Impact of COVID-19 on Engineering Courses at West Texas A&M University

Dr. Kenneth R. Leitch P.E., West Texas A&M University

Kenneth R. Leitch holds a Ph.D. in civil engineering from New Mexico State University and M.B.A. from Colorado Christian University. He is an Associate Professor of civil engineering at West Texas A&M University in Canyon, Texas. He is a registered P.E. in Texas and Indiana and a LEED Green Associate. His primary interests are in sustainable development, construction materials, photogrammetry, structural analysis, transportation safety and structures, STEM outreach, and engineering instruction.

Dr. Roy Jean Issa P.E., West Texas A&M University

Dr. Issa is a professor of Mechanical Engineering at West Texas A&M University. He joined the School of Engineering, Computer Science and Mathematics in 2004. His background is in the area of thermal-fluid sciences, particularly in single and multi-phase heat transfer. He received his B.S. and M.S. degrees in Mechanical Engineering from University of Tennessee, Knoxville, and Ph.D. degree in Mechanical Engineering from University of Pittsburgh. Dr. Issa has 4 years of prior work experience in the aerospace industry and 8 years of experience in the steel rolling industry. His work experience in the aerospace industry included lift-off load studies on the shuttle control system, assembly of space station Freedom, hydraulic line model developments of the thrust vector control system, and robot programming for foam and paint stripping of the SRB tunnel covers. While working in the steel industry, he conducted extensive studies on the cooling of rolls and flat products in the hot strip mill, and mill torsional vibration and torque amplification studies. He is a co-inventor on a US patent on the rolling of flat products. His academic activities focus on conducting research in areas that are important to the industry but is fundamental in nature such as using multiphase (air-mist) cooling in the quenching of metals for the steel industry, tempering of glass for the auto industry, and chilling of beef carcasses for the meat processing industry. In addition, he has conducted studies on sustainable energy systems such as wind towers for indoor cooling, green roofs, active solar distillation systems, and the incorporation of phase change materials in conventional building walls. His recent studies focused on the enhancement of the thermal transport in heat exchanger systems using nanofluids. Dr. Issa is an author and co-author of over 50 journal and conference papers in the area of heat transfer and fluid dynamics. He was selected a Fulbright Scholar to Austria in 2016.

Dr. Nathan Howell, West Texas A&M University

I am an associate professor examining micropollutants in natural water systems: their origins, processes that control their distribution in the environment (air, sediment, soil, and water), and their fate-and-transport and risk to biota and humans. My research includes experimental studies, field measurements, and model development. I am also investigating large deep groundwater aquifer water quality data sets to determine what possible use such water could be to alleviate water stress.

Dr. Emad Manla, West Texas A&M University

Dr. Manla joined the College of Engineering as an Assistant Professor of Electrical Engineering in 2019. Prior to that, he worked at the University of New Haven as a Visiting Assistant Professor for three consecutive years where he taught a wide variety of courses in Electrical Engineering and Calculus. He received his M.S. and Ph.D in Electrical Engineering from the University of Wisconsin Milwaukee in 2009 and 2015 respectively. Dr. Manla’s research interests include Energy Storage System Testing and Modeling, Electric Drives, Automobile Electrification, Smart Grid, and Power Electronics.
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Kenneth Leitch, Roy Issa, Emad Manla, and Nathan Howell
College of Engineering
West Texas A&M University

Abstract

The objective of this work-in-progress study is to gain an insight into the effect COVID-19 pandemic may have had on the outcome of junior and senior-level undergraduate engineering courses offered at West Texas A&M University. The paper compares the assessment and performance of these courses across different engineering programs, namely Mechanical, Civil/Environmental, and Electrical Engineering. The paper also compares the findings across multiple semesters for the delivery mode of the courses (face-to-face, hyflex, and online), and the adjustments faculty had to make in the design of their courses. The paper examines the impact the pandemic may have had on the students’ enrollment, number of students dropping the courses, students’ satisfaction with their courses, and their access to the laboratories, machine shop, and technology resources. Students were surveyed at the end of each course. Problem-based and project-based courses from third and fourth-year engineering are selected for this study. Courses include select junior and senior level courses and capstone senior design from the mechanical, civil/environmental, and electrical engineering programs. The pandemic situation with its challenges has provided the faculty with a unique opportunity to learn best practices in promoting students learning and engagement in such situations.

Keywords: COVID-19; face-to-face, hyflex, and online instruction; civil, electrical, environmental, and mechanical engineering; senior capstone design; lecture and laboratory courses

Introduction

The COVID-19 pandemic dramatically affected engineering course instruction in transformative ways that are just beginning to become apparent to faculty, administrators, and students alike. Our goal here is to document how a primarily undergraduate engineering program with majors in civil/environmental, electrical, and mechanical engineering has been impacted by the technological and societal changes wrought by the pandemic.

At the time of this writing in early 2022, the pandemic has been with us for just over two years. A cursory review of literature reveals early observations and that there is much to study regarding the effects of the pandemic on engineering education instruction and assessment. Multiple conferences reported on how engineering programs pivoted to online instruction\(^2,3,4\) which normally proceeded in the same manner with a few weeks leading up to a full move to online instruction necessitated a unified departmental approach along with cooperation from information technology (IT) personnel to implement Zoom/WebEx/Microsoft Teams and a learning management system (LMS) for synchronous and/or asynchronous instruction.
Special attention was given to laboratory courses\textsuperscript{5,6}. The most common methods were to provide limited access to facilities or simply to film experiments and/or distribute laboratory kits such as by pick-up or mail to students.

Senior senior/capstone courses\textsuperscript{7,8} are especially impacted as they are the ultimate courses taken by students and important for assessment. Capstone courses that require a fabrication component were especially tricky as most university campuses were closed except for mission critical activities and would necessitate personal protective equipment (PPE) until vaccines were widely available.

**Impact on Lecture and Lecture-Laboratory Based Junior and Senior Level Engineering Courses**

*Mechanical Engineering*

Mechanical vibration is offered during the senior year in the mechanical engineering program. The course introduces the students to single and multi degrees-of-freedom systems covering both free and forced vibration with emphasis on numerical analysis methods. Figure 1 shows the assessment of mechanical vibration over the last six semesters. Two quizzes, 3 exams and a project are typically given throughout the semester. Average scores are calculated based on the students’ performance on the exams and the project separately (Fig. 1). Results show the average scores on the exams ranged from the mid to high 70s pre-pandemic days. The scores were slightly affected by the pandemic in a positive way and increased into the low 80s with the transition to remote and hyflex (defined as the option to be in class or online for instruction, short for hybrid flexible\textsuperscript{1}) teaching modes. This improvement in the exam performance could be attributed to having access to recorded presentations, and access to recorded homework solutions in addition to attending live remote lectures. With the return to in-person teaching, lectures and homework solutions were no longer recorded and scores returned to the level seen pre-pandemic days. Projects given in vibration were always experimental in nature pre-pandemic days. With the transition to remote and hybrid teaching modes, numerical projects were given instead. Even though the students’ preference was always for experimental projects, they performed well on numerical projects. Fewer number of students were failing with the transition to remote/hybrid teaching, but the number of students dropping the course has increased.

![Fig. 1 Assessment of Mechanical Vibration](image-url)
Civil Engineering

Four different junior level civil engineering courses were assessed by the authors. The civil engineering program frequently offers upper-level courses once per year. The transportation and geotechnical engineering courses were Spring offerings while the structural analysis and civil construction materials courses were Fall offerings.

In examining the Spring semester courses, it is of note that both the geotechnical (Fig. 2) and transportation engineering courses (Fig. 3) were impacted by the abrupt switch to online only instruction after Spring break concluded. Spring break is normally between the tenth and sixteenth week of a standard semester, where that final week is for final examinations. The geotechnical engineering course is a lecture/laboratory format. As it was seen that the pandemic was approaching, most of the standard laboratory activities were completed as the switch to online occurred with two optional laboratory activities being cancelled. One important laboratory occurred during the shutdown and was filmed for students with data provided for processing. Course performance had a dip in Spring 2020 versus 2019 and the recovery in 2021 with some students present. The transportation engineering course is a lecture format with two projects entailing data collection of traffic counts. The Spring 2020 project was accomplished just before shutdown but Spring 2021 relied on just four students to help collect the data, as the majority of students only participated online in the hyflex format. Each class experienced declining enrollment due to difficulties such as work and health. Transportation went from 23 students in Spring 2020 to just 13 in Spring 2021. Geotechnical Engineering declined from 17 to 10 students in the timeframe. Thankfully in Spring 2022, both courses have recovered to 15 students each with most participating in class unless a student is in COVID-19 quarantine.

In examining the Fall semester courses, there was a significant decline in course performance in the structural analysis class (Fig. 4) where the average course grade declined more than 5% and 16% of students did not complete the course. That course was hyflex in Fall 2020 but only a few students attended in class which hurt performance. This performance recovered in Fall 2021 as most students were present in the class. The civil construction materials (Fig. 5) did not suffer a decline in performance in Fall 2020 which is probably due to students being required to come to the laboratory portion of the course. This indicated that face-to-face instruction even with face coverings and 50%
maximum capacity in classrooms and laboratories improved student comprehension in civil construction materials versus the thinly attended hyflex version of structural analysis in Fall 2020.

**Electrical Engineering**

West Texas A&M University started offering a Bachelor’s degree program in Electrical Engineering in Fall 2016. In new programs, the expectation is for enrollment to gradually increase over the years. It was interesting to observe how this newly introduced major was going to perform during the pandemic. Figure 6 shows the assessment of Power Systems, a senior level course that discusses electrical systems such as transformers, three phase systems, synchronous generators, and electrical power flow. There is a laboratory component that trains students on three phase circuits, synchronous generators, and transformers. The grade breakdown includes four homework assignments, four quizzes, two midterm exams, final exam, and laboratory. The results show that performance did not get affected much during the pandemic when teaching suddenly transitioned to an online platform due to the fact that students had access to recorded lectures they could access multiple times. The performance after the college reopened its in-person teaching seems to have dropped. No students dropped before, during, or after the first wave of the pandemic, but the performance seems to have dropped after students came back for in person classes.

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**Fig. 4 Assessment of Structural Analysis**

**Fig. 5 Assessment of Civil Construction Materials**

**Fig. 6 Assessment of Power Systems**

**Fig. 7 Assessment of Power Electronics**
Combined Engineering

Multiple engineering bachelor’s programs take the fluid mechanics course at WTAMU. The course in an introductory fluid mechanics course in fluid mechanics fundamentals with an emphasis on engineering applications without extensive use of calculus and differential equations. The material is suitable to prepare mechanical, civil, and environmental engineering undergraduate students for the Fundamentals of Engineering (FE) exams according to the emphasis that is in their field. In other words, the students from multiple programs take fluid mechanics as a single course. However, there are some instances in the course (about 3-4 lecture periods and sometimes a lab) where they learn differing content according to their specific engineering program.

For the analysis in this paper, we have aggregated the data from all three sections (mechanical, civil, and environmental) as provided in Fig. 8 (next page). The figure shows both exams grade, the simple average of three unit exams during the term, and then the score for the final exam. The percentage of students who completed the course to the end but received a grade of D/F are shown as %Fail and the those that dropped the course early are provided as %Drop.

The course in Fall 2019 was a standard face-to-face (F2F) course with the only alternate form of attendance being asynchronous lecture capture. Our campus did not return in person after Spring Break 2020. Thus, in Spring 2020, the course is considered hybrid in that it was F2F in the first half and entirely virtual delivery in the second half. The course involves laboratories. There were some laboratories which were dropped for the second half due to the virtual course delivery. In Fall 2020 and Spring 2021, the course was delivered as hyflex, which we define as the course being regularly delivered in person but with students permitted to attend entirely or partially remote as they deemed necessary or according to quarantine restrictions. In Fall 2021, the course was offered as F2F again with lectures recorded. No virtual live attendance was permitted.

The data indicate some of the highest performance out of five-semester period was at the onset of the pandemic in Spring 2020. We expect that this may be because during the transition to entirely virtual course delivery, exams, which had previously been given only in a classroom on paper, were converted entirely to a digital, proctored format. In order to make sure that this format was fair, the instructor may have at times made the exams easier than would normally have otherwise occurred. Student performance decrease noticeably in the Hyflex period of Fall 2020 and Spring 2021 with especially poor performance in Spring 2021. Note during that semester that failure rate was 29% and the combined failure/drop rate was about 1/3 of the class (33%). Contrastingly, by Fall 2021, the grades on exams were similar to the pre-pandemic semester of Fall 2019. Still, in Fall 2021 the fraction failing and dropping were elevated relative to pre-pandemic.
A look into particular student comments in Fall 2020 and Spring 2021 provides some additional insight into the potential reasons for a drop-in student performance during the 2020-21 school year, when the course was conducted in hyflex.

- Please, if using the prior semester's tests as a means of helping students, don't completely shift the next test from that. It hinders a student's effectiveness in their studying and makes them rely heavily on the book. (Fall 2020)
- The book was super important because it was used during the exams. The homework covered each topic successfully. Exams were quite difficult, but because I did not prepare the way I should have. (Spring 2021)
- The exam questions are written by the instructor which are very hard to study for. I think working more problems in class instead of reading the slides would be more helpful. I also think that the exam questions should at resemble questions or examples from the textbook. (Spring 2021)

The comments do not speak specifically to the nature of the pandemic. Students are not faulting the pandemic or the hyflex delivery version of the course. Neither do they note anything particular about the way in which they attended the course. They could have attended in person or in virtual form, and this may have played a role in their performance. They all refer to exams written by the instructor. The instructor gives old exams problems to aid them in their preparation, which he did not do before the pandemic. Students at times now may rely too heavily on old exam problems to study and thus not be ready to solve newly written exam problems.
Impact on Senior Design Capstone Courses

Mechanical and Electrical Engineering Senior Design

In Mechanical and Electrical Engineering Senior Capstone Design, students work in teams to engineer innovative solutions to complex real-world problems. The capstone project integrates theory and application of the engineering curriculum and incorporates all aspects of the design process to develop new and creative solutions that meet the customer’s need. The design projects are fairly diverse due to the diverse interests of the students. A short list of these projects that materialized during the last two years include: agricultural spraying drone, bleach concentration feedback control system, anaerobic digester coupled with a heating system, vapor-cloud explosion test structure, search and rescue drone deployment system, dual-axis solar tracker, six degrees-of-freedom robotic arm for steam sterilization, and all-terrain rescue trailer. Several of the projects are sponsored by industry partners, while others are sponsored by the college of engineering and faculty researchers. The groups are guided by the leadership of a primary instructor who oversees the groups progress and assigns the grades. However, it is customary for groups to seek advice from other faculty members based on the specialty area and from experts outside the campus community. The benefit for the faculty members of being sponsors is for the faculty to build relationships with the department and other involved faculty that can advance the faculty’s research since many of the senior design projects are pilot studies initiated by the faculty.

Before COVID-19 pandemic, senior design students were required to deliver three live formal presentations: an oral presentation at the semester midterm to the engineering faculty, a poster presentation at the IEEE Forum held in Amarillo, Texas, and a final poster and oral presentation at Senior Design Night that takes place at the end of the semester and is attended by industry sponsors and invited guests in addition to engineering faculty members. The Senior Design Night ceremony usually includes at least 200 total attendees, and awards are presented for projects excellence.

When social distancing regulations were set in motion in Spring 2020, all live events were replaced by virtual meetings using Zoom video conferencing. Senior design students pre-recorded their presentations and submitted them ahead of time before attending virtual Q&A sessions to respond to questions from the faculty audience. Forty minutes were allocated to each group’s recorded presentation (a duration that was identical to the live presentation), while thirty minutes were allocated to each Q&A session (an increase by a factor of two in comparison to the live presentation). The groups IEEE poster presentations were also converted to 15-minutes pre-recorded presentations. Due to social distancing, Senior Design Night ceremonies were cancelled.

In Spring 2020, the course started out as face-to-face, and groups had access to the department’s machine shop as they worked on their projects. However, when courses were forced to move to a fully online mode in the middle of the semester, students had to work off-campus on their projects. In Fall 2020, senior design was offered in a hybrid mode. Some students attended portions of the course in-person when others were joining it remotely, and vice versa. In both semesters, groups met with the instructor of record on weekly basis for advice and updates. In Spring 2021, the course returned to face-to-face mode. Assessment of the senior design projects was based on ABET new accreditation student outcome criterion 3-1 through 3-7. An online assessment form using Qualtrics Survey.
Software was created for this purpose as shown in Fig. 9. The form was administered to faculty and industrial visitors attending the presentations. The scoring of each criterion ranges from 0 to 4. A score of 0 stands for “not attained”, while a score of 4 stands for “strongly attained”.

Fig. 9 Senior Design Online Assessment Form

Fig. 10 shows a comparison in the assessment of senior design projects over four semesters in which 8 projects were given in Spring 2019, 7 projects in Spring 2020, 5 projects in Fall 2020 and 8 projects in Spring 2021. On an average, 4 students were assigned per project. Fig. 10 shows the overall scoring of the projects (average score of criterion 3-1 through 3-7) was the highest pre-pandemic senior design days. The performance of the groups declined by 11% at the start of the pandemic, while it dipped even further by almost 15% (from pre-pandemic days) when the mode of delivery was hybrid (Fall 2020). Once the delivery mode returned to face-to-face (Spring 2021), the group’s performance started to increase to a level closer to that of pre-pandemic days but remained slightly lower by 5%. Fig. 10 also shows the correlation between the projects average score and the number of projects requiring time extension. On an average, the higher the percentage of projects requiring time extension, the lower was the projects performance. Even though in Spring 2020 it took the groups 19.4 weeks on average for the groups to finish the projects (longest duration in comparison to other semesters), the performance was not the lowest since only 43% of the groups requested time extension. In comparison, 80% of the groups in Fall 2020 required 18 weeks of extended time on average to complete their projects. A plausible explanation for this is as follows:
- Access to the machine shop was allowed halfway through Spring 2020. The majority of the groups were able to acquire their supplies from vendors, and perform much of the fabrication and testing on campus by mid-March before campus closure took place.

- As the pandemic progressed (Fall 2020, hybrid mode), it took longer time for students to get their supplies from vendors and to get access to off-campus machine shops. In addition, a larger number of students started facing financial hardship, psychological wellbeing decline or having family members affected by the COVID-19 virus. Even though the students had access to the campus facilities, weekly meetings continued remotely with the groups. It comes as no surprise that Fall 2020 had the most negative impact on the senior design groups.

- With the return to in-person meetings (Spring 2021), the benefits to senior design was obvious due to more interaction and hands-on work within the groups. This also allowed for more direct and personalized contact between the groups and their project advisors.

\[\text{Fig. 10 Assessment of Mechanical and Electrical Capstone Senior Design Projects}\]

**Civil and Environmental Engineering Senior Design**

Civil and Environmental engineering conducted their senior capstone course each Fall and Spring in the study period of Spring 2019 through Fall 2021. Their capstone course is generally conceptual as the plans produced are for projects that if built would be in the tens of thousands to millions of dollars each, and they are not required to build a physical representation of these projects, only a technical report and drawings for the projects. Also, during each semester studied, only one project was completed during any semester. As such, there were little to no difficulties for these students to complete their work. All submissions were digital in nature and students could opt for either an in-person presentation (except Spring 2020) or a virtual presentation via Zoom or WebEx, both of which are available to the university community for usage. The same assessment form as for Mechanical and Electrical Engineering is utilized for assessment purposes.
Gathering Feedback from Students

Surveys were administered to engineering students enrolled in the above courses in the Spring and Fall 2020 semesters to assess the impact the new modes of delivery (face-to-face, hyflex, and online) may have had on the students understanding of the material being taught. Below are some of the students’ responses:

- “Switching this course to online is doable. however, if possible have in person meetings frequently as well.”
- “I am not sure if there are any improvements necessary. I did not sign up for an online course but that is what this course ended up being and it was not bad at all. It took a little bit to get used to but Dr. xxx made it very easy to learn the material in an online setting.”
- “Dr. xxx made available all of his own notes, which was extremely helpful. It is really nice to be able to watch his lecture, and have his notes. I feel that it makes it much easier to understand his thinking and where he is going.”
- “With everything going on, I feel that the way this course was handled this semester was great. I loved weekly online meetings.”
- “None really. Dr. xxx did well and it is difficult to tell what can be improved during a semester such as this simply because of the unique situations presented by COVID-19. For the given situation, I believe this class was conducted well and appropriately for our situation. Classes conducted over zoom were done well.”
- “The notes were extremely helpful and the use of them while following along in the recorded lecture was helpful in understanding the material.”
- “None, given this unique semester, I believe this class was conducted well. Zoom was conducted well.”
- “Dr. xxx was nice to learn from. Kept class topics relevant to course objectives. Zoom was conducted well and Dr. xxx always maintained availability throughout the semester. Overall a positive experience.”
- “Dr. yyy’s teaching methods carried over well online. Video [lectures] were conducted nearly identically to live lectures, even including opportunities for student to test their comprehension.”
- “Dr. yyy, you are the best teacher that I have ever had in my life. You always deeply explain all the materials and inspires me in this field. I did not know how interesting electrical and electronic major is until taking your classes. I know that we are all suffering a hard time, and I am so appreciated for dedicating your time in making the recorded lectures. I would like to take this opportunity to thank you for everything that you have done for us.”
- “The first part of the semester went well; the power point slides were available to students and I could easily follow along. The second half has been a challenge due to the world circumstances but overall the lecture videos and communication from the instructor were spot on and Dr. yyy helped a lot!”
Recommendations and Conclusions

Every university was confronted the need to pivot to a mix of online or hyflex instruction and assessment during the COVID-19 pandemic. West Texas A&M University is part of a Texas A&M University System (TAMUS), a resource that helped to formulate problem solving and policies and the sharing of resources, especially with our relatively remote geographic location. True to the problem-solving methodology common to all engineering disciplines, the students, faculty, and staff pivoted to ensure the continuity of instruction. If the pandemic were to occur twenty years earlier, the technological tools used at this point were not developed to the point that the pivot was capable in a few short weeks in 2020. Student performance in junior and senior level undergraduate courses did take a hit during the pandemic due to the sudden change in instruction format but also due to financial hardship and health issues that affected students and faculty alike. The authors hypothesize that student choice of format of attendance (in-person, virtual life, or asynchronous video viewing) affected participation quality and quantity in ways that may have been detrimental. The authors plan to follow up in the next year to report on freshman and sophomore level courses, as it is thought there may be more impacts to learning and retention for this student population. There has been recovery in performance in junior and senior level undergraduate classes as solutions to the pandemic have been implemented. The technological tools that were becoming established by 2020 were supercharged for adoption such as the use of teleconferencing, digital submission of assignments and examinations, digital textbooks and references, and more. Another topic of interest will be to determine if cheating was occurring, especially with online test taking, as technology also makes it relatively easy to obtain help during tests unless strict testing protocols are implemented. Engineering education has truly lived up to its problem-solving emphasis and the pandemic merely sped up technological advances for engineering education.

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