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Development of a Dramatic Story Plot and Adventure Racing Activities within an Undergraduate Reinforced Concrete Design Course (Work In Progress)

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Abstract

Stories have been, and always will be, powerful tools to inspire humans. For thousands of years, people relied upon the use of stories to pass along history and culture from generation to generation. Yet, with the development of formal education in the last couple centuries, stories seemed to have been removed from learning and instead, content and knowledge has been centered in the classroom. This can equate to the dull presentation of facts, figures, and formulas, stripped of any relationship to the world, let alone to the imagination.

In a period of time where the world seeks engineering innovation, common teaching practices seem to stifle creativity in the classroom. Professional organizations like ASCE emphasize that civil engineering programs need to prepare their graduates to face unique problems in the workforce that will require innovative solutions [1-3]. However, these same students likely spent a number of years not exercising this creativity.

The following paper documents a work in progress on the creation and implementation of a dramatic story plot within the technical content of an undergraduate reinforced concrete design course. The final goal is to reimagine the undergraduate engineering course experience-transporting it from a series of lectures on distinct topics to an integrated story plot. The new format would weave technical and historical content with a fictional story plot to keep students engaged as if they were reading a novel. Students also need to attend class and complete tasks/activities to follow all parts of the storyline, almost gamifying some of the content to encourage students to complete the necessary technical work.

Some specific activities and thematic elements will be highlighted, providing other instructors with a guide to including similar activities in their courses. Student survey data will be presented along with relevant assessment data. Through story-telling and student feedback, readers will be transported to a new universe of learning with the goal of igniting their own creativity to inspire innovative solutions for their respective classrooms.

Motivation

In recent years, various engineering education organizations have urged civil engineering programs and educators to increase creativity in the classroom. When viewing the current home page for American Society of Civil Engineers (ASCE), the following statements head the website: "Tough problems require innovative solutions. Now is the time to be bold. ASCE members engineer tomorrow and reimagine infrastructure. Move forward faster with ASCE [1]."

Furthermore, the ASCE Civil Engineering Body of Knowledge, 3rd Edition (CEBOK3), has incorporated creativity and innovation into two of its outcomes, Professional Attitudes and Professional Responsibilities [2]. Regarding the rationale for developing student outcomes related to Professional Attitudes, "ASCE calls for civil engineers to be innovators and integrators of ideas

and technology across public, private, and academic sectors. To achieve this vision, civil engineers must be creative, dependable, flexible, and curious about new ideas [3].” ASCE CEBOK3 stipulates that the achievement of this outcome for engineers entering the workplace should be a combination of undergraduate education and mentored experience, stating the “undergraduate experience should plant the seeds of professional attitudes and include education and basic practice in creativity, curiosity, flexibility, and dependability” [3]. CEBOK3 addresses innovation within the outcome of Professional Responsibilities and defines it as “a new idea, process, or device that alters societal ways of doing or being” [3]. The document goes on to emphasize that beyond holding the safety of the public paramount, engineers have a responsibility to be innovators, relying on creativity since every project presents a unique combination of “technical, safety, historical, environmental, political, and cultural issues” [3].

The ABET Engineering Accreditation Commission likewise holds civil engineering programs accountable to assess student outcomes, including (1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics, and (2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors [4]. In order for students to achieve these outcomes, it is reasonable to expect students need to explore and to evaluate a number of solutions or designs to achieve the optimal balance of earth’s resources and public welfare. Creativity and innovation can lead to new and better designs that could supplant former ways of engineering.

In light of the previous discussion on creativity and innovation, it is fair to address the typical engineering classroom. Engineering educators need to embrace and to demonstrate these concepts of creativity and innovation in their undergraduate engineering teaching, yet too often instructors follow the standard delivery of information and problem solving using non-engaging techniques. Instructors frequently rely on traditional textbooks to present theory and additional practice for problem-solving. Lectures often cover information in a one-way dynamic, with the instructor presenting information to students and/or demonstrating problem solutions without providing practice for students to obtain the “mentored experience” suggested by CEBOK3. Even active learning strategies can center on textbook problems that may seem disassociated from real-world scenarios.

Reimagining the Undergraduate Course Experience

Therefore, if the engineering profession expects the new generation of engineers to be creative and innovative, educators must also challenge themselves to explore and to evaluate new teaching modalities to inspire these future engineers. CEBOK3 states “[innovation] stems from creative thinking, which includes the capacity to combine or synthesize existing ideas and expertise in original ways” [3].

Inspired by the concept of themes and story-telling as a useful tool to convey lessons and engage students in the classroom [5-7], the author has set out to create a unique experience in an undergraduate reinforced concrete design course. The basic idea is to develop a dramatic story plot to parallel the technical and historical content of reinforced concrete design. Much like a fictional novel, action movie, or television series, the element of drama is meant to maintain student interest

and curiosity in the content. The goal is for students to be self-motivated to attend class, to solve engineering problems, and to read the textbook and other technical literature because they not only want to be able to apply these skills in their future careers, but they are interested to learn what happens next in the story. Thus, the story aims to increase both the interest value and attainment value with respect to subjective task values as motivators for activity choices, while lowering the perceived cost of completing all aspects and all assignments of the course [8].

By intertwining engineering lectures with suspense and excitement, the skilled teacher becomes like ancient storytellers, who can make classes memorable and instructive, and can transfer passion for the subject matter to the students [9]. In fact, higher context cultures, like some Native American tribes of the American Southwest, still use stories as the primary means of passing history from one generation to the next, because the details are better retained than listing or memorizing significant events [10]. Jesus Christ, arguably one of the most influential individuals in history, relied heavily upon the use of stories (parables) and metaphor to teach His disciples, who in turn have passed these stories down for over 2000 years. Even ChatGPT lists "storytelling" as its number 2 strategy when asked how to make engineering videos more engaging [11].

When considering the competition for students' attention, it is no wonder that traditional courses fall short of engaging the students' interest. Therefore, the work in progress seeks to challenge the norm by combining the technical and historical content with the dramatic story-telling elements of a fictional novel. The goal is for students to want to read the textbook, to want to come to class, and to be inspired to pursue their own creativity within engineering. For without creativity, innovations in engineering will not take place.

The Rise and Fall of Concreto- Title of Proposed Story/Textbook/Workbook

The goal of the work in progress within this paper is to redesign the typical undergraduate reinforced concrete design experience. The author envisions this to occur by redesigning the typical engineering textbook to appeal to the interests of engineering students and to include a fictional story plot to drive students' desire to read further. In addition, the story plot comes to life during in-class activities, challenges, and lab modules.

- Redesigned Textbook
    - Technical Content
        - The newly created textbook will contain all the technical content to enable an undergraduate student to complete the required learning objectives for the course.
        - The topics and learning objectives will align with typical concrete design courses taught across the United States as well as existing textbooks.
    - Course Content and Examples
        - Within the technical content created, some portions of the textbook will be omitted. These portions will correspond with instructor class notes for which the student is expected to attend class and "complete" their textbook by writing down the necessary information and completing the example problems.

- Historical Context
  - Along with technical content, historical context around concrete design will be given.
  - These historical elements will help to develop the story of concrete design across the centuries, inviting students to not only explore how to design, but why we follow certain procedures or provisions.
    - For instance, ancient Roman civilizations used naturally occurring pozzolans (like volcanic ash) to create strong and durable concrete, which is why so many of their structures remain to this day. Engineers continue to use pozzolans (like the industrial by-product fly ash) as an admixture in concrete.
- Interactive Story Plot
  - To fully develop the use of story to teach and engage, students will follow the fictional story plot of Concreto and Steelio, as they figure out how they can come together effectively to create reinforced concrete.
  - The fictional story plot will be denoted by different font/typeface so students clearly separate fiction from reality. The idea of a graphic novel format is also being considered.

- Interactive Course Experience
  - Adventure Racing / Lockbox Challenges
    - In addition to typical classroom lessons (instructor providing notes and solving example problems with students), several lessons will have students working in teams to solve concrete design challenges.
    - Adventure Racing challenges require students to solve riddles or problems that direct them to locations across campus, where they complete a task or find another clue, ultimately leading them to a final location for the class period.
      - For instance, the instructor has students race across campus to selected concrete structures to collect parameters for their course design project.
    - Lockbox challenges require students to solve problems for specific answers that will provide the combinations to unlock a box, leading to another problem or item.
      - For instance, the instructor has students resolve the loads in a concrete frame to open a series of boxes. Ultimately, the final code allows them to choose a box at the front of the room with an admixture inside that their team will use in an upcoming lab and report/presentation. Faster teams get to have first choice among the admixture selection.
  - Lab Modules
    - Undergraduate reinforced concrete design courses are often 3 credits lecture, 0 credits lab. To provide students a real chance to experience the material of concrete, the instructor will include a couple lab modules within the course.

A Work in Progress

Without additional support, the redesigned textbook will take some time to create and implement. However, to date, the author has created the interactive course experience desired in the first 25% of the Concrete Design course. As part of a previous institutional grant, the author included some Lockbox activities, and the first six lessons have been successfully reimagined with part of the dramatic story plot implemented. These lessons were first implemented in Fall 2022.

- Lesson 00
  - Students receive an email and video from fictional character Steelio to meet him and Concreto in-class on the first day.
- Lesson 01
  - Steelio mysteriously vanishes.
  - Students are introduced to their reinforced concrete building design project and form teams.
    - To obtain the parameters of the project (number of building stories, types of occupancy, and square footage), teams are given "Private Investigator" photos of the fictional character Concreto and must complete a scavenger hunt across campus to find the concrete building elements. Figure 1 contains an image of an associated graphic novel style story.
    - The author also used the AI website *Typecast* to put fictitious voices to the characters in the comic.

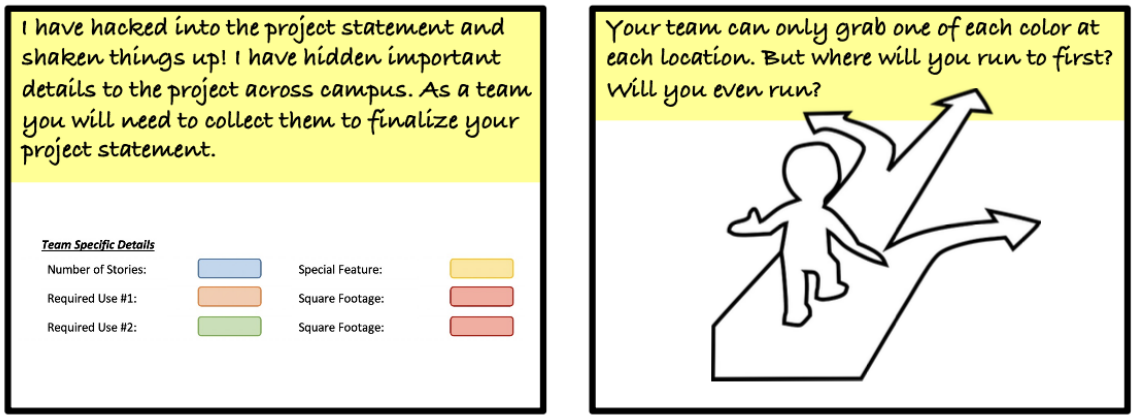
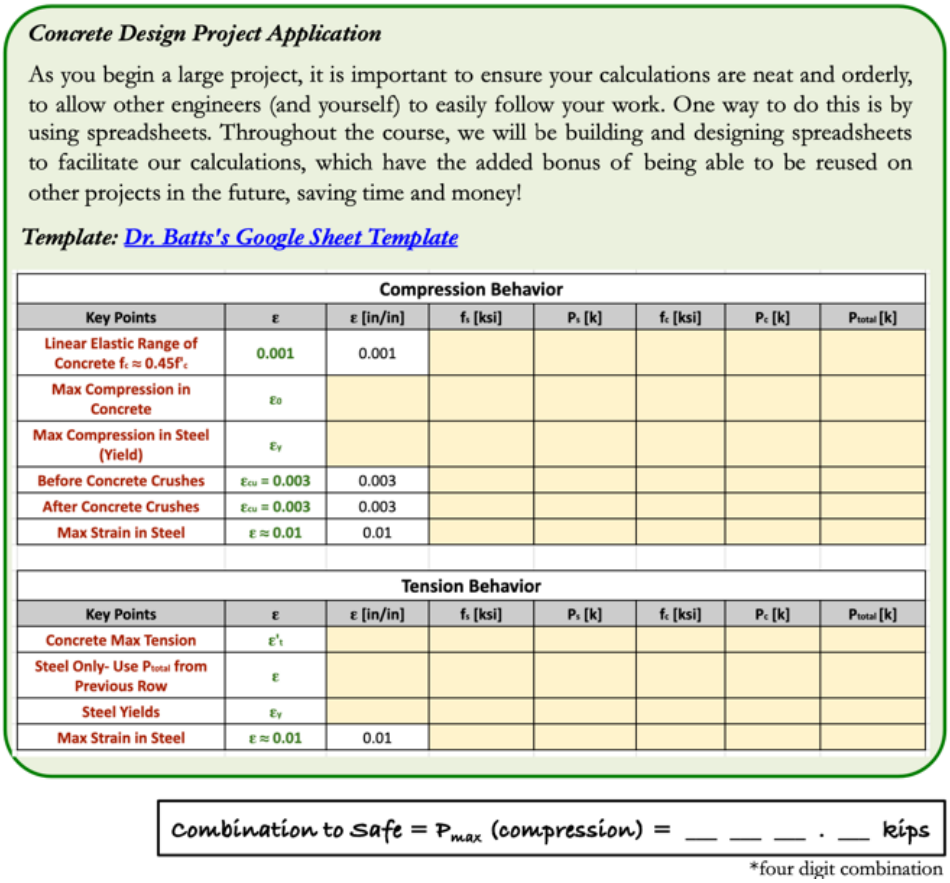


Figure 1: Example of Graphic Novel for Concreto and Steelio Fictional Story Plot

- Lesson 02
  - Stress-Strain Models for Concrete and Steel
  - Additional content to help prepare students for the activity in Lesson 03 is given by video as a homework/reading assignment.
- Lesson 03
  - Students apply calculations from Lesson 02 to complete a lockbox challenge (see Figure 2)



Concrete Design Project Application

As you begin a large project, it is important to ensure your calculations are neat and orderly, to allow other engineers (and yourself) to easily follow your work. One way to do this is by using spreadsheets. Throughout the course, we will be building and designing spreadsheets to facilitate our calculations, which have the added bonus of being able to be reused on other projects in the future, saving time and money!

Template: *Dr. Batts's Google Sheet Template*

Compression Behavior

Key Points	ε	ε [in/in]	f_s [ksi]	P_s [k]	f_c [ksi]	P_c [k]	P_{total} [k]
Linear Elastic Range of Concrete $f_c \approx 0.45f'_c$	0.001	0.001					
Max Compression in Concrete	ε_0						
Max Compression in Steel (Yield)	ε_y						
Before Concrete Crushes	$\varepsilon_{cu} = 0.003$	0.003					
After Concrete Crushes	$\varepsilon_{cu} = 0.003$	0.003					
Max Strain in Steel	$\varepsilon \approx 0.01$	0.01					

Tension Behavior

Key Points	ε	ε [in/in]	f_s [ksi]	P_s [k]	f_c [ksi]	P_c [k]	P_{total} [k]
Concrete Max Tension	ε'_t						
Steel Only- Use P_{total} from Previous Row	ε						
Steel Yields	ε_y						
Max Strain in Steel	$\varepsilon \approx 0.01$	0.01					

Combination to Safe = P_{max} (compression) = ___ ___ ___ . ___ kips

*four digit combination

Figure 2: Sample from Student Worksheet Guiding them to Different Lockbox Combinations

  - As teams finish, they get to select an admixture they will need to study to determine chemical properties, dosage, and the effect on the resulting concrete strength/workability/durability.
- Lesson 04
  - Load Path, LRFD Methodology, ACI 318-19 Code Provisions for Loads
- Lesson 05
  - Apply content from Lesson 04 to complete another Lockbox Challenge. Teams reveal a note from Steelio.
- Lesson 06
  - Teams cast concrete modulus of rupture specimens using their different admixtures.
  - These specimens cure for 28 days and then are broken (Figure 3).

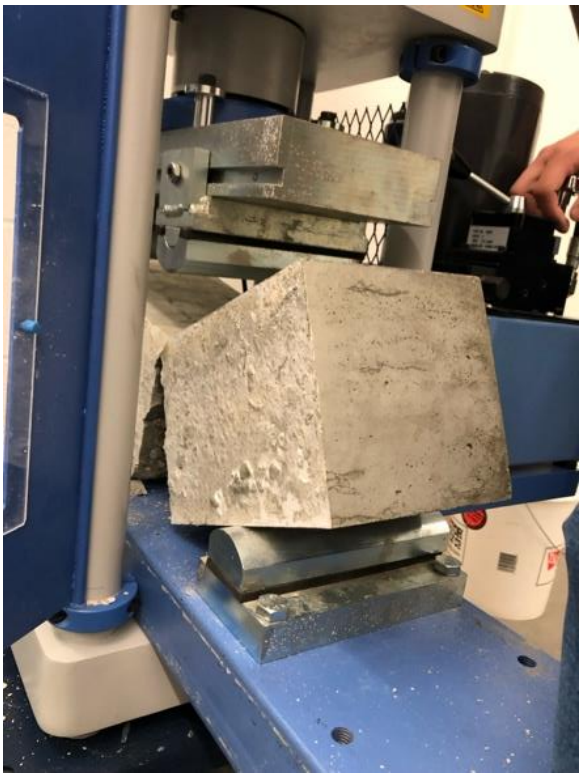


Figure 3: Student Performing Concrete Modulus of Rupture Test

- Skill 27A: Admixtures
    - Student teams write a two-page report and complete a 10-minute class presentation on their admixtures (at the start of Lessons 07-10).
    - Supports ABET Student Outcome 7: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies [4].
- Class Ending
    - It is envisioned that the final day will end with students realizing that… Well, the complete story plot and ending have yet to be implemented, but the author has the ending planned and hopes readers of this paper are intrigued to look forward to the final work.

Quantitative Feedback

As previously described, the dramatic story plot is not complete and has only been implemented to date in approximately 8 classes or 27% of the course content. However, qualitative and quantitative feedback has been solicited from the students in the end of semester anonymous student evaluations conducted by the university using the IDEA Student Ratings Systems. The following survey questions were selected for examination.

Survey Questions- Likert Scale

Student Ratings of Learning on Relevant Objectives
(1- Strongly Disagree, 2- Disagree, 3- Neutral, 4-Agree, 5- Strongly Agree)

A. Gaining a basic understanding of the subject (e.g. factual knowledge, methods, principles, generalizations, theories)
B. Learning to *apply* course material (to improve thinking, problem solving, and decisions)
C. Developing specific skills, competencies, and points of view needed by professional in the filed most closely related to this course
D. Developing creative capacities (inventing; designing; writing; performing in art, music, drama, etc.)
E. Gaining a broader understanding and appreciation of intellectual/cultural activity (music, science, literature, etc.)
F. Developing skill in expressing myself orally or in writing

Table 1: Student Ratings of Learning on Relevant Objectives- IDEA Raw Average Results

Semester	**Class Size**	**Responses**	**Likert Scale Question Results- Average**					
			A	**B**	**C**	**D**	**E**	**F**
Fall 2017	2	n/a	-	-	-	-	-	-
Fall 2018	12	8	4.5	4.4	4.3	3.8	3.0	2.9
Fall 2019	16	10	4.4	4.5	4.0	3.3	3.3	3.7
Fall 2020 (*in-person)	18	15	4.7	4.4	4.4	4.3	4.2	4.2
Fall 2021 (*in-person)	11	7	4.4	4.3	4.6	3.6	3.6	3.9
Pre-Test Weighted Average			**4.5**	**4.4**	**4.3**	**3.8**	**3.6**	**3.8**
Interactive Story Plot, Videos, Assignments Added to Course								
Fall 2022	14	8	4.8	4.5	4.8	4.5	4.4	4.5
Fall 2023	8	8	4.4	4.4	4.3	3.9	3.6	3.5
Fall 2024	8	6	3.8	4.0	4.0	3.7	3.5	3.7
Post-Test Weighted Average			**4.4**	**4.3**	**4.4**	**4.1**	**3.9**	**3.9**

From the data collected and summarized in Table 1, it is observed that students generally agree or strongly agree with most of the Likert Scale questions.

Questions A, B, and C were selected for the study to ensure the rigor of the course was unchanged and that students continue to meet the learning objectives for the course. When viewing the data, the responses pre- and post-implementation of the interactive story plots and assignments for these questions show similar results which seems to indicate the addition of the story plot is not detracting from the ability of the students to learn and apply the content from reinforced concrete design.

Questions D and E were selected to study the students' opinion on developing their own creative capacities related to the class, which would support the goals of ASCE and ABET to inspire more creativity and innovation in undergraduate engineers. While the overall class sizes are low, it seems the addition of the interactive story plot and activities may have led students to feel more creative as a result. It is noted the data is trending down from Fall 2022, so the instructor will need to continue to monitor the results and emphasize these ideals in future semesters.

Question F was selected to analyze the effect of the implementation on one's ability to express oneself verbally or in writing. It was hypothesized that the new dimension of the class could make students more comfortable or capable of expressing oneself; however, the data is inconclusive. At the very least, the change in format has not caused a regression with regards to this objective.

Student Ratings- Formative Feedback on Teaching Essentials
(1- Strongly Disagree, 2- Disagree, 3- Neutral, 4-Agree, 5- Strongly Agree)

A. Demonstrated the importance and significance of the subject matter
B. Made it clear how each topic fit into the course
C. Explained course material clearly and concisely
D. Introduced stimulating ideas about the subject
E. Stimulated students to intellectual effort beyond that required by most courses
F. Formed teams or groups to facilitate learning

Table 2: Formative Feedback on Teaching Essentials- IDEA Raw Average Results

Semester	**Class Size**	**Responses**	**Likert Scale Question Results- Average**					
			A	**B**	**C**	**D**	**E**	**F**
Fall 2017	2	n/a	-	-	-	-	-	-
Fall 2018	12	8	4.9	4.8	4.8	4.4	4.8	4.8
Fall 2019	16	10	4.5	4.8	4.8	4.3	4.5	4.6
Fall 2020 (*in-person)	18	15	4.5	4.7	4.7	4.5	4.7	4.5
Fall 2021 (*in-person)	11	7	5	4.9	5	4.6	4.7	4.3
Pre-Test Weighted Average			**4.7**	**4.8**	**4.8**	**4.4**	**4.7**	**4.6**
Interactive Story Plot, Videos, Assignments Added to Course								
Fall 2022	14	8	4.6	4.8	4.9	4.6	4.9	4.3
Fall 2023	8	8	4.5	4.4	4.6	4.4	3.8	4.3
Fall 2024	8	6	4.0	4.2	4.2	4.0	4.2	4.5
Post-Test Weighted Average			**4.4**	**4.5**	**4.6**	**4.4**	**4.3**	**4.4**

From the data collected and summarized in Table 2, it is also observed that students generally agree or strongly agree with the statements used by the IDEA survey to describe the instructor's ability with regard to each of the teaching essentials selected.

Teaching Essentials A, B, and C were selected for the study to ensure the implementation did not detract from the organization of the course. Unfortunately, the data does seem to show a slight decline in the instructor's ability to demonstrate the importance and significance of the subject matter as well as a decline in course clarity and organization. This may be due to the fact the implementation is only within the first few weeks of the class and then is a bit lost after that, possibly leaving students a little confused. In looking at the results from Fall 2022, it is more positive that there is no change or even slight improvement, so perhaps the professor did a better job the first year of implementation on explaining that the revamp was not complete and appreciating their patience as he/she gradually changes the course.

Teaching Essentials D and E were selected to study the students' perception of the instructor to provide and inspire stimulating ideas about the course. Again, Fall 2022 seemed to show a significant improvement compared to the previous version of the course with results trending downward in Fall 2023 and Fall 2024. This area will continue to be monitored by the instructor.

Lastly, Teaching Essential F was selected to see if the change in format of in-class activities led to students better appreciating their project group members. While there does seem to be a decrease post-implementation, the author would deem the results inconclusive. Specifically, at least one team in both Fall 2023 and Fall 2024 had significant team issues with individuals who failed to participate in the team project (and also failed the course). With the low class size, it is possible that these teammates rated this Teaching Essential lower as a result, thus impacting the average.

Qualitative Feedback

While the numbers are useful to examine, survey questions do not always capture the sense of excitement or anticipation the students might have with regards to the development of the dramatic story plot within the reinforced concrete design course. The following feedback was given by students in Fall 2022, Fall 2023, or Fall 2024 in response to any of the following open-ended questions at the end of the survey:

- Comments
- My favorite part of the CENG 4362 course was...
- If I could change or add anything to CENG 4362, it would be...

Student Comments and Feedback

- More of the lock boxes.
- The organized class lecture
- I like the way the class was set up and with the mastery style coursework
- The professor making the content interesting
- The lecture notes and calculations were well organized and an attentive student would easily understand course.
- Even though the lectures are over an hour, you keep my attention throughout the class. That may also partially be due to the time. A class at 9:30 is easier than an 8:00 am. Nonetheless, you connected what we learned to what would be done in real life.
- What happened to Steelio? I shore would like to know
- The fun the class was
- working in classroom setting with dr batts helping us

- Steelio and Concreto was a neat idea. Dr. Batts is an excellent professor and mentor.

Confounding Variables

While the quantitative and qualitative data seem promising the interactive story plot is slightly improving the course experience, it is important that two additional conflicting variables be included for transparency. Over about the same timeframe, the instructor has also introduced two other initiatives to the class. First, in Fall 2021, the instructor began a mastery-based assessment practice for the class. Rather than a series of homework assignments followed by two summative exams on technical content, the instructor now posts skills assessments within Blackboard. The skills are graded using a letter-based system with a rubric that includes neatness and organization to calculations beyond correct answers [12]. Students appreciate the new format and the instructor believes it has positively impacted learning in the class.

Also, since Fall 2021, the instructor has been emphasizing the use of spreadsheets to solve analysis problems and to aid in the subsequent design of members. This implementation has been more gradual, with each semester having more required skills to which students must submit a spreadsheet solution. It is hoped this effort helps students develop skills that will benefit them in their future engineering design offices.

Future Work

As the instructor continues to teach the course annually, he/she will work to gradually implement more of the storyline so that in a couple more years, the entire course will include the new interactive format. The instructor is also exploring opportunities to provide more collaboration with other faculty and to provide course release time to work on the project. As the implementation continues, the data described herein will be tracked and additional feedback may be solicited from the students.

Acknowledgements

The author would like to thank the Faculty Learning Commons at Angelo State University for the initial funding to develop and implement the three lock box / adventure racing activities for this course to date.

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