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Teaching Engineering Virtually: A Rapid Response to Address the Academic Challenges Generated by COVID-19

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Abstract

In this study, an alternative pedagogical framework was established to address the academic challenges posed when undergraduate engineering students in a private university in Texas were mandated to seek off-campus housing due to the outbreak of COVID-19. As a result of the rapid transition to remote instruction, traditional and effective pedagogical methods implemented for in-person instruction had to be modified to overcome challenges such as the lack of academic resources, established campus practices that promote effective learning (e.g., study groups), and time-zone differences. Additionally, the instructional format had to be adjusted to ensure that the academic development of the students was sustained until the completion of the semester. In this study, a survey was conducted with a cohort of 42 students enrolled in the Rigid Body Dynamics engineering course to gauge responses and understand their perspectives regarding the implementation of the emerging CIRE model, which is the acronym for Communication, Initiation, Reduction, and Extension. Results indicate that the new model eased the challenges posed by remote instruction. The constant communication of the instructor with the cohort of students allowed an easy transition to remote instruction, answered homework and lecture questions in a timely manner, and allowed students to remain engaged despite the challenges of being remote. Further, initiating homework sets during class eliminated confusion on various problems and allowed for students to complete the assignments without the access to study groups whose time zones were in conflict. Results also indicate that reducing the number of problems on homework sets and extending submission deadlines allowed students to continue learning despite the challenges.

Introduction

Instructional methods in engineering education have evolved over time with the intention of conforming to academic and professional standards. Such pedagogical strategies have been developed and implemented to enhance comprehension, student engagement, and scholarship abilities [15]. The most prevalent and utilized of these methods include Problem-based learning (PBL), Project-based learning, and visual cuing. PBL's primary objective involves developing self-directed capabilities and critical thinking skills through problem-solving, interpersonal skills, and team skills [17]. Project-based learning, on the other hand, enriches student comprehension by giving a closer perception towards professional development by incorporating project-based instruction [27], [28]. Research further attest that retention rates in engineering education increase when visual supports are integrated during instructional settings [16]. In this regard, de Koning *et*

al. reported that students elevated their academic performance when utilizing visual cueing as evidenced by increased higher scores on both comprehension and transfer tests [7], [8], [9], [10].

Subsequent research themes have further transpired in STEM fields relating to classroom environments, academic inclusion, engagement in research opportunities, team dynamics, leadership roles, and communication. One of the most impactful themes geared toward strengthening student learning, engagement, and success is classroom environment, which alludes to the climate, tone, or ambience that influences the setting [11], [12], [13]. The literature reports that educational productivity in the classroom factors with the surrounding social environment [5], [24], [25], [26]. Marquez and Garcia, for instance, developed the ECNQ model (e.g., acronym for Engage, Communicate, Names, Questions), which is an active and dynamic approach towards engaging students in the engineering classroom, and works towards disrupting traditional normalized, ineffective teaching practices that limit and/or stifle student participation by helping to engender conditions for deep learning, active participation, and engagement [14]. Results of the empirical study indicate that utilizing the four communication strategies minimizes traditional classroom power relations, strengthens student-instructor communication, increases student collaboration, and fosters an active learning environment that enhances student engagement and learning [14].

The effectiveness of these instructional practices, however, have depended on two principal conditions: 1) undergraduate students residing or traveling from off-campus housing, which allows for the utilization of campus resources such as study spaces, books, outdoor recreation programs, computer labs, internet service, advising programs, etc., and 2) established campus practices adopted by students, which involve the formation of study groups, attending office hours, communicating after lecture hours, etc. These two conditions have factored towards the implementation of specific pedagogical methods and development of campus resources/programs to enhance comprehension, student engagement, and scholarship abilities.

Authors such as Pascarella & Terenzini, Tinto, and Thomas have argued that student success will transpire in higher education if all learners are integrated into the social and academic fabric of the respective institution [18], [21], [22]. Research suggest that having additional resources on campus such as peer tutoring, academic advising, personal and career counselling, and disability services may be compensatory in various ways [19]. It can assist disadvantaged students overcome potential lack of academic information, cultural capital, or academic preparedness [2], [21]. In a study conducted by Bauman *et al.* in 2004, the likelihood of students using campus services was analyzed [3]. Results indicate that three quarters of the participants were likely or very likely to utilize career counseling services, while half of the students mentioned the likelihood of using financial aid, time management workshops, and stress management resources [3].

Research further attests that campus outdoor recreation programs and facilities provide numerous benefits such as student recruitment, retention, and the opportunity to support academic programs. Andre *et al.* concluded that benefits such as lower levels of stress and anxiety, increased academic success, smoother transition to college, and better mental and physical health result from students utilizing campus outdoor recreation programs [1]. Further, it is well established on the literature that students' ability to work with others in academic settings is significantly improved as a result of outdoor education experiences [1]. For instance, Cooley *et al.* observed an improvement in the students' perceived group-work skills as well as the attitude and confidence toward group work [1], [6]. Sibthorp *et al.* concluded that students found gratification in learning by using outdoor

education resources, while Bell and Holmes reported higher learning outcomes on students participating in an outdoor adventure-based seminar course [4], [20].

In this study, an alternative pedagogical model was established with the intention of addressing the academic challenges posed when undergraduate engineering students in a private university in Texas transitioned to remote instruction and were mandated to seek off-campus housing due to the outbreak of COVI-19. Due to the rapid transition during the Spring 2020 semester, traditional and effective pedagogical methods implemented for in-person instruction required expeditive modification to overcome challenges experienced by students, including lack of accessibility to academic resources and established campus practices. In this regard, the instructional format was amended to ensure that the academic development was sustained throughout the completion of the semester.

Proposed Work

The emerging model is termed CIRE, which is the acronym for Communication, Initiation, Reduction, and Extension (Figure 1). This model was developed based on four critical aspects: a) a combination of teaching practices employed by the author during lecture sessions; b) post-course evaluation of teaching experiences; c) literature on instructional best practices; d) sensitivity of circumstances surrounding students during COVID-19. The combination of experiential knowledge, post-course reflection and scholarly literature provided a framework through which the purposed model was conceptualized, developed, and implemented.
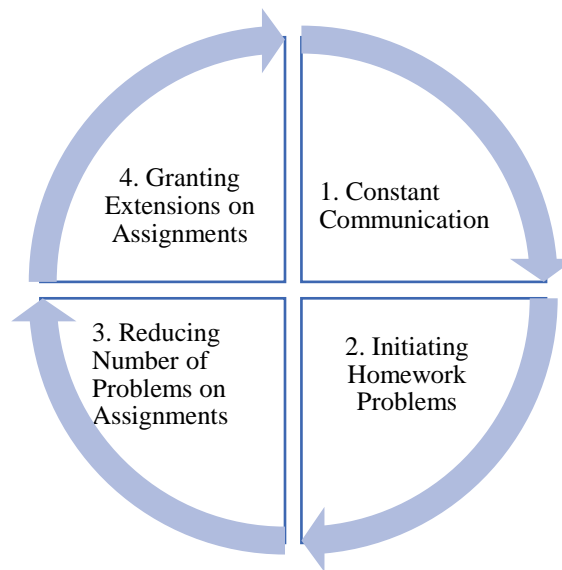

Figure 1. Proposed CIRE Model

Strategy 1. Constant Communication

In the first strategy, it was imperative to establish constant communication with the cohort of students given the uncertainty of lecture format, assignment policies, office hours, and grades for the remainder of the semester. A two-week period of transition was granted by the institution to vacate campus, while a few [students] were granted the option of remaining on-campus due to

undisclosed circumstances. The majority, nonetheless, traveled out-of-state and had to adjust to different time zones. Given that the course would progress fully online for the first-time, having constant communication was critical to the instructor, and was accounted immediately after the academic changes were announced. In this regard, establishing regular communication would ease the transition from one instructional format to another, and consequently eliminate the amount of confusion transpiring in a very short period of time.

The instructor utilized two platforms to recurrently communicate: 1) email, and 2) CANVAS portal. Additionally, a week prior to resuming the semester fully online, the instructor hosted two mock Zoom sessions with the intention of clarifying the lecture format moving forward. The following topics were recurrently communicated via email or the CANVAS portal:

a. Accessing Zoom link for lectures and office hours

b. Class structure – relating to new format

c. Virtual office hours

d. Homework and exam format

e. Grading policies

f. Submission policies for homework and exams

g. Extension on assignments

Strategy 2. Initiating Homework Problems during Lecture

In the second strategy, the instructor decided to initiate several of the homework problems during lecture sessions. This procedure was primarily established given that study groups were unable to meet in-person, and those who were associated with a group and wanted to continue meeting via online platforms, would find it challenging to communicate periodically as a result of time-zone differences, or lack of resources (e.g., poor internet connection, etc.). Initiating homework problems during lecture was additionally introduced for those who attended office hours regularly on campus, but would find it challenging attending virtual office hours, or uncomfortable communicating/participating via online platforms.

As such, a collaborative effort from the instructor and students allowed for equation(s) required in most [homework] sets to be identified during lecture sessions. Attending virtual office hours was also emphasized constantly in each lecture session for those who needed additional assistance with homework sets. In addition, students who could not attend virtual office hours were encouraged to contact the instructor and schedule a virtual appointment at a manageable time.

Strategy 3. Reducing Number of Problems on Assignments

Another strategy implemented on the proposed CIRE model involved reducing the number of problems assigned on homework and exams. This approach was motivated based on: 1) the complexity of the technical themes covered at the outbreak of COVID-19, 2) for those study groups unable to virtually connect, and 3) to alleviate the workload assigned from respective courses. This precaution was further considered given that all divisions of study transitioned online simultaneously, and the process of implementing alternative pedagogical strategies for remote instruction was nonexistent. The uncertainty surrounding these unknown variables was carefully accounted for by the instructor. As such, approximately eight problems were assigned per

homework set before the outbreak of COVID-19. However, this figure was reduced by half during the period of remote instruction without sacrificing the academic rigor of the course.

Strategy 4. Granting Extensions on Assignments

The fourth strategy of the proposed model involved granting extensions when submitting homework assignments. Given the rapid transition to remote instruction, it was anticipated that a considerable representation of students would encounter personal and/or academic challenges amidst the unprecedented crisis. As such, the instructor clearly emphasized, via email and during lecture sessions, the willingness of granting extensions to those experiencing family distress, internet disruptions, difficulty completing homework sets, or wellbeing concerns. An additional adjustment during the period of transition involved homework submission. Before the outbreak, a physical copy of the assignment was submitted in the classroom. However, the submission format shifted to an online portal for the remainder of the semester. For most undergraduate students, however, this format was rather contrasting and needed an additional efforts to cope with the logistics.

Methods and Analysis

For this research study, the authors employed a social constructivist theory with the intention of guiding the research and meaning making process. Social constructivist theory posits that knowledge is actively constructed by individuals through engagement in different social settings and interactions [23]. This philosophy on knowledge views the learners as active participants in the learning process and positions educators as facilitators to create the conditions that support and nurture inquiry, relationships, and collaboration [23]. Further, this theoretical position provides a framework through which student experiences are examined and learning environments are structured and enacted by the educator.

The proposed CIRE model was piloted with 42 undergraduate students enrolled in the Rigid Body Dynamics course at a small private research university in Texas to inquire into its effectivity. Participants included sophomores pursuing Mechanical Engineering. Primary methods of data collection included a self-developed, small survey instrument administered electronically which contained four open-ended questions. This approach was implemented to create an organic environment that encouraged participant autonomy and respected individual and collective experiences. As such, the administered survey consisted of the following questions:

Question 1: How do you feel about the professor's communication via email or Zoom during the period of remote instruction?

Question 2: The professor worked part of homework problems during class given that campus resources were inaccessible. Share your thoughts.

Question 3: Given that all classes were taught remotely and the workload for many students increased, the professor decided to reduce the number of problems on homework without compromising the academic standards. How did you feel about this change?

Question 4: Given all the challenges faced by the students during period of remote instruction, the professor decided to extend submission times for assignments, and allow more time for exams. What do you think about this?

Results

Communication Effectiveness

Based on the first open-ended question, students shared relevant information regarding their professor's digital communication methods. Results indicate a positive level of student satisfaction with their remote learning communication experiences. Several students indicated that the professor established a clear, consistent, and adequate form of communication. Student responses are listed below:

> *"I felt that all my questions or concerns were answered promptly and I never had a problem with communication during remote instruction."*

Other students echoed the comment shared above by stating the following:

> *"It was easy to communicate and get responses and help when needed."*

> *"Still very responsive and very easily accessible."*

Another student shared the following comment:

> *"I really appreciated how accessible Prof. X made himself."*

These results highlight that instructors must be proactive, flexible, and responsive to ensure students were provided with timely, individualized support.

Instructional and Pedagogical Supports (Question 2)

Due to the shift to online, remote instruction, the professor responded by employing several instructional and pedagogical strategies to help address some of the challenges students of learning off-campus. The second open-ended question on the survey stated the following: *The professor worked part of homework problems during class given that campus resources were inaccessible. Share your thoughts.* Overall, student responses illustrated a significant level of satisfaction regarding instructional supports offered by the professor. Several students noted how this particular strategy benefited their experience with classwork:

> *"That helped me a lot in finishing the rest of the homework sets. It provided a solid baseline. I think even just doing a random example rather than a specific hw (homework) problem would be useful."*

> *"This was very helpful so we weren't not completely lost, and if you needed additional help office hours were very accessible."*

> *"Absolutely. The professor was phenomenal at working out hw problems with the class during class time and during office hours."*

> *"This helped out a lot, especially with topics that were hard to understand with just the theory lectures."*

One student response illuminated the value of the strategy to mitigate the challenges associated with remote learning, such as isolation and separation that many students face within this learning context.

> *"I really appreciated it, I found that without access to friends and study groups it was more difficult for me to start homework problems by myself, so having that help from in class really let me be successful on the homework."*

As indicated by student responses, the professor's strategic decision to intentionally working part of homework problems in class, greatly helped to alleviate anxiety and confusion and enhance overall understanding of theoretical concepts. Moreover, this pedagogical technique helped to address and mitigate some of the obstacles of remote learning and instruction.

Instructional and Pedagogical Supports (Question 3)

As mentioned in the previous section, the instructor implemented four specific pedagogical and instructional strategies to respond to the new learning environment. The third technique included the decision to reduce the number of problems on homework without compromising the academic standards. Based on student responses, this strategy was well received as indicated by the following open-ended comments:

> *"I liked it as there was less work in that challenging time. I think if I were going into an online semester taking dynamics I would want more problems to cement the knowledge."*

> *"I liked this change because I felt we still had ample practice with problems and the concepts and we didn't have to spend extra time doing the same problems over again."*

> *"This allowed me to manage the class and retain material better because I could focus on quality."*

Several students shared that this strategy benefited and responded needs beyond the classroom as they adapted to a new learning environment.

> *"If anything I felt my workload decrease after moving to online only, and I was lucky that I stayed at my previous living arrangement. But I'm sure this was very helpful to students who had to relocate and found the move to online challenging."*

> *"I also really liked this change, having most of the rest of my classes gain heavier workloads meant that having a smaller workload in this one really allowed me to be*

successful, and I feel like I still learned the material of the course even with a lighter load."

As indicated by the results above, the intentional decision to decrease course workload by decreasing the amount of problems had a positive effect on overall student learning and comprehension. By emphasizing quality over quantity, the students learned and mastered course-learning objectives. Additionally, by lowering course workload, students were empowered to allocate valuable study time to other areas of their coursework.

Instructional and Pedagogical Supports (Question 4)

The fourth pedagogical strategy implemented to proactively address challenges of remote instruction was extended submission times for assignments and increased time to complete course exams. As indicated by the comments below, the inclusion of additional time greatly benefited students by mitigating some of the potential challenges associated with remote learning. Moreover, increased time helped to alleviate additional stress and anxiety.

> *"I really appreciated this. It was hectic with many classes and issues at home. This definitely allowed me to manage my time and not stress too much about the assignments."*

> *"I thought this is very true. Having the open note is exams and hw (as usual) allowed us to focus on the learning even though we were remote without putting pressure on the students with a hard and quick due date."*

> *"I believe this was very helpful in alleviating and not causing any additional stress."*

Additionally, one student recognized and noted the significance of additional time to complete coursework by acknowledging the both the academic and social/familial impact of the COVID-19 pandemic.

> *"I feel that extended submission times are almost a necessity for online learning, given Wi-Fi issues and problems that might arise with sick family members."*

Based on the responses collected, increased time to complete assignments and exams was well received and appreciated by the students. As students navigated through this new learning format, the pedagogical supports implemented by the professor proactively addressed challenges associated with remote instruction and learning.

Conclusion

The outbreak of COVID-19 prompted institutions into a state of bewilderment and disarray by completely upending traditional learning contexts and environments. Most institutions responded by terminating in-person instruction and shifting to a fully remote context. This unprecedented landscape required both educators and students to rapidly adapt to distinct academic settings and consider novel approaches that would filter into uncharted learning environments. As such, educators were challenged to reimagine, reassess, and reconfigure their courses and develop

schemes that would satisfy course objectives and simultaneously supplement student academic needs.

This study examined the pedagogical and instructional strategies employed by a professor transitioning to online instruction amidst the COVID-19 outbreak. These strategies included effective communication, modeling homework problems, reducing coursework load, and increasing time to complete coursework. Findings indicate that students were highly satisfied with the implementation of these practical strategies. Collectively, the Communication, Initiation, Reduction, and Extension (CIRE) framework functioned as pedagogical and instructional supports to address both instructional and socioemotional challenges that many students encountered during the shift to remote instruction. This study and its findings adds to nascent research exploring rapid responses by faculty to address issues associated with remote instruction and document effective instructional practices.

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