Full Paper: Implementation of Course Structure in STEM Courses for Student Motivation and Learning, and Lab Innovation

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The present study is an extension of implementation of the course structure which was initially designed, developed, and implemented at Texas A&M University for engineering courses. This study extends its implementation to other STEM courses to assess its applicability and effectiveness in science related courses. The course structure is employed at the Chemistry department at University of Texas Rio Grande Valley (UTRGV). The present study is an autoethnography of the implementation of the course structure and its effectiveness assessment. This study highlights the implementation of the course structure considering student motivation and learning since student motivation is an important research area for modern instructional design. Lab course motivation is incorporated by asking the students to make TikTok videos of labs and submitting them on Blackboard.

1. Introduction

Apart from the traditional face-to-face mode of instruction, online and hybrid courses have existed for many years. Due to COVID-19, academic institutions were forced to transform their primary mode of instruction of face-to-face delivery to online and hybrid modes of instruction. This forced the academic institutions and faculty to adapt to the new technology and modes of instruction. Faculty were forced to transform their instruction methodologies overnight. This posed a challenge to the faculty especially with zero or minimal experience in teaching the hybrid and online modes of instruction. This exposed the faculty to learn many intricacies of online and hybrid modes of instruction. The major challenge, faced by faculty and students alike, was delivering/learning the material effectively due to the loss of motivation for various reasons. The present study was inspired by due to these challenges. The present study is an extension of an earlier designed effective course structure for hybrid courses in AY 2020-21 [1]. Most higher education institutions moved towards fully Face-to-Face (F2F) instruction starting Fall 2021. The present study was further extended to incorporate last year's designed course structure aimed at hybrid mode to a fully F2F mode of instruction. Student motivation is an important aspect of the study to make sure that the results are applicable to a variety of higher education institutions with all student populations, especially the first-generation students.

Wiebe et al. [2] developed an online and face-to-face introductory engineering graphics course to present analysis of student's usage of online resources for further augmentation of the instructional support received in class. A similar study performed by He et al. [3] investigated the flexible hybrid format by performing the study on a fundamental of electrical engineering course and explored other factors such as student motivation on the exam performance. Ahn et al. [4] investigated student's interaction with online videos in a hybrid course format for the Mechanics of Materials course. Kazeruni et al. [5] performed a comparison between two pedagogical approaches involving traditional engineering and business school courses. The goal was to combine both approaches in a single course of Introduction to Nanobiotechnology and Nanobioscience and help the students develop complementary skills. Spearrin and Bendana [6] performed a study using a course in aerospace engineering to include a project-based approach. The course used the design, analysis, manufacturing, testing, and launching of mid-power solid propellant rockets. A similar study performed by Myose et al. [7] investigated student performance characteristics in a hybrid class for the engineering course of Statics.

The above-mentioned studies fell short of designing a common course structure for engineering and STEM related courses. This motivated the initial inquiry and a study performed by Arshad and Romatoski [1] to design the instructional course structure, which has proven beneficial for the faculty and students alike.

Autoethnography focuses on the cultural analysis and interpretation [8] and self-analysis that produces purposeful implications for educators [9]. Starr et al. [9] discusses autoethnography, and its methodological implications as well as its value as a research method and examines the relationship between autoethnography and the philosophical and practical implications.

Kahl et al. [10] performed a study to encourage the instructors to engage in autoethnographic writing about their own teaching which will provide the necessary insight and knowledge to implement the pedagogy based on critical communication. Warren et al. [11] performed a study to propose reflexive autoethnography. The study proposes that the instructors should pose questions to themselves, such as, what do they believe about teaching, and why they believe what they believe about teaching. This approach aims towards critically informed pedagogical philosophies.

1.1 Problem Identification

One of a common aspect amongst the studies cited above was the lack of investigation, and implementation of a course instruction structure for the specific courses mentioned in the studies. This provided the researchers in the present study a unique opportunity to create, devise, investigate and implement a course structure that can help STEM instructors to teach effectively in all modes of course delivery, including the traditional face-to-face, hybrid, and online classes.

1.2 Current Approaches to the Problem

Previous studies have been focused on one course in one given institution at a given time, which shows a deficiency in developing a holistic approach to solve a common engineering and STEM instructional problem. That's why this study provides a holistic picture and approach to the problem [1].

1.3 Gaps in Current Approaches

There is a gap and deficiency in developing a holistic approach to solve a common engineering and STEM instructional problem. The uniqueness of the present study is the design of course instruction structure for STEM related courses which has previously been successfully implemented in multiple multidisciplinary engineering courses at two higher education institutions. This study will use a common course instruction structure that was developed and successfully implemented with excellent results by Arshad et al. [1]. Instructors in STEM have been teaching the courses by their own experiences and through experiences of their mentors and/or colleagues. In this study, a specialized course delivery structure developed to help the faculty deliver the courses in the most effective manner is now extended to F2F STEM instruction.

1.4 Proposed Solution

The present study extended the designed and implemented effective course delivery structure to STEM courses at University of Texas Rio Grande Valley (UTRGV). To obtain comprehensive results, the study design utilized multiple modes of instruction. It requires high-level student engagement for the student learning and success. On the part of faculty and instructors, it requires a lot of effort, hard work, and innovation to make sure that the students learn the material effectively as well as retain the knowledge. Going through with this exercise as a new instructor and trying to find any material or course structures in the literature as well as discussion with senior and fellow faculty members, it became evident that there was a lack of a common designed STEM course delivery structure. The present study extended an earlier designed engineering course structure to STEM courses at UTRGV as well as applied use of TikTok videos for lab courses and posting them on Blackboard. This ensured effective student learning and success as well as provided the instructor with an effective tool to prepare the teaching materials and use pedagogical skills.

2. Methods

2.1 Study Design

The present study encompassed comprehensive application and study of the designed course structure to in-person Face-To-Face instruction to Freshmen and Sophomore level chemistry courses that included both the lecture & lab components at University of Texas Rio Grande Valley (UTRGV) for the Fall 2021 - Spring 2022 semesters.

2.2 Participation Information

Although the course structure was applied to several Freshmen and Sophomore level chemistry courses at University of Texas Rio Grande Valley (UTRGV) shown in **Table 1**, the present study only focuses only on one course to discuss and disseminate the findings.

Table 1: UTRGV courses taught with modes of instruction from Fall 2021 – Spring 2022

Courses	**Mode of Instruction**
	Face-To-Face (F2F)
CHEM 2123: Organic Chemistry I	Fall 2021, Spring 2022
CHEM 1111: General Chemistry I	Fall 2021, Spring 2022
CHEM 1112: General Chemistry II	Fall 2021, Spring 2022

Among the courses delivered at UTRGV, the course of General Chemistry I, highlighted in orange in **Table 1**, was selected to discuss the findings since it was delivered using the Face-to-Face mode of instruction.

2.3 Data Collection

General Chemistry is a core course taught nation and worldwide in chemistry programs. The course was delivered in multiple semesters from Fall 2021 - Spring 2022 via face-to-face instructional format. **Figure 1** shows the improved version of the course structure flowchart that was primarily designed, developed, and implemented at Texas A&M University in an earlier study [1]. The course delivery structure is now extended to STEM courses as well. At the same time, its use can benefit student retention due to increased student motivation in learning the course material in engineering programs.

The designed course structure, shown in **Figure 1**, designed a pedagogical methodology by using various activity-based modules. The lecture part of the course was divided into learning modules that utilized PowerPoint presentations and OneNote. Student engagement can be gauged by various tools such as one-minute paper. YouTube videos were utilized to enhance student learning and engagement. Employing the above designed course structure helped in developing student interest in the class and effectively engaged the students in the class.

Labs were delivered in F2F mode of instruction in Fall 2021 and Spring 2022. The lab component was divided into two portions: experiment & discussion, and data share. First, the concepts and theory along with the experimental procedure were discussed and the experiment was performed. The data was then obtained, discussed, and shared with the students online. All assignments, lab reports, projects, quizzes, and exams were required to be submitted online and were graded online using Top Hat, Labflow as well as instructor annotations. An additional feature and innovation of this study was the inclusion of the idea of TikTok videos for the labs. This idea proved very beneficial and motivated students to learn the lab material effectively. This methodology was most effective in motivating the students and capturing student attention.

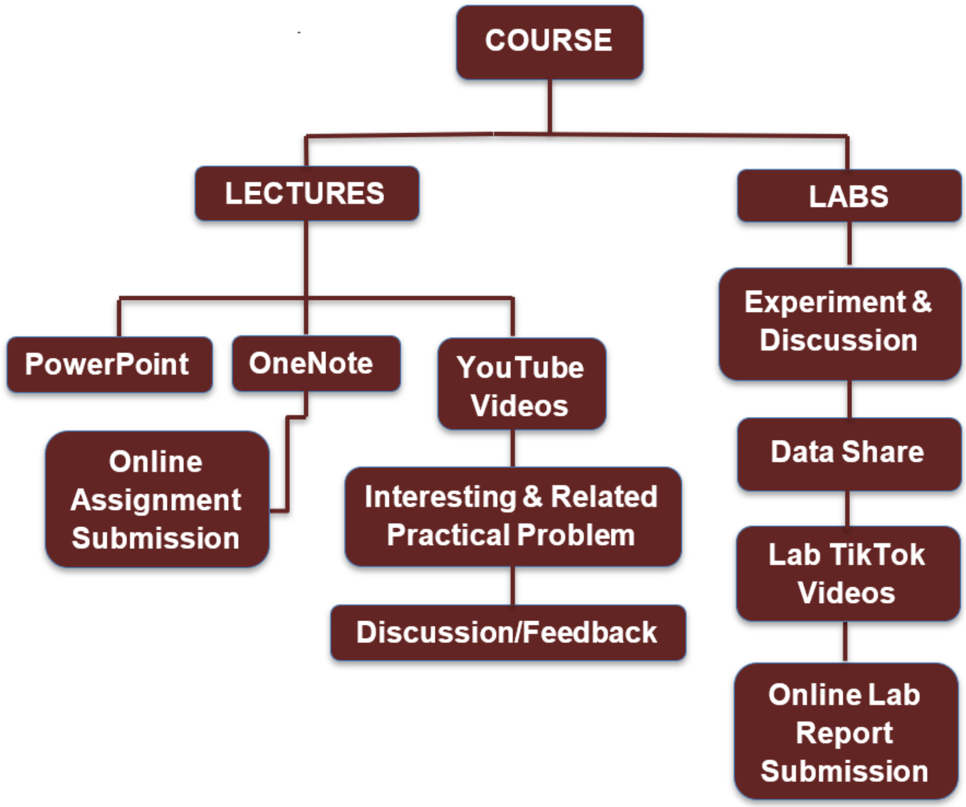

Figure 1. Improved course structure initially designed and employed at Texas A&M University for engineering courses [1], now extended to other STEM courses in Chemistry at University of Texas Rio Grande Valley (UTRGV)

2.4 Data Analysis

Autoethnography [12] is a tool used as a self-reflection for recognition and documentation of personal experiences. The above study utilized an autoethnographic approach to understand the results obtained. The following questions were used to understand the results and answer the complexity of an effective learning strategy:

- What was the background and context of your teaching experience?
- What teaching and learning changes were implemented during the teaching experience?
- What were the lessons learned from your teaching experience?

These questions are addressed, answered, and discussed in detail by the instructor under the Results and Discussion section.

3. Results and Discussion

3.1 Instructor Reflection: Background and Context:

I am a lecturer at a university which provides education to an underserved population in US (about 26,405 undergraduate students). I have been employed there since January 2021. During and post COVID-19, I encountered challenges, such as, student motivation. To evolve and innovate in my teaching methodologies for student motivation, I came started looking for an effective course structure for STEM students and landed upon an interesting study [1] which focused on engineering courses but claimed to be equally applicable to STEM courses. Since such course structure in STEM were not existent, I employed it in my courses to test its effectiveness for science courses, specifically, to courses in chemistry. It became a success story in terms of student learning and success, which motivated me to further think and innovate and I started asking students to make TikTok videos of the experiments performed by each lab group in the labs. This proved beneficial for student engagement and learning.

3.2 Examples of Teaching and Learning Changes Implemented:

Lab TikTok videos: The idea of including lab TikTok videos proved very beneficial and motivated students to learn the lab material effectively. This methodology was most effective in motivating the students and capturing student attention. The students were divided into various groups and each group was tasked to create TikTok videos for each lab performed in the course. This motivated the students to participate in the labs and learn the material effectively. The videos were not graded material, rather they were used as a tool to motivate student learning and success.

3.3 Lessons Learned:

The course structure with lectures via PowerPoint, OneNote, YouTube videos and homework assignments for after class activities was used in multiple classes. Applying the course structure to various courses allowed the researcher/instructor to gain better insights. Student insights proved beneficial while considering the learning and pedagogical methodologies. Student evaluations for the instructor at University of Texas Rio Grande Valley (UTRGV) showed positive feedback due to employing the course structure. The end of semester course evaluations/survey mean/average, for all courses under study shown in **Table 1**, was above the department mean/average. Implementation of the designed course structure and pedagogical methodologies contributed towards student learning and success. This study produced positive feedback from the students, generating high course evaluations for the courses employing the employed course structure [1]. Therefore, it can be deduced with confidence that the above-mentioned course structure is both effective and helpful for student learning and success in STEM courses.

4. Conclusions

Study performed at University of Texas Rio Grande Valley (UTRGV) employed a well-defined course structure primarily designed for engineering courses at Texas A&M University. The implemented course structure proved equally applicable for STEM courses. Effective results were verified through student evaluations and reflection. The study was inspired and motivated by the existence of a course structure designed at Texas A&M University for engineering courses, but the results produced by the study showed far reaching results that the same structure can be employed for STEM courses. It can further be concluded that the same course structure can be employed for STEM related courses as the structure has been applied to multiple different courses at different universities with different student populations and class sizes. Further improvement and innovation led to the inclusion of TikTok videos for the experiments performed in the labs. This also proved to be a successful inclusion and innovation in terms of student learning and motivation.

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