3-16-2022

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Recommended Citation

Marquez, E., & Garcia, S. (2022, March), INNOVATIONS IN ENGINEERING EDUCATION FOR FAST-PACED VIRTUAL SUMMER COURSES Paper presented at 2022 ASEE Gulf Southwest Annual Conference, Prairie View, Texas. https://peer.asee.org/39187

Paper ID #35739

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Innovations in Engineering Education for Fast-paced Virtual Summer Courses

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Abstract

In this study, the recently developed CIRE (Communication, Initiation, Reduction, and Extension) pedagogical model was modified to generate an effective framework for a virtual, fast-paced summer engineering course in a private university in Texas. Transitioning to fully online courses in the wake of COVID-19 required rectifying traditional instructional methods to overcome challenges such as the lack of academic resources and established campus practices, while simultaneously ensuring the academic development of students. Thus, a pedagogical framework known as the CIRE model was recently designed and implemented in a Rigid Body Dynamics course, which according to the study, generated favorable results. To test its accurateness, the proposed CIRE model was adopted for a Statics-Strength of Materials summer [six-week] course taught in a slightly different timeframe. The implementation of the model was a proactive approach to the fast-paced structure of the summer course and allowed the students to enhance their academic preparation despite the virtual setting attempt. As such, a survey was conducted with a cohort of twenty-four students to gauge responses and understand their perspectives regarding the pedagogical framework. Results indicate that the implementation of the CIRE model, with its two modified components, allowed engineering students to have a holistic understanding of the course material despite the fast-paced timeframe. Students were further able to successfully complete assignments individually and correlate theoretical aspects with engineering applications.

Introduction

Since the period of COVID-19 initiated, faculty members have been on a transitional period modifying conventional pedagogical methods for online instruction to enhance student engagement, comprehension, and scholarship abilities. The need for such modifications is to overcome two types of challenges: 1) student's lack of accessibility to academic resources and campus practices, and 2) retention rates in engineering education (e.g., not the focus of this paper). According to research studies, the effectiveness of conventional practices depends on two major aspects: 1) classroom environment, and 2) students being able to access campus resources such as study spaces, books, outdoor recreation programs, advising programs, computer labs, and internet services [11], [12], [13], [19].

From these conventional practices, though Problem-based learning (PBL) [17], Project-based learning [27], [28] and visual cuing [7], [8], [9], [10] represent effective methods implemented in the classroom, the most impactful towards strengthening student learning, engagement, and success is classroom environment [5], [14], [15], [16], [17]. Studies reveal that the climate, tone, or ambience that influences the setting minimizes classroom power relations, strengthens student-instructor communication, fosters an active learning environment, and increases student collaboration [11], [12], [13], [23], [24], [25], [26]. Pascarella *et al*. further concluded that the social and academic fabric of institutions are necessary for students to experience academic success [18] [21], [22]. For instance, studies suggest that retention rates, opportunities to support academic programs, and student recruitment are benefits of campus facilities and outdoor recreation programs in higher education [1], [3]. Institutions have further allocated resources to assist disadvantaged students overcome academic preparedness and cultural capital [2], [21]. These resources include peer tutoring, stress management resources, time management workshops, academic advising, and personal and career counselling [1], [4], [6], [20].

Since COVID-19 initiated, engineering departments across the country have additionally struggled with retention and passing rates. As such, faculty members are repeatedly being challenged to modify pedagogical methods for online instruction. According to the retention rates from Texas Public Universities, The University of Texas Rio Grande Valley, for instance, has an average freshman retention rate of 75%, which is relatively low compared to institutions in Texas such as UT Austin (95%), Texas A&M University (92%), UT Dallas (88%), and the University of Houston (85%), but higher than many other institutions across the state. For an undisclosed public university in Texas, statical measures indicate that retention rates of first year (full-time) students have been at an average of 60% between the Fall of 2015 and Fall 2019. However, it is observed that during the Fall of 2020, which includes the academic year during COVID-19, the retention rates of incoming students fell to 53.3%, while the retention rates within that institution also dropped to 60.9%. Further, passing rates in introductory courses in such undisclosed institution have significantly dropped during the pandemic. For instance, Introduction to Civil Engineering had passing rates in the Fall 2019 and Spring 2020 of 84.4% and 91.9%, respectively. However, this past academic year, which was surrounded by COVID-19, the passing rates fell significantly to 69.9% in Fall semester and 63.1% in the Spring semester. Similarly, the passing rates in Introduction to Electrical Engineering fell significantly from 75% in the Fall 2020 to 39.2% in the Spring 2021 semester. These results are alarming for incoming students, and the trends give an overall perspective on the further need for faculty members to implement innovative pedagogical schemes.

Considering these factors, an emerging model termed CIRE (e.g., acronym for Communication, Initiation, Reduction, and Extension - Figure 1), was designed and implemented by Marquez and Garcia [Spring 2020] in a Rigid Body Dynamics engineering course, (e.g., one full semester duration) which transitioned to online instruction at the start of COVID-19 [15]. The model consists of incorporating four major pedagogical strategies: 1) constant communication, 2) initiating homework problems during the lecture, 3) reducing the number of problems on homework and exams, and 4) granting extensions on homework assignments [15]. According to the model's first strategy, the instructor established constant communication with the students via email and CANVAS portal to ease the transition from in-person instruction to online learning and consequently eliminate the amount of confusion transpiring in a very short period of time [15].

In the second strategy of the CIRE model, the instructor decided to initiate several of the homework problems during lecture sessions [15]. This procedure was primarily established 1) for those who attended office hours regularly on campus, and would find it challenging attending virtual office hours, and 2) since study groups were unable to meet in-person [15]. Further, the third strategy involved reducing the number of problems assigned on homework sets and exams. According to the model, 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 [15].

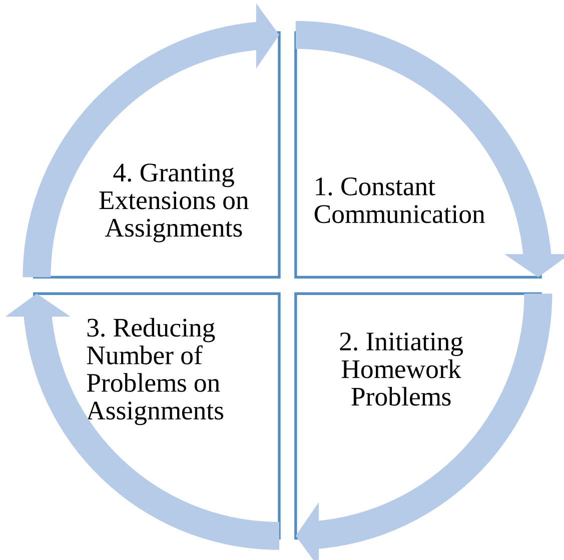

Figure 1. CIRE Model: Introduced in 2020

The fourth strategy of the established 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.

Based on the assessment of the established CIRE model, results indicate that students were academically and personally satisfied with the implementation of the four practical strategies, which addressed the challenges associated with remote instruction and learning [15]. Given that the model emphasized quality over quantity, results further elucidate the ability of students to learn and master course objectives during the period of remote instruction and thus allocate study time to other areas of their coursework [15]. Results also indicate that stress and anxiety levels were reduced with the implementation of the CIRE model during the transition to online learning [15].

Proposed Work

For this study, two of the four pedagogical strategies developed in the CIRE model were modified to generate an effective framework for a virtual, fast-paced [six-week] summer engineering course in a private university in Texas. Particularly, the *Initiation* (Strategy 1) and *Extension* (Strategy 2) components of the CIRE model were modified to adapt to the fast-paced structure of the course and allow students to enhance their academic preparation despite the virtual setting. This modification of the CIRE model was effectuated based on four critical aspects: a) a combination of teaching practices employed by the author during lecture sessions; b) post-course evaluation of CIRE model; 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.

Modified CIRE Strategy 2

For this modified strategy, rather than initiating homework sets during the lecture sessions, as established in the CIRE model, step-by-step examples were performed during lecture sessions to strengthen the intuitive nature of solving technical problems. This procedure was modified to promote problem solving skills during homework sets, rather than students having to depend on the faculty instructor to initiate problems repeatedly. The step-by-step examples performed during class covered major concepts for specific homework sets. The goal in this modification was for students to identify a problem formulation pattern that would be needed for each set, starting from drawing free-body diagrams (FBDs) correctly, labeling reference frames, establishing mathematical conditions, generating assumptions, and understanding solutions.

Initiating step-by-step examples during lecture was additionally introduced for those students who would find it challenging attending virtual office hours or communicating/participating via online platforms.

Modified CIRE Strategy 4

When the CIRE model was established, its fourth component included granting extensions on homework assignments and allowing a total time between three to five hours to complete online, closed-book closed-note exams. In this study, nonetheless, the model was modified to include a 24-hr window when taking closed-book closed-note exams. Given the intensity of the face-paced summer course, the exam window was extended for three reasons: 1) for those students who would encounter anxiety and/or wellbeing issues due to COVID-19, 2) for students who would experience internet disruptions during the process, and 3) to observe the academic performance of students during exams when granted additional time. The third reason is of particular interest to the authors, particularly since it is believed that student performance on exams could potentially increase with a larger timeframe. For the summer course, nonetheless, students were allowed to use a one-page formula sheet during exams.

During the course length, the instructor posted lecture notes, homework assignments, and homework solutions on the CANVAS portal as supplement to assist students with course material. Additionally, all lectures were saved and recorded in the Zoom cloud in case students needed to review lecture concepts independently. However, during the exam window, the instructor removed all student access to lecture notes, homework assignments and solutions, and recorded lectures to enforce academic integrity.

Methods and Analysis

For this research, a case study approach was implemented to examine the effectivity of the modified CIRE model for a fast-paced [six weeks] summer course. In this regard, a small, self-developed survey was generated as the primary data collection method, in which questions were intended to understand classroom experiences regarding the pedagogical framework. A total of twenty-four students enrolled in a Statics-Strength of Materials course at a small private university in Texas participated in the survey. Further, it is noted that descriptive statistics were employed for analysis and presentation of data results. Nonetheless, the study poses the following limitations: (a) small sample size; (b) self-developed survey instrument; (c) convenient sampling procedure.

The administered survey consisted of five open-ended questions:

> *Question 1*: How do you feel about the professor's communication regarding HW assignments, class updates, or announcements via email/CANVAS or Zoom?
>
> *Question 2*: The professor worked step-by-step examples during class given the challenges posed by remote instruction. Share your thoughts about this approach.
>
> *Question 3*: Given the challenges of remote instruction and of the short summer semester, the professor reduced the number of problems on homework assignments, and removed a semester project. With these changes, do you still think you learned the course material?
>
> *Question 4*: In a regular semester with face-to-face instruction, exams are facilitated in a classroom setting with a 3-hour allotted time. For remote instruction, rather than having classroom exams, the professor decided to give take-home exams with a 24-hour timeframe. How do you feel about this change?
>
> *Question 5*: How was your overall experience with course this summer? (e.g., lectures, assignments, office hours, etc.)

Results

Communication Effectiveness (Question 1)

Based on the data collected from the study, it was evident that communication was an essential component in students' learning experiences. Repeatedly, timely communication afforded students opportunities to stay on pace with class assignments and address any queries that surfaced throughout the course. Students indicated that the professor established a clear, consistent, and adequate form of communication. Student responses are listed below:

> *"Good! Kept us up to date, responsive to questions/concerns. A few small moments of confusion here and there, but nothing that couldn't be easily cleared up or worked around."*

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

> *"Communication was great, and deadlines were very clear and doable. The deadlines allowed enough time for all assignments but also did not allow for idleness and lack of challenges in the course."*

> *"Communication was clear; I enjoyed how communication occurred over zoom and in the form of canvas announcements."*

> *"The communication was clear and concise, and I never had any questions regarding assignments or updates as a result."*

These results highlight the need for instructors to 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 step-by-step examples during class given the challenges posed by remote instruction. Share your thoughts about this approach.* Overall, student responses illustrated a significant level of satisfaction regarding instructional supports offered by the professor. Several students noted how this strategy benefited their experience with classwork:

> *"I thought this was really beneficial since oftentimes professors give students the theory but do not really show how to apply it in different examples. This was probably my favorite part about lecture since we got to apply the knowledge, we had previously learned right then and there."*

> *"This was a great approach for the harder problems since it gave a foundation for us, additionally the purpose of homework is to prepare for exams and practice concepts that we will be applying as engineers. Therefore, it is more important to know how to solve a problem than to waste too much time trying to figure it out with no progress. Personally, the way I learn better is by seeing an example then by repetition of other problems like it so this approach was great."*

As evidenced by student responses, the professor's strategic decision to intentionally work step-by-step problems during class, greatly aided students' understanding of theoretical concepts and their related applications. 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 professor implemented several pedagogical and instructional strategies to respond to the new learning environment. This included the decision to reduce the number of homework assignments and removed a semester project without compromising academic standards. Based on student responses, this strategy was well received as indicated by the following open-ended comments:

> *"Most definitely! I think the homework problems were quite diverse in nature and were very thorough in asking us about multiple topics in one single question. I think the work we were assigned this semester was the perfect balance between learning in lecture and applying our knowledge in homework."*
>
> *"Yes, I thought the amount of work was adequate for a summer course, and I was still able to learn the material sufficiently."*

One student response illuminated the value of the aforementioned strategies in not only comprehending course material, but also afforded the opportunity to engage in personal research efforts.

> *"I know I learned the course material and I absolutely enjoyed the experience. It even led me to do my own research on topics that weren't necessarily needed for the course, but I just found interesting as an aspiring mechanical engineer."*

As indicated by the results above, the intentional decision to decrease course workload by decreasing the number of assignments 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)

Another pedagogical strategy implemented to proactively address challenges of remote instruction was to include a 24-hr window when taking 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 having the 24-hour window to complete the exams since it allowed me to take a break from the exam if I was stuck on a problem and come back to it later with fresh eyes. I also take long to work through problems because I doubt myself sometimes so I try to work out problems in different ways to see if I can get the same result using different methods."*
>
> *"It made the exams much easier, I'm not sure whether this is a good or bad thing. One of the challenges of many exams is that you know the materials/methods, it's just a matter of accessing your memory quick enough to remember the appropriate tools to solve the problem. Having a longer test time resolves this constraint."*
>
> *"This change was extremely helpful, I very much appreciated the ability to take a step back and think through problems over the course of a full day, and to look at*

tricky problems with fresh eyes. I also appreciated the increased flexibility given other summer commitments such as travel."

"I enjoy a larger time span, not only for comfortability but because it allows me to check my work as thoroughly as possible. This is essential as an engineer because I assume that in industry, it is far more important to produce quality work than fast work."

Based on the responses collected, increased time to complete exams was appreciated and welcomed by the students. This enabled students to carefully navigate through this new learning format. Thus, the pedagogical supports implemented by the professor proactively addressed challenges associated with remote instruction and learning.

Overall Experience (Question 5)

The final question posed to students participating in the study was to gain insight into their overall summer course learning experience. Student responses indicated positive experiences despite the logistical and pedagogical challenges posed by remote instruction. The following statements illustrate students' overall course experiences:

"I really loved it!! I'm so glad I decided to take the course this summer…I felt like I learned a lot despite the fast-pace of the course."

"I enjoyed the course, it made me eager to learn more about mechanics of materials later in the mechanical engineering curriculum."

"Excellent! The class seemed useful in the long term, was clear and easy to retain knowledge. There are some inherent limitations to online classes, such as Zoom fatigue, which did get to me near the end, but the instructor kept it fun and engaging so it wasn't so bad in that regard."

"I had a great experience in the course this summer. It was my first mechanical engineering course and it helped solidify my interest in this career path. The lectures were easy to understand, the assignments were relevant to the topics covered in class and helped develop my knowledge of statics, and office hours were always there for if I had a question about something regarding the course."

"Overall, I enjoyed the class more than I expected. This class allowed me spend more time on statics topics and assure that I have a strong foundation with this subject in the future as an aspiring mechanical engineer."

As indicated by the responses above, the pedagogical and instructional approaches modified in the CIRE model applied for the fast-paced summer course afforded students the opportunity to effectively engage and effectively learn course material.

Conclusion

The outbreak of the coronavirus threw institutions of learning into a state of confusion and disarray by completely upending traditional learning contexts and environments. Most institutions responded by canceling in-person classes and shifting to remote instruction. This new, uncharted landscape required both educators and students to engage differently and consider novel approaches to respond effectively to the different learning environment. As such, the COVID-19 pandemic challenged educators reimagine, reassess, and reconfigure their courses and develop strategies to meet course objectives and student needs.

For this study, two of the four pedagogical strategies developed in the CIRE model were modified to generate an effective framework for a virtual, fast-paced [six-week] summer engineering course in a private university in Texas. Particularly, the *Initiation* (Strategy 1) and *Extension* (Strategy 2) components of the CIRE model were modified to adapt to the fast-paced structure of the course and allow students to enhance their academic preparation despite the virtual setting. Findings indicate that students were highly satisfied with the implementation and modification of these practical strategies. Collectively, the modified 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 add to nascent research exploring rapid responses by faculty to address issues associated with remote instruction and document effective instructional practices.

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