]. It is evident that, even in asynchronous courses, students value having access to their instructors.

Benefits of VOH. A study comparing virtual and in-person office hours, found that students utilized both VOH and in person office hours at the same rate. However, results showed that students who were enrolled in courses with VOH reported higher satisfaction with VOH than their counterparts, who only had traditional, in-person office hours offered. Students were surveyed to identify barriers to in-person office hours; many gave multiple, compound, responses, with 22.4% of students reporting that instructors were sometimes not available during the scheduled office hour time. 15.7% of students also reported that it was difficult to schedule a time to meet with their instructor outside of office hours [2]. VOH provide a meaningful solution to both of these barriers, as instructors can schedule a virtual time for all students to attend. The "virtual" aspect of these office hours allows instructors the flexibility to meet from anywhere (conferences, vacations, personal time, illness, etc.). Aside from instructor access, 66.3% of students cited inconvenience as the largest barrier for not attending in-person office hours, 51.7% of students said' that they did not have time to make it to the office hours. Additionally, other students, 14.6%, had scheduling issues with work, other studies, or other classes that would not allow them to attend in person [2]. In today's fast-paced atmosphere, students have many demands on their time, as such, finding a time for the entire class to meet on campus can be a huge barrier to learning conducted outside of class time [11]. Here, VOH allows for students to participate from wherever they are and allows for sessions to be hosted later in the evening when students are not in classes and are not likely to be working.

Undergraduate student perceptions of office hours were collected from a range of 81 students from a mid-sized Texas university, where 70% contributed positive responses towards VOH, multiple benefits were observed and reported by students who attended [12]. Identified benefits included "more opportunities to communicate with their professor," "easier to contact professor," "convenient," and "more comfortable to talk to the professor." Again, access and communication with the instructor are highlighted by the students here. In addition to this theme, most students who indicated positive feelings towards VOH cited convenience and accessibility as the main reason. These individuals' responses focused on three factors: the convenience of communicating with their instructor from the comfort of their own personal setting, the ease of not having to work out a specific meeting time with their instructor, and having the opportunity to communicate with their instructor outside normal office hours. The obvious goal of office hours is to provide student support and promote student help seeking, VOH creates a convenient path for both of these goals to be achieved. It should be noted that in order for VOH to be effective, student expectations should be instituted [13, 14], and effective pedagogy should be utilized [5, 15, 16].

VOH in STEM. A study published in 2022 was conducted at a comprehensive university in California, with the goal of investigating motivations and barriers for student office hour attendance in science, technology, engineering, and math (STEM) disciplines [17]. The focus on STEM disciplines in this study is important as many studies that currently report on the use of both traditional and VOH [9, 10], do not focus on or include STEM disciplines, which are vital to the growth and development of modern society. Over 500 students were surveyed in this study, individuals represented most life science majors. Most students (63.9%) reported convenience and flexibility as an advantage of VOH. Interestingly, the second most common response (11.4%) was the lack of anxiety and intimidation students felt when going into VOH as opposed to in-person office hours. Another study [13], found that students with low confidence and course enjoyment levels attended VOH more frequently. Researchers concluded here that this could be due to a sense of security and a lack of embarrassment when asking questions of a "simpler" nature in front of other students [18]. Office hours empower students to step outside of their social comfort zones, allowing learning to take place without fear of error or judgment. Removing this fear and allowing for conducive, collaborative learning, is a key factor when face-to-face interaction isn't possible due to geographic location, lack of economic dispersion, or critical situations such as during the pandemic, when learning was conducted nearly 100% online [19]. The lack of physical interaction during COVID-19 demonstrated that VOH was not just a helpful tool, but a necessary one [16, 17].

Recorded access to course content. While students attend live VOH to learn course material, assignment requirements, and to get questions answered, students across studies have expressed an appreciation for recorded sessions for a variety of reasons [10, 17]. Many cite that it increases flexibility, in that students are able to go back and re-watch videos as many times as needed to ensure comprehension [2, 19]. Others have noted that it provides increased

access to those who are unable to attend the live VOH sessions due to other obligations at the time sessions are offered [11, 20, 21]. Recorded lectures that are posted on open platforms, such as YouTube, also allow students to independently overcome learning barriers, such as following complex processes and intricate details detrimental to concept understanding [19]. A study published in 2021 surveyed engineering students on the student experience of virtual learning experiences during the COVID-19 pandemic. Particular appreciation was expressed by students for courses that had prerecorded lectures which were later followed by more engaging, interactive components during live sessions. Here, students valued the time spent focusing on their questions and problem-solving during sessions [19]. The time spent answering student questions and focusing on deeper learning/clarification is another commonly observed benefit of VOH. Across studies, this is a popular reason why students attend VOH – to get help working through and understanding content [13, 17]

Student satisfaction. Student satisfaction is a huge factor in learning. If students are not satisfied with their experience during office hours, in-person or virtual, attendance will likely dwindle and worse, students' learning will be of poorer quality [22, 23]. As such, it is important to touch on student's satisfaction levels associated with VOH. Literature has reported that students reported high levels of satisfaction with VOH. Common themes of satisfaction are beneficial impacts on student-faculty communication outside of the classroom [2], positive feedback from student end-of-course evaluations [10, 24], usefulness of the instant messaging portion of VOH [9], and increased of interest in students' respective areas of study [13]. Considering the pedagogical potentials of VOH as noted in the review of literature, researchers at X University were interested in studying the use of VOH in their engineering courses. An exploratory study [25] was conducted in the courses of three engineering instructors who taught three different courses (Circuit Analysis and Design, Heat Transfer, and two sections of Dynamics). The instructors then participated in an interview after at least one semester of utilizing VOH (*See Appendix A for interview questions.)*

Overall, the instructors believed that VOH were beneficial to the students in their courses. Benefits of VOH identified by the instructors included: not having to reiterate material, accommodation of more students, constructive meetings, and increased participation from students. The instructors stated that there was more student involvement in the course with use of VOH. Each of the instructors also reported that they planned to continue using the same method of VOH in their future courses. The study indicated that student faculty interactions can be increased in frequency and depth with VOH. None of the instructors felt that VOH increased office hour attendance, however, the instructors did find there to be more interaction between themselves and students than they had in previous semesters when they did not use VOH. Based on the positive results of this exploratory study that focused on instructor perspectives, the current study was designed to investigate student perspectives on the impact of VOH on: their learning, efficient use of their time, and motivation to interact with their instructor regarding course content.

3. Method

The VOH analyzed in this study were held at a university in the Northwestern United States by two Mechanical Engineering faculty members and one Electrical Engineering faculty member. Rather than calling them virtual office hours, they were renamed "Happy Hours," based on an anonymous student comment, in order to create a positive and informal context [26]. Typically, Happy Hours were held twice a week throughout the entire semester and replaced traditional office hours. Sessions were held on nights before lectures to allow for clarifying questions prior to class. This was particularly beneficial for lecture days where there were in-class quizzes or exams. No new content was introduced as student attendance was not mandatory. Sessions were typically held from 7–9 pm, with the intent of accommodating the greatest number of students' schedules. Timing varied slightly if students had time conflicts. As Happy Hours were held in a virtual space, students could join the session regardless of location and were able to call in using a variety of convenient devices such as computers, tablets, or cell phones.

During the session, the instructor shared their screen via Zoom, displaying documents, the instructor could then write out problems using a Microsoft Surface or an iPad. Students also had the option to share their screen if needed, allowing for a clearer explanation of questions. Interaction between peers or the instructor were facilitated through the "raise hand" feature and the chat box. While multiple students could actively participate in this format, others were able to benefit from passive participation, and instructors only had to answer questions once. It was intended to be a collaborative environment where students were able to ask questions about possible solutions and discuss with the instructor and each other. By solving problems together, students solidified their

Table 1. Research Questions

Research Questions
RQ 1. In what ways does virtual office hours impact students' perception of learning engineering-related course content?
RQ 2. Do virtual office hours increase contact time between students and instructors?
RQ 3. What is the learner perception of virtual office hours as an efficient use of their time?
RQ 4. What factors motivate students to reach out to the instructor virtually as compared to through face-to-face office hours?

understanding of the approach, which made assessments easier. If additional assistance was needed students always had the option to schedule an in-person consultation. Instructors could also choose to record sessions, so that students who could not attend were still able to view it. In addition, this added recording gave students another learning tool, in that they could view the video whenever needed. Videos were posted for the entire semester, allowing students to use them as a review method for quizzes and exams.

Students in each of these courses completed an end of course survey with 13 questions that aimed to gather their perspectives on VOH. In order understand how VOH impacted student learning, the following research questions were asked:

3.1 Theoretical Framework

Many different theoretical frameworks exist for use in analyzing students' perceptions and learning. Identifying how different students perceive an event is an approach utilized by many education research studies, this is because students' perception of an event can influence how students experience and react to said event [4, 27–29].

Research Questions 1, 2, and 3 (see Table 1) of this study utilize variation theory [30]. Variation theory, "offers a theoretical framework from which to explore possible variations in experience and the resulting differences in learning and understanding . . . Two individuals who experience the same phenomenon may focus on different features and, thus, come to understand the phenomenon differently." [30, p. 9]. Variation theory is predominantly used in mathematics pedagogy, where it focuses on the object of learning and its presentation through the intended, enacted, and lived objects of learning. The goal of this theory is to conclude with a description of the nature of a particular phenomenon.

As such, the specific goal of this study is to understand engineering students' perceptions of VOH in order to determine if it is a productive use of students' time. Students oftentimes do not experience or perceive the same course benefits or barriers as instructors predict they will [1, 31–34]. Variation theory highlights this misalignment, and notes that it can lead to negative impacts on student learning [35]. Studies show that students' learning is heavily influenced by their perception of activities and assignments, something that is mostly out of the instructor's control and effectively predicted through their perception of instructor behaviors [17].

Research question 4 (see Table 1) explores students' motivations for instructor contact during office hours. Many overlapping constructs and theories are utilized to consider each of the complex facets that are encompassed in students' motivations [36–40]. RQ 4 is viewed through the lens of self-determination theory (SDT) as a framework. SDT proposes that in order for students to feel intrinsic motivation, their necessities of autonomy, competence, and relatedness must be considered and met [39, 41, 42]. This study utilizes the SDT framework to understand engineering students' self-reported motivations for instructor contact during VOH as opposed to regular office hours.

3.2 Study Settings

Three separate courses utilized VOH as a learning tool throughout the course, Dynamics (ENGR 220), Circuit Analysis and Design (ECE 121), and Heat Transfer (ME 320). During VOH sessions, students in each section were able to view the instructors screen as well as listen to their explanation through means of an online platform. Students that were logged into the session had the ability to either use their microphone to respond or type their response for the instructor to see. In addition to the live video, a recording of the session was also uploaded to blackboard for those who were unable to attend as well as for later reference. The sessions were set up as a virtual tutoring session and consisted of several practice problems for the students to go through.

3.3 Participants

Each course had a range of 15–40 students in each section. Table 2 depicts the enrollment rate of each section along with the corresponding survey response rate. The Dynamics course had two separate sections (ENGR 220-1 and ENGR 220-2), resulting in a total of 4 total sections involved in the VOH experience. In total, 173 students were enrolled and 154 participated in the survey. Students were all undergraduates and came from electrical, civil, and mechanical engineering disci-

Table 2. Student Enrollment and Survey Response Rate

Course	Students Enrolled	Student Survey Responses
ENGR 220-1	34	28
ENGR 220-2	59	48
ME 320	52	50
ECE 212	28	28
TOTAL:	173	154

plines. Historically, demographics within the engineering department are 19% female, 81% male, 33% first generation college students, 26% minorities, and 74% white.

3.4 Data Collection

After one semester of VOH implementation, students completed an anonymous Qualtrics course evaluation survey regarding their experience. Questions on the course evaluations were utilized for: this study, department required data collection, and personalized instructor feedback. Appendix B lists the sixteen qualitative and quantitative evaluation questions pertaining to the RQs of this study.

3.5 Analysis

Student course evaluations contained both quantitative and qualitative data, as such these were organized both numerically and thematically, respectively. The organization of this data allowed for proper analysis of the students' feedback regarding VOH. For the quantitative data, students were given the chance to respond to seven different questions. Students rated their agreement with a given statement on a Likert scale of 1 to 5 where 1 indicated, "strongly disagree," and five indicated, "strongly agree."

Students were also asked to respond to eight qualitative questions in a few sentences. Appendix B illustrates the alignment between the research and evaluation questions. Thematic coding was used to organize the qualitative responses using blanket statements based on common themes within the students' responses. These responses were then grouped into categories based on their likeness to the blanket statements. The total number of student responses to each question was taken at the end of the thematic coding. In the occurrence of an outlying response that did not fit into a specified category, the response was placed into a miscellaneous category. If placed in this category, the response was taken out of the overall amount of student responses for that question. As qualitative responses allowed students to respond in several sentences, some responses contained multiple themes relating to the blanket statements, thus they were placed in multiple categories. This did not affect the amount of student responses, as such some percentages did not sum to 100%.

4. Results

Based on the evaluations, the majority of students found VOH beneficial. A common theme was that it was a convenient time to contact their instructor. Many stated that they attended to ask questions, get additional help, and gain a better understanding of the course work. This was a time for many to reinforce what was taught in the classroom. Some even found a correlation between attendance and higher test/quiz scores. Students were more motivated to contact their instructors via VOH than in person office hours and even prefer it over traditional office hours. Those who did not benefit from VOH often found them unnecessary for their comprehension or had a scheduling conflict. Several students complained about the pace of the lesson and found the recorded video to be more helpful overall as they could go through the material at their own pace. Overall, VOH were found to be useful to some students, because they did not have to go on campus, were not as intimidating as face-to-face office hours, and solidified course material.

The attendance for each section was self-reported (see Table 3), answering "yes" indicates attendance of at least 1 VOH session, while answering "no" indicates no VOH attendance during the semester. This is important to consider, as a lack of attendance invalidates some of the student responses. Their answers are valid to questions such as why they could not attend but are invalid to questions such as how the sessions helped them master course content. Participation percentages are critical in gaining better insight to the variances between scoring of courses.

4.1 Quantitative Results

Students rated their agreement with a given statement on a Likert scale, with 1 being "strongly disagree," and 5 being "strongly agree." The first given statement in Table 4 illustrates students' feedback on if attending VOH positively impacted their learning in the course. Each section scored an average above four, being "agree." Based on survey responses, it was found that most students thought

Table 3. VOH attendance

	YES	NO
ME 320	95%	5%
ECE 121	90%	10%
ENGR 220-1	70%	30%
ENGR 220-2	75%	25%
AVERAGE	83%	17%

Table 4. Average Student Likert Responses to Survey Statements Regarding VOH

Average Student Likert Responses to Survey Statements Regarding VOH					
Given Statement	**ME 320**	**ECE 121**	**ENGR 220-1**	**ENGR 220-2**	**Overall Average**
(RQ1) Attending VOH positively impacted my learning of content in this course.	4.6	4.3	4.2	4.2	4.3
(RQ2) Availability of virtual office hours increased my access to the course instructor.	4.6	4.1	4.3	4.2	4.3
(RQ3) Virtual office hours was an efficient use of my time.	4.4	4.1	4.1	4	4.2

Table 5. Average Student Likert Responses to Survey Statements Regarding VOH vs. Face-to-face Office Hours (RQ4)

Average Student Likert Responses to Survey Statements Regarding VOH vs. Face-to-face Office Hours (RQ4)										
	ME 320		**ECE 121**		**ENGR 220-1**		**ENGR 220-2**		**Overall Average**	
Given Statement	**VOH**	**Face-to-face**	**VOH**	**Face-to-face**	**VOH**	**Face-to-face**	**VOH**	**Face-to-face**	**VOH**	**Face-to-face**
My motivation reaching out to my instructor is usually high using:	3.9	2.9	3.7	3.5	3.3	3.3	3.4	3.4	3.6	3.3
I prefer to attend an office hour with my instructor that is:	4.2	2.9	3.8	3.6	3.3	3.6	3.2	3.6	3.6	3.4

VOH were helpful to their mastery of course content. These results address the first research question of this study and show that VOH are indeed a course tool that has a positive impact on students' perception of learning in engineering courses.

The second RQ was next addressed through the second statement included in Table 4. Each section again had an average response rating above four, for "agree." Based on these findings, it was found that students felt their access to their instructor was improved through utilization of VOH. Looking at Table 3, a slight association is evident between the percent of student attendance and the ratings given in Table 4. Ratings for instructor access in ME 320, where 94.8% of students attended at least one VOH, are notably higher than the other three courses. The results for ECE 121 however, report a below average rating for increased instructor access while still having an above average attendance rate (90.1%).

RQ 3 was addressed by student responses to a prompt regarding their satisfaction of the use of VOH in relation to learning efficiency (see bottom row of Table 4). Each section rated their agreement above a four, with only one section rating their agreement right at a four, for "agree." These findings show that students overall found VOH to be an efficient use of their learning time. Students have many demands on their time, VOH being perceived as a valuable and efficient use of students' time, motivates more session attendance and additional learning time.

The fourth RQ was linked directly to student motivation in contacting an instructor virtually compared to a face-to-face setting. Two prompts were presented to students regarding both their preference and motivation. Overall, most sections scored between a three and a four in regard to motivation utilizing either method of office hours (see Table 5). These results revealed that most students felt "neutral," or agreed with the statement. Both sections of ENGR 220 responded that they were equally as motivated to reach out via VOH or face-to-face sessions. In ECE 212, students were a little more motivated to reach out using VOH as opposed to face-to-face sessions. ME 320 showed the most variance between their preference, with a difference of an entire point in their motivations for reaching out to their instructor. Students in this course were much more likely to be motivated to reach out using VOH than face-to-face sessions. The results for face-to-face sessions fell at a 2.9, slightly below "neutral," therefore falling closer to the "disagree" category.

Students' preference however had much more mixed results (see bottom row of Table 5). The two ENGR 220 sections reported that they preferred to attend face-to-face sessions with their instructor slightly more than they preferred to attend VOH. The lower scoring trend for this ENGR 220 course is most likely due to the lower VOH attendance rate (see Table 3). ECE 121 reported the inverse of this phenomena, with students preferring to attend VOH slightly more than they preferred to attend face-to-face sessions. The biggest range was encapsulated in the ME 320 responses where students indicated they preferred to attend VOH with their instructor much more

than they preferred to attend face-to-face sessions. The difference here was 1.3 points, with the response for VOH being 4.2, ''agree,'' and the response to face-to-face being 2.9, ''disagree.'' Based on the results from all courses, it was found that students have mixed preferences on which type of session they prefer to attend. The overall mean response however, labeled as ''Overall Average'' in Table 5, shows that the entire sample size was slightly more likely to prefer attending VOH as opposed to face-to-face sessions with their instructors.

4.2 Qualitative Results

This study aims to look deeper than just the agreement or disagreement with a given statement. Qualitative questions were utilized to dig deeper into the reasons *why* students felt an agreement or disagreement with the provided statements. In Fig. 1, students' responses to the qualitative aspect of this prompt, and address exactly *how* VOH attendance helped students to master the course content. RQ 1 addresses students' perceived learning, the quantitative data yielded the response that most students thought VOH were helpful to their mastery of course content. Students' responses to this first question showed that many of them felt the additional practice problems offered, real-time Q/A, and in particular, the access to a more in-depth explanation of course material, available at VOH helped them to master the course content. One student stated that VOH, ''helped me under-

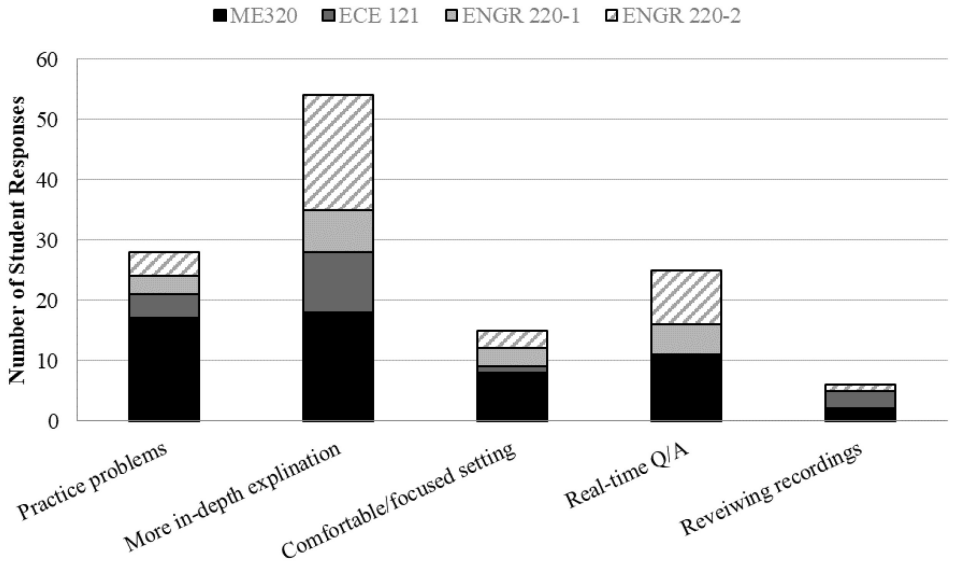

Fig. 1. How VOH Attendance Helped to Master the Content.

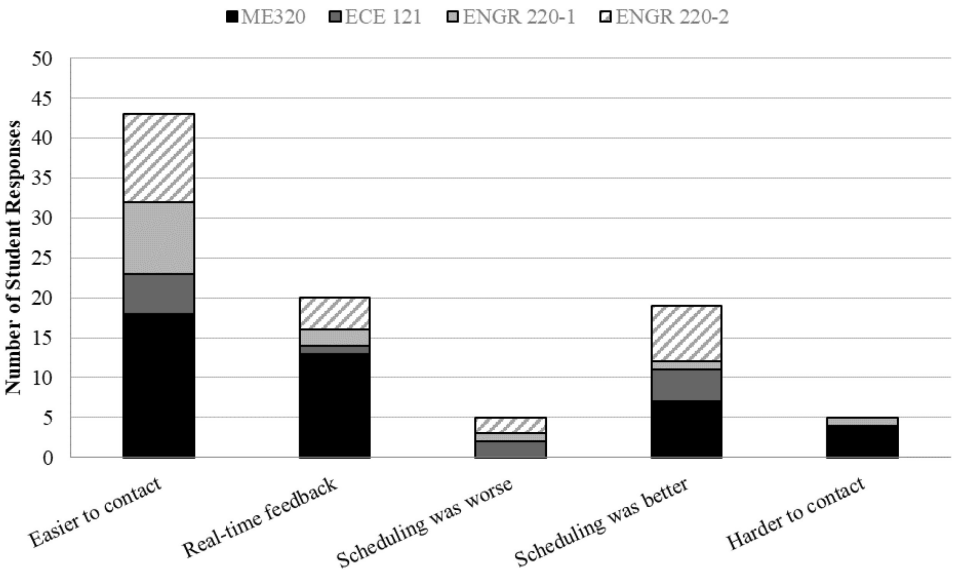

Fig. 2. Why Instructor Access Increased/Decreased Due to VOH.

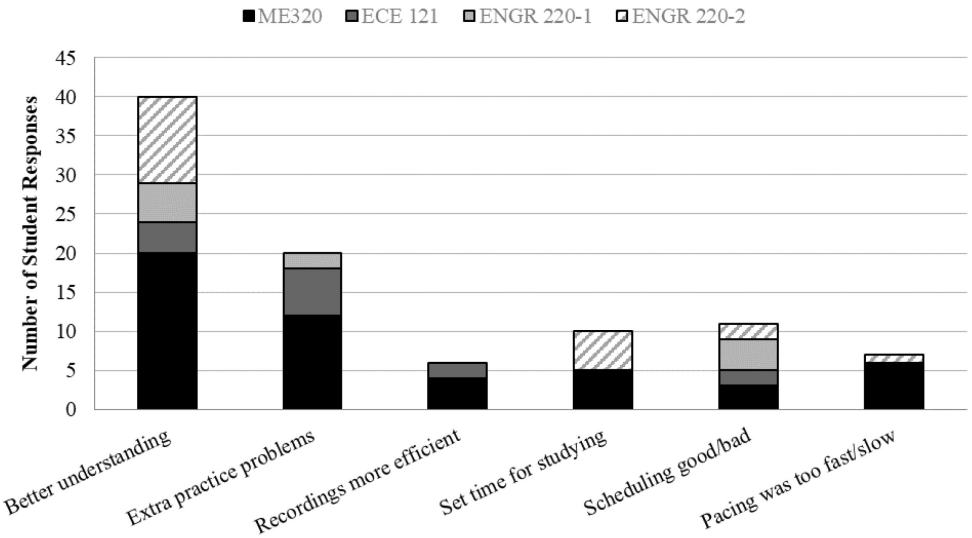

Fig. 3. Why VOH Were/Weren't an Efficient Use of Time.

stand difficult problems and further my engineering experience.''

RQ 2 addresses instructor access, as shown in the students' quantitative responses, students generally agreed that instructor access was increased through VOH. Their responses as to why instructor access increased are included in Fig. 2. Most significantly, students found that their instructor was easier to contact during VOH. One student responded that this was because it, ''Gave the opportunity to answer time-sensitive questions that otherwise go unanswered over email.'' Along with this, around 20 student responses explained that scheduling made it easier for them to attend, as it, ''Added about 2 extra hours of instructor availability per week,'' as one student stated. Several students stated VOH made it harder for them to contact their instructor as they had other time commitments or found it difficult to get the instructors attention during the session.

The qualitative data for RQ 3 indicated that students were overall satisfied with VOH and found them to be an efficient use of their learning time. As indicated in Fig. 3, students felt it was efficient as it allowed them better understanding of the course material. One student stated: ''It was a very efficient use of my time, getting more exposure on how problems need to get done and the proper use of the tools we were using.'' Many responded that VOH allowed them to be successful and get a higher grade in the course. If students found VOH not to be an efficient use of their time it was because they could not attend, or that it lacked the pacing they preferred. Some thought the instructor went through the questions too fast and they were unable to give input, others felt it too slow.

RQ 4 was addressed in two comparative graphs in the quantitative results section. Findings showed that students had mixed responses to their motivations and preferences on attending VOH or face-to-face sessions. As indicated in Fig. 4, the most common reason students were motivated to attend VOH was the increased access to practice problems. In addition to this, students reported the scheduling of these sessions to also be an influencing factor along with an improvement in their comprehension, resulting in a better grade. One student stated, ''I was motivated because my grades started to increase. Exams, Quizzes, Homework increased so I wanted to attend more.'' For those who were unmotivated to attend, it was usually a result of utilizing different forms of help, scheduling conflicts, or that they preferred a one-on-one setting.

Students' preference for attending VOH as opposed to face-to-face sessions were also reported to be mixed, with some preferring the virtual option while others preferred the face-to-face option. The findings regarding the qualitative aspect of students' preference for the virtual option (see Fig. 5) revealed that convenience and clarification were the leading factors. One student responded: ''I can get help from the instructor without having to go out to campus and ask any questions that I thought of after lecture.'' Some students, A little under 20% of the overall student sample, preferred to attend face-to-face sessions. Of this percentage, the majority came from the ENGR 220 course where 25–30% of both sections self-reported that they had never attended a virtual session. About 10% of students had no preference between the virtual and face-to-face options.

RQ 4 was also addressed through the self-reporting of the number of VOH sessions attended and the

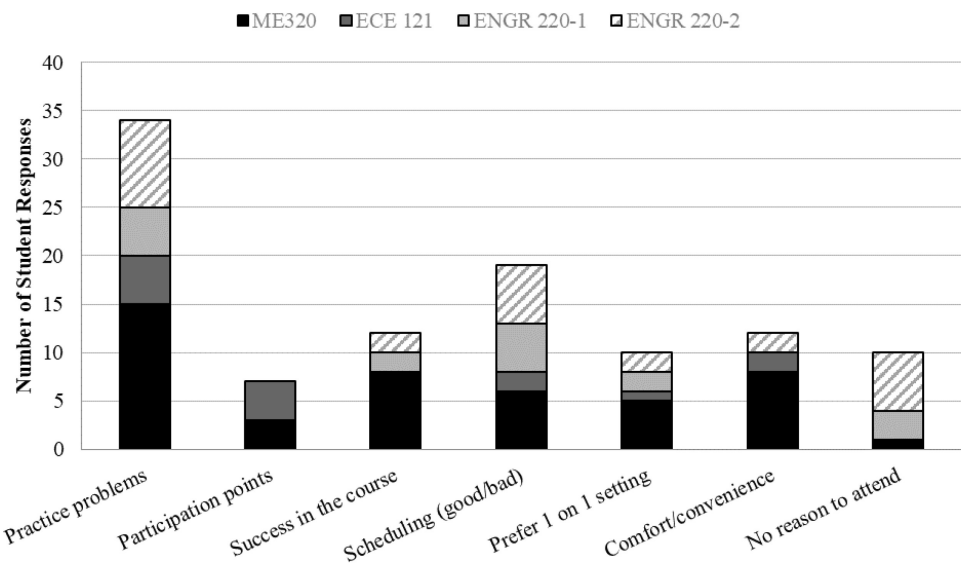

Fig. 4. Motivation for Attendance/Lack of Attendance.

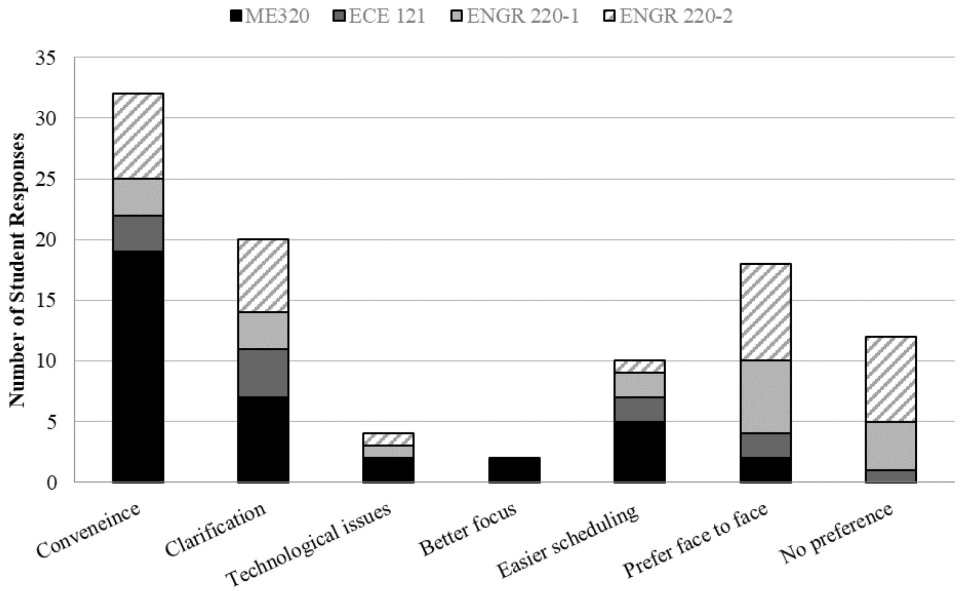

Fig. 5. Why Students Prefer the Virtual Aspect.

reasoning as to why students chose to attend VOH. Fig. 6 illustrates the number of VOH attended by each section. Note again that the ENGR 220 sections reported that 25–30% of the students never attended a VOH session, these are taken into account in the 0-5 column where students attended 0-5 sessions. An equal number of students from each section were in the 6–10 column, 19 students from ME 320 attended 11–25 VOH sessions.

Most students attended to get extra help or clarification from the lectures (see Fig. 7). Reasons for attending VOH were cited by students as better course understanding, and convenience and scheduling. These reasons were cited by over 50% of students. Others were unable to attend due to scheduling or technical difficulties.

The final student evaluation question relating to RQ 4 was if there were any suggestions to improve VOH (see Fig. 8). Nearly 65% of students responded that VOH needed no changes or improvements. These responses were removed from the figure below to allow for easier interpretation of the 35% of students who responded with various suggestions for improvement. Mixed responses were received regarding pacing, some students suggested a faster pace, while others, slower. The same responses were received for scheduling, some students suggested earlier in the day, while others later. Several students also suggested a

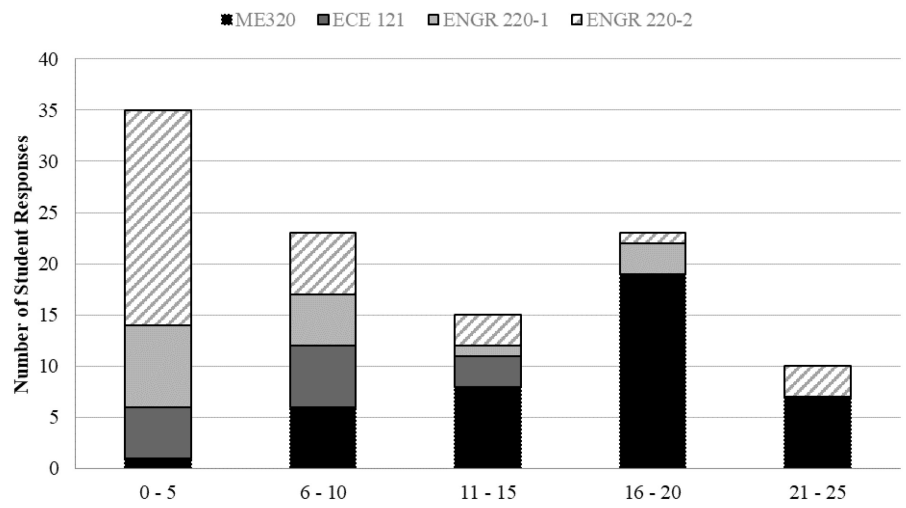

Fig. 6. Number of VOH Attended.

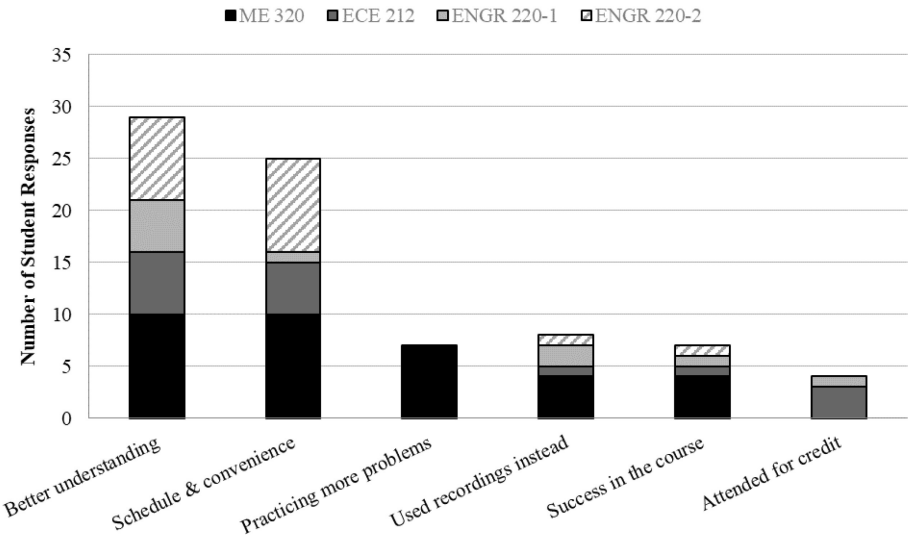

Fig. 7. Why Students Chose to Attend VOH.

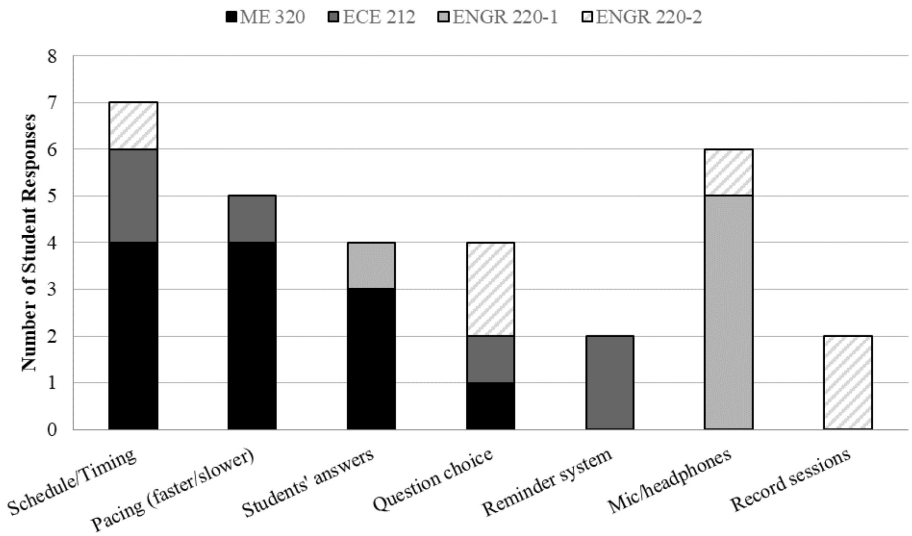

Fig. 8. Suggestions on how to Improve VOH.

new method for audience participation as they found typing in the chat box to be chaotic at times and microphone use to be intimidating. Students also responded that they would like more involvement in the process and the opportunity to suggest the questions the instructor works through. For the courses that lacked posted recordings of the sessions, students stated that this was something they would have utilized. Both sections of the ENGR 220 course had a general complaint concerning the sound quality of the sessions; however, this was an isolated issue relating to the instructor's headset.

5. Discussion

Overall, meaningful information was found that addressed each of our research questions. The investigation into RQ 1 found that VOH impacted students' perception of learning in the sense that most students thought VOH helped them to master the course content. The student Likert response was an average 4.3 across all sections, indicating that VOH positively impacted perceived mastery of course content. In particular, students perceived the additional practice problems offered, real-time conversation, and access to deep explanations to be the most helpful aspects of VOH.

Data in response to RQ 2 found that VOH did increase contact time between students and instructors. Students responded with an average Likert response of 4.3, agreeing that VOH increased the access to their instructor. Qualitatively, many students responded that their access increased due to real time feedback, better scheduling times, and their instructor being easier to access through VOH. A few students stated that VOH decreased the amount of time they were able to interact with their instructor as they found it difficult to get their instructors attention during sessions or due to other scheduling commitments.

RQ 3 investigated the learner perception of VOH as an efficient use of learning time. Students surveyed across all sections had an average Likert response of 4.2, agreeing that VOH were an efficient use of their time. The main qualitative reasons cited by most students were positive, in that it allowed them to have a better understanding of course concepts and more practice with problem solving. Several students who had negative feedback on the efficacy of VOH cited the pacing was either too fast or too slow, and that scheduling was an issue.

RQ 4 sought to unravel the factors that motivated students to reach out to their instructors virtually, compared to traditional in-person office hours. Students responded that their motivation for reaching out to their instructor was slightly higher using VOH as opposed to traditional office hours. The most common reason for this was reported as students' increased access to practice problems. Other influencing factors were listed as scheduling and improved comprehension. Those who were not motivated to reach out typically utilized different forms of help in the course, had scheduling conflicts, or preferred a one-on-one setting. Students were also surveyed regarding their preference of attending VOH or traditional methods. Here, students responded with almost no preference towards virtual office hours or face-to-face office hours. Convenience and clarification were leading themes in preference towards attending VOH, while nearly 10% of students responded they had no preference. Over 50% of all students cited their reasons for attending VOH were better course understanding and convenience or scheduling.

When surveyed, nearly two thirds of students cited that VOH needed no improvements, while mixed feedback was given from the rest of students. Some had preferences on pacing, slower or faster, while others had suggestions on scheduling, earlier or later. Students overall provided a lot of positive feedback on the use of recordings, students in those sections which did not utilize recordings noted that they would have gladly utilized this feature. Several students suggested a new method for audience participation as they found the instant message chat box to be chaotic and the microphone use to be intimidating at times. Students also responded that they would have appreciated more involvement in choosing the set of questions the instructor works through during VOH.

5.1 Limitations

Several limitations have been identified in the case of this study. The student experience of the class may differ by instructor teaching strategies/styles and individual personality differences that may have an impact on the level of interaction and communication used in that specific class. Therefore, broad generalizations on the impact on VOH cannot be made.

Each of the three courses had different requirements and areas of study. Specifically, students in the 300-level heat transfer course are required to complete a number of prerequisite courses, such as fluids and thermodynamics, that also utilize VOH. Students in lower-level classes such as ECE121 and ENGR220 do not have this past experience with VOH since they have taken only a small number of prerequisite courses which typically do not utilize VOH. This may have impacted how students utilize VOH as certain areas of engineering are easier to communicate via VOH, while others are much more comprehensive in person. Some students also had

different levels of access to technology that is required in order to make the best use of VOH.

There was no comparison made between classes which were supported by face-to-face office hours and those taught by the same instructor using VOH. Fifthly, further statistical analysis of the quantitative data was not possible due to a technological system changeover which took place after initial quantitative data analysis. Furthermore, all of the data utilized in this study is based on student perceptions, which are subjective and may be impacted by factors beyond the control of this study. All students may or may not have had the time/bandwidth to attend VOH outside of class hours due to family and or work commitments. Therefore, VOH may not serve to benefit all students.

6. Conclusion

The findings of this study are some of the first to be published in the field of Engineering Education. VOH have been utilized by many disciplines, however in STEM courses they may look different. Communicating abstract topics when the opportunity for face-to-face contact is limited or inconvenient can be difficult. Utilizing VOH with a platform such as Zoom allows students the ability to learn complex topics from the comfort of their own study space.

Each research question of this study was answered via student responses. Based on the student feedback received, VOH have positively impacted students' perceived learning in engineering courses. The efficacy of VOH depends highly on the instructor and the structure of the session, student feedback clearly supported use of effective pedagogy in VOH. Students were motivated to attend for a variety of reasons, a leading reason being contact with their professor. Here, this demonstrates how VOH facilitates the increase of time students and teachers spend interacting.

In the post pandemic world, remote learning is still a preferred method of learning for many students, teachers, and universities. Further research on ways to make VOH more effective for student learning needs to continue in order to provide a more diverse and effective learning scene for those in higher education.

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Appendix A

Interview questions used to gain the faculty perspective of VOH
1. What are your reasons for choosing to offer virtual office hours as compared to traditional face-to-face office hours?
2. In what ways do you think attending virtual office hours will impact the learning of engineering content?
3. What are your observations/perceptions of changes in student learning as a result of attending virtual office hours?
4. What are your perceptions on whether and/how attending virtual office hours is an efficient use of the instructor and the students' use of time?
5. What are some ways in which you changed your course design to make the most efficient use of virtual office hours?
6. Based on your experience of teaching using virtual office hours, what are some lessons you have learned regarding the most efficient use of virtual office hours?
7. What is the difference between virtual office hours and traditional ones?

Appendix B

Correlation between research questions and student course evaluation questions

Course Evaluation Questions	**Construct**
Did you attend any virtual office hours?	
Attending virtual office hours positively impacted my learning of content in this course **[(1) Strongly Disagree — Strongly Agree (5)]**	RQ1. Perceived Learning
In a few words, state why or why not, attending virtual office hours helped you master content in this engineering course?	RQ1. Perceived Learning
Indicate your level of agreement to the following statement: Availability of virtual office hours increased my access to the course instructor **[(1) Strongly Disagree — Strongly Agree (5)]**	RQ2 Student Instructor Interaction
In a few words, state how the availability of virtual office hours increased your access to the course instructor. If it did not necessarily increase access, please then state the reasons why.	RQ2 Student Instructor Interaction
Indicate your degree of agreement to the following statement: Virtual office hours was an efficient use of my time. **[(1) Strongly Disagree — Strongly Agree (5)]**	RQ3 Student Satisfaction
Please describe why you think virtual office hours was or was not an efficient use of your time?	RQ3 Student Satisfaction
Indicate your level of agreement to the following statement. My motivation of reaching out to my instructor using virtual office hours is usually high **[(1) Strongly Disagree — Strongly Agree (5)]**	RQ4 Student Motivation
Indicate your level of agreement to the following statement. My motivation of reaching out to my instructor using face-to-face office hours is usually high **[(1) Strongly Disagree — Strongly Agree (5)]**	RQ4 Student Motivation
In a few words, please describe below why you were motivated or not motivated to attend virtual office hours.	RQ4 Student Motivation
Indicate your degree of agreement to the following statement. I prefer to attend a virtual office hour session with my instructor **[(1) Strongly Disagree — Strongly Agree (5)]**	RQ4 Student Motivation
Indicate your degree of agreement to the following statement. I prefer to attend a face-to-face office hour session with my instructor **[(1) Strongly Disagree — Strongly Agree (5)]**	RQ4 Student Motivation
In a few words, please describe below why you prefer or do not prefer to attend a virtual office hour session.	RQ4 Student Motivation
Could you please state approximately how many virtual office hour sessions you were able to attend this semester?	RQ4 Student Motivation
Please describe your reasons why you chose to attend or not to attend the virtual office hours offered in this course?	RQ4 Student Motivation
If you have attended at least one virtual office hour session, do you have any suggestions on how to improve a virtual office hour session to make it more supportive of your learning? Please, share below:	RQ4 Student Motivation

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