Say Yes to the Stress: Escape Rooms in Civil Engineering Classrooms

Major Brett Rocha, United States Military Academy

MAJ Brett Rocha is a second year instructor at the US Military Academy in the Department of Civil and Mechanical Engineering. She received her B.S. in Civil Engineering from USMA in 2012, her M.S. in Engineering Management from Missouri University of Science and Technology in 2016, and her M.S. in Civil Engineering from University of Central Florida in 2021. She teaches mechanics of materials, design of steel structures, and design of concrete structures.

Dr. Kevin Francis McMullen, United States Military Academy

Kevin McMullen is an Assistant Professor in the Department of Civil and Mechanical Engineering at the United States Military Academy, West Point, NY. He received his B.S. and Ph.D. in Civil Engineering from the University of Connecticut. His research interest areas include bridge engineering, protective structures, and engineering education.

Capt. Michael Rocha, United States Military Academy

CPT Michael Rocha is a second year instructor at the United States Military Academy in the Department of Mathematical Sciences. He received his B.S. in Mathematical Sciences with Honors from USMA in 2012 and his M.S. in Statistics and Data Science from University of Central Florida in 2021. He teaches probability and statistics.

©American Society for Engineering Education, 2023

Say Yes to the Stress: Escape rooms in Civil Engineering Classrooms

Abstract

Over the last two decades, escape rooms have emerged as a social and team building activity. Participants must work in a team to solve complex puzzles by finding clues within the event space. These puzzles can range from word finds, math problems, riddles, or identifying clues. Escape rooms vary in difficulty. They should be difficult enough where they cannot be solved by a single participant, but easy enough that they can be solved in less than an hour. Recently, educators have explored implementing escape rooms as an active learning activity for secondary and higher education. Multiple studies have been conducted in STEM classes. The goal of this study was to investigate the use of escape rooms in civil engineering courses to improve students' ability to solve an ill-defined problem and connect clues to the course content. The escape rooms required students to work as a team, communicate their solutions effectively, and increase their engagement and interest with the course material. Two different escape rooms have been developed and implemented: one in a mechanics of materials course and one in a design of reinforced concrete structures course. Both escape rooms were implemented as end of course review session where students were tasked with solving multiple linked, but separate puzzles on cumulative course topics. These puzzles assessed whether the students could identify the type of problem and key information and solve the problem by connecting the clues to course concepts. The escape room activity was assessed based on student survey feedback, instructor feedback, and student performance on the final examination. While participation in the escape room did not have a significant impact on the students' performance, the students found the escape room to be an engaging activity which encourage teamwork and collaboration as well as review of the course material. Upon completion of the escape room, students had identified concepts that they needed to review prior to the final examination. This paper presents the design, creation, execution, and results of an escape room activity implemented in these two civil engineering courses.

Introduction

Escape rooms are an interactive game where teams work together to solve puzzles in order to collect clues to ultimately escape the room (or solve the final puzzle) [1]. Escape rooms typically have a fixed time limit, which increases the unpredictability of success and can encourage additional engagement and active participation [2], [3]. Participants typically complete escape rooms as social or team building activities. Escape rooms have three primary formats: single room, multi-room, and escape room in a box. The single room and multi-room escape rooms are typically developed by commercial companies where the participants enter the room and are completely engulfed in the escape room experience with clues scattered throughout the event space [4]. An escape room in a box is where all the clues and pieces needed to solve the puzzles are provided to the participants in a single box, but the participants need to solve puzzles to unlock certain clues [5].

When creating an escape room, there are three design paths; linear, open, and multi linear [6]. The linear design requires teams to solve the puzzles in a sequential order where the solution of one puzzle leads to the next until the final puzzle is solved. Open path design allows numerous

puzzles to be worked on simultaneously with no specific order, but all puzzles need to be solved to have all the clues needed to solve the final puzzle. Multi-linear has numerous paths that will intersect allowing for different avenues to get to the same end state.

Large in-person commercial escape room companies have purchased or rented large venues such as warehouses or malls to build customized escape rooms [4]. These locations typically have one to over ten unique escape rooms for customers to choose from. The escape rooms typically vary in difficulty level and number of participants. Escape room difficulty is typically rated from 1-5 based on the average escape rate for the room measure as the percentage of participants who successfully complete the final puzzle. The average escape rate for most escape rooms is 41% [7]. Mystery Room is an escape room franchise with twenty-five locations in ten states. Mystery Room reports a 46%, 53%, and 64% escape rate for their level-1 novice rooms and 25%, 28%, and 34% for their level-4 expert rooms[4]. The number of participants can range from 2 to approximately 10 participants. The size of the groups directly impacts the level of participation required for each participant [8].

The escape room in a box has been developed by game manufacturers such as Escape the Crate [5]. This company has a subscription service that send an escape room monthly to its subscribers. The manufacturer describes their escape rooms as “very linear” due to the fact that all clues are included in the box. A lengthy search of escape rates for escape rooms in a box did not return any results more than likely because this would require the participants to self-report their success or failure at completion of the escape room.

Design of escape rooms must begin with an engaging and entertaining theme to engulf the participants in the activity. A good theme takes the players to a different place and causes them to lose track of time [6]. This is an important aspect of escape room design is encouraging engagement from all players [3]. Creating a balance between requiring creative and critical thinking is essential. The puzzles should be difficult enough to keep all players engaged, but not so difficult that the players become discouraged or overly stressed [6], [9]. However, the ability to involve choice in the participants decision making can increase their level of engagement as they recognize that their choices can influence the results [10], [11]. Another key element about escape rooms is they commonly involve numerical combination locks, which require the participants to use clues to identify the code to unlock the next puzzle. This provides the participant with additional motivation to “escape”.

Educational escape rooms have been utilized in primary, secondary, and higher education [1], [12]. Escape rooms have been developed for chemistry [13], engineering [14]–[16], computer science [17], medicine [18], nursing [19], and pharmacy classes [20], [21]. However, the authors review of the literature did not find any escape rooms developed for civil engineering education. The authors also identified that many of the studies on gamification of classroom activities lack substantial assessment of student outcomes [22]. Most existing literature assesses students’ attitude towards learning.

The goal of this study was to design, implement and assess two unique escape rooms in civil engineering courses: Mechanics of Materials (MC364) and Design of Reinforced Concrete Structures (CE483). The research question that this paper sought to answer was: *did*

participation in the escape room improve students' ability to achieve the course objectives? This paper will present an overview of the design of the two escape rooms and an assessment of the escape room based on student performance on a final exam and student feedback.

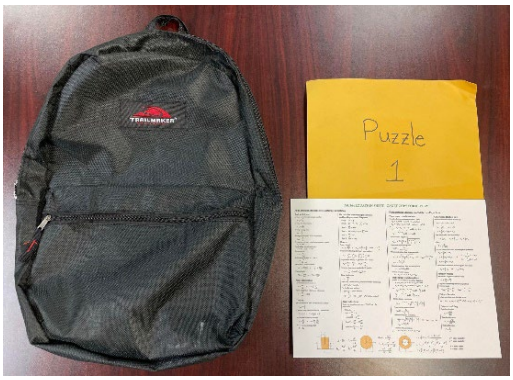
Design of Escape Room

While both escape rooms were designed to test concepts from civil engineering courses, the two escape rooms had completely different designs. The differences in the design of the escape rooms ranged from the type of escape room, the organization of the puzzles, the resources available to the students, the size of the teams, and the backstory or theme of the escape room.

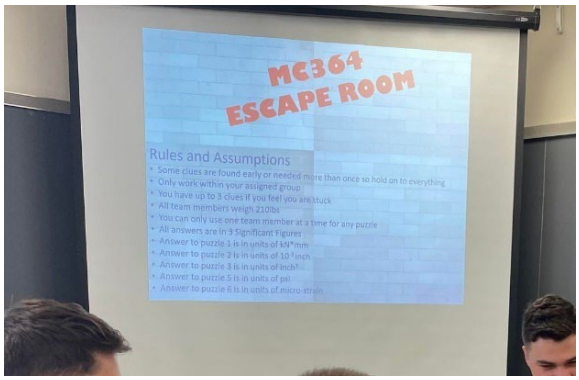
The Mechanics of Materials escape room was designed as an escape room in a box with a linear path. As described in the introduction, the design was based on commercially available escape room in a box where all clues and materials needed to solve the puzzles were included in a single package. The package used for this escape room was a locked backpack as shown in Figure 1a . At the start of the escape room, the students were provided with the backpack and a folder containing the first puzzle, an equation reference card, and a material properties table from the 5th Edition of Mechanics of Materials by Timothy Philpot [23]. In total, the linear path included five puzzles. Students were required to solve each puzzle in sequence to successfully meet the objective of the escape room. A set of clear guidelines were provided to the students at the start of the escape room regarding rules and key assumptions as shown in Figure 1b. The built in structure of a linear path makes it easier for players to solve the escape room [6].

A fictional scenario was developed where the students were required to navigate a steam tunnel in search of a boiler room to increase the heat in the building where they would be taking their final exam. Each of the five puzzles were tied into the theme leading the students to the next challenge that needed to be overcome to seize the opportunity to get final exams cancelled. The students were given 75 minutes to solve the five puzzles. The five puzzles covered key course concepts of torsional analysis, statically indeterminate axially members, flexural loading, stress transformation, thin-walled pressure vessels, and failure theories. The five puzzles and all clues provided are shown in Figure 1c.

The Mechanics of Materials escape room was executed on the final day of class for the semester as a course review exercise. The escape room was delivered in two out of nine sections of the course. The students in the sections chosen for the escape room experience were not told before arriving to class that they would be executing an escape room. The sections were broken down into three teams consisting of six students. Throughout the semester the students worked in three-person lab groups. Two lab groups were combined to form six-person teams that would execute the escape room. The students were authorized to use the textbook and class notes to complete the puzzles but were given everything that was required to solve the puzzles in the provided folder and backpack. An image of the students participating in the MC364 escape room are shown in Figure 1d and 1e.

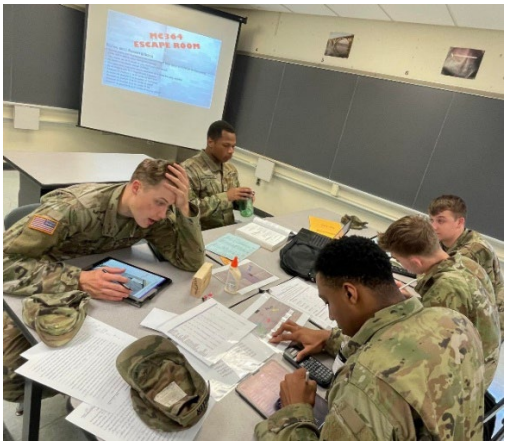


(a)



(b)

(c)



(d)

(e)

Figure 1: The MC364 Escape Room – a) Image of supplies initially provided to the students, b) Image of rules slide, c) Overview of all puzzles, d) Image of students participating in the escape room, e) Image of instructor providing hints to the student teams.

The Design of Reinforced Concrete escape room was a full scale escape room with multiple rooms the students were required to navigate through. The escape room was executed on a single floor of a building with three rooms with cypher locks and a loading dock. Figure 2b shows an image of the locked door with a cypher lock. The students had a choice in selecting a path to solve the escape room. The players had to unlock the three rooms in order to gather all the clues needed to solve the final puzzle. One of the rooms contained two puzzles and each of the other two rooms contained one puzzle. The puzzles required the students to search the room for clues to determine what course concept was needed to solve the puzzle. Unlike the Mechanics of Materials escape room, the students were not provided with everything needed to solve the puzzles. The student's personal copy of the Building Code Requirements for Structural Concrete (ACI 318-19) was needed to solve the puzzles [24]. This reference was used throughout the entire course and the students were expected to bring it to every lesson. In total, the open path design required the students to solve six puzzles to win the escape room.

The theme of the CE483 escape room aimed to introduce the students to forensic engineering and engineering ethics in addition to reviewing course concepts. The escape room was themed as a case study of the Harbour Cay Condominium collapse [25]. The students were given 90 minutes to determine who was at fault for the collapse. The results of the investigation conducted by the National Bureau of Standards were used to create puzzles to assess the students' ability to achieve the course objectives [25]. However, the numbers were changed to facilitate appropriate codes for the combination locks, but the puzzles followed the storyline. The six course concepts covered were moment envelopes, detailing reinforcement, punching shear, nominal moment capacity, development length, and material properties.

The CE483 escape room was intended as a course review activity but was executed during the final lab period for the course, which was five lessons before the end of the course. The students were not notified before arrival to the lab period that they would be executing an escape room. Upon arrival at the loading dock, they were instructed to gather with their lab groups, which they worked in throughout the semester. The lab groups each consisted of four students. Each lab group was assigned a table with their initial briefcase, which contained the clues for the first puzzle as shown in Figure 2a. At the start of the lab period, a prerecorded video introduced the scenario and set the stage for the escape room as shown in Figure 2c. The relatively small enrollment allowed for four teams of four students in both sections. The students were authorized to use the course textbook and any class notes to complete the escape room. Figure 2d shows the students participating in the escape room. After completion of the escape room, all teams, regardless of if the successfully escaped or not, took team photos as shown in Figure 2e and 2f, similar to those taken after a commercial escape room.

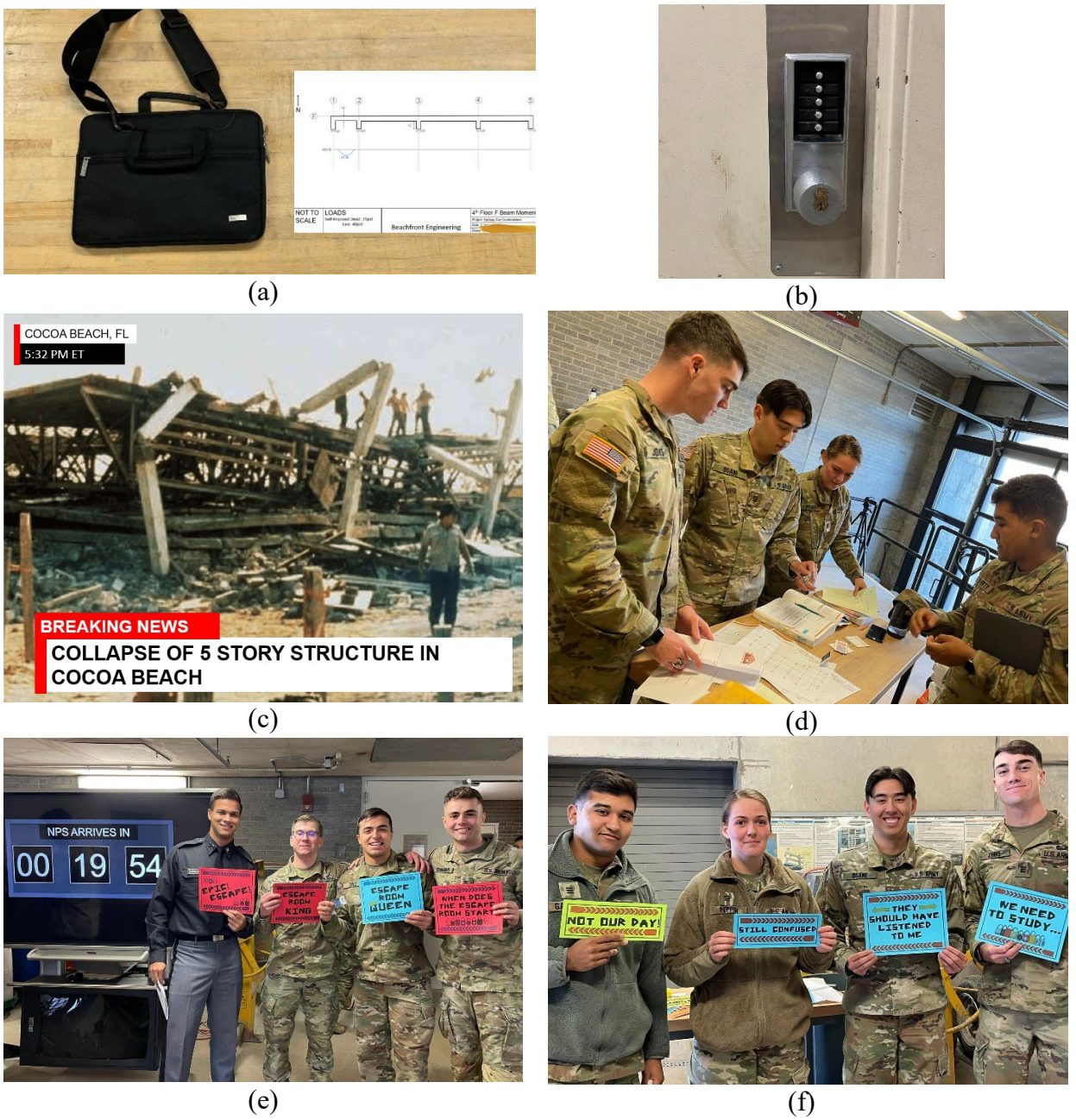


Figure 2: The CE483 Escape Room – a) Image of initial brief case with clues provided to the students, b) Image of room door with cypher lock, c) Image of scenario presented to students on Harbour Cay Condominium Collapse [25], d) Image of teams participating in the escape room, e) Image of a team after they escape, f) Image of a team who did not escape.

While the MC364 and CE483 escape rooms were designed differently, there were similarities between the two experiences. At the start of both escape rooms, the students were provided with some general rules and simplifying instructions. These were presented as a bulleted list on a PowerPoint slide that remained available throughout the execution of the escape room as shown

in Figure 1b. During the execution of the escape room, the teams could request three hints from the instructor as shown in Figure 1e. Opportunity to receive hints is essential to prevent stagnation of the game [22]. The escape room in a box concept was much easier for the instructor to monitor as all students were in one room and were required to work on the puzzles in sequential order [26]. The full-scale, multi-room escape room required the instructor to constantly move between the three rooms and the loading dock to monitor the students' performance and be available to provide hints. Additionally, both the escape room in a box and the full-scale escape room required approximately forty hours to build and prepare by the instructor. A portion of the preparation for the execution was to complete a trial run of the escape room with other instructors. It took a single instructor sixty minutes to complete the MC364 escape room. Two instructors completed the CE483 escape room in 65 minutes. The trial run was essential to ensure clarity of the clues, difficulty of the puzzles, and time required to complete.

Results & Discussion

Before assessing whether the educational escape room was effective in reviewing course material, the quality of the escape room should be assessed. Upon completion of the escape rooms, the authors evaluated the escape rate and student feedback to measure the quality of the two escape rooms. The escape rate for the educational escape room was compared to the escape rate for a commercial escape room. The escape rate for the MC364 escape room was 50% across six teams. The escape rate for the CE483 escape room was 75% across the eight teams. The MC364 escape room was on par with the escape rate for a level one, novice escape room. However, and the high escape rate for the design of reinforced concrete escape room indicates that 90-minute time limit provided the students too much time to solve the puzzles. For the six teams that successfully escaped the average completion time was 70-minutes.

The second metric was a survey of the students after completing the escape room. The goal of the survey was to understand the students' familiarity with escape rooms and identify areas of strength and areas for improvement. Ten students completed the survey for MC364 and twenty-five completed the survey in CE483. The first question asked how many students had participated in an escape room previously which resulted in almost an even split for both courses as seen in Figure 3. For those who had participated in an escape room previously, there was a follow-on open-ended question asking if they felt the escape room was similar to a commercial escape room. Unanimously, the students stated that the two were similar. The survey also asked the students to rate the difficulty and length of the puzzles using a Likert scale. For the MC364 escape room all students thought the puzzles were appropriately difficult, and for the CE483 escape room 96% of students thought the puzzles were appropriately difficult as shown in Figure 4. The escape rate and the students survey responses indicated that the escape room had a high-quality design.

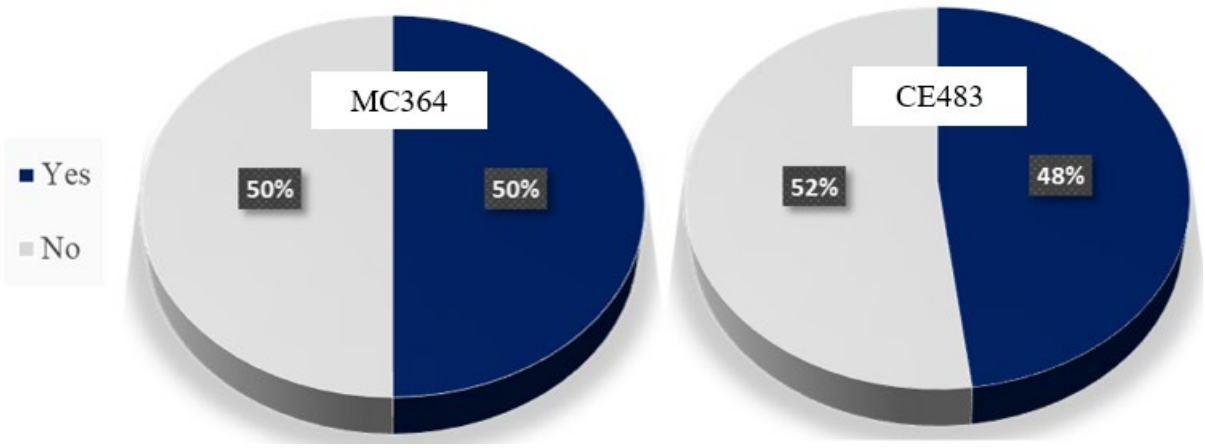


Figure 3: Students Reported Prior Escape Room Experience

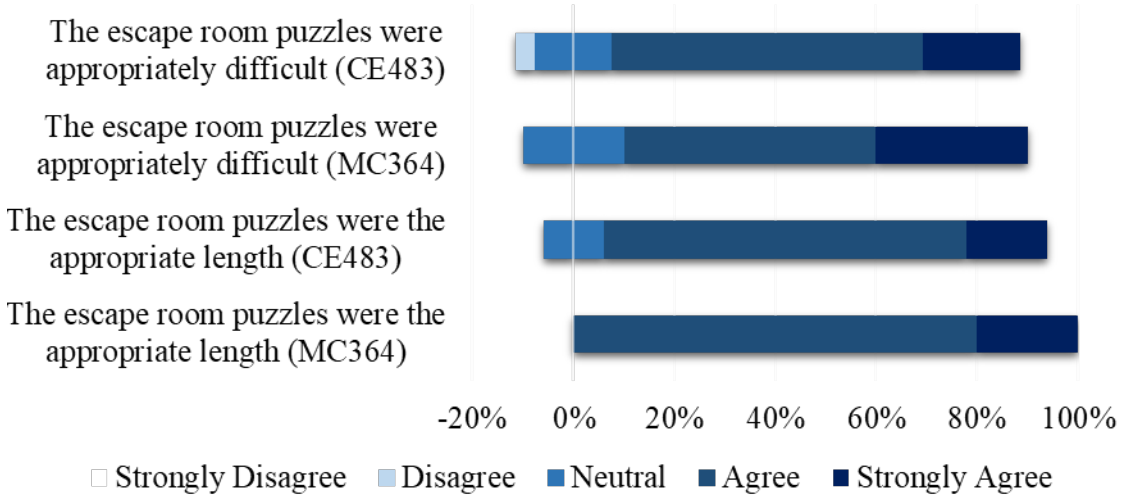


Figure 4: Students Opinions on Escape Room Quality

After assessing the quality of the escape room, the authors assessed the students' ability to achieve the student outcomes through performance on the final examination. The students were divided in to a control group, those who did not complete the escape room, and an experimental group, those who completed the escape room. A two-sample t-test was conducted on the average grades on the final exam. For the MC364 escape room, the control group was the seven sections of the course that conducted the traditional course review lesson without an escape room. For the CE483 escape room, the control group was the data from the previous semester course offering. Table 1 shows the observed difference, the calculated t-statistics, and p-values for the overall final exam grade as well as individual question topics for the mechanics of materials final exam. Overall, the results indicated no significant differences in test performances between the two groups except for questions 4 and 7, which covered statically indeterminant beams (p-value = 0.0013) and combined loading (0.0175), respectively. The significance in question 4 performance looks to be from a second population with abnormally low performance; the general behavior of most of the samples behave in a similar manner. Students who participated in the escape room averaged 5% better on the combined loading question. It is interesting that the

experimental group performed better on the combined loading question as this was not a topic that was addressed in the escape room review activity. Table 2 shows the observed difference, the calculated t-statistics, and p-values for the overall final exam grade as well as individual question analysis for CE483. Overall, the results indicated no significant differences in test performances between the two groups in either overall performance or for any individual question.

Table 1 Mechanics of Materials T-Test Results

	Difference	T-Statistic	P-Value
Final Exam:	0.002	0.098	0.922
Indeterminant Axial	-0.003	-0.045	0.963
Torsion Analysis	0.0153	0.567	0.572
Flexural Analysis	-0.002	-0.073	0.942
Indeterminant Bending	-0.085	-3.286	0.001
Stress Transformation	-0.025	-1.607	0.11
Thin-Walled Pressure Vessel	-0.054	-1.589	0.114
Combined Loading	-0.049	-2.405	0.017

Table 2 Design of Reinforced Concrete T-Test Results

	Difference	T-Statistic	P-Value
Final Exam:	-0.007	-0.273	0.786
Short Answer	-0.048	-1.769	0.082
Materials	-0.046	-1.052	0.296
Flexure	-0.029	-0.945	0.348
Shear	-0.033	0.54	0.591
Development Length	-0.043	-1.568	0.121
Deflections	0.0151	1.618	0.110
Columns	0.006	0.098	0.922
Footings	0.061	1.615	0.111

A Least Squares Linear Regression was used to analyze association of escape room group with performance on the final exam after controlling for variation in prior academic performance among cadets. To control for variation in academic performance, the student performance on midterm examinations was accounted for in the analysis. Overall findings for MC364 indicated the three midterm exams had significant association and predictive power on final exam performance, but that participation in the escape room had no significant difference in final exam score after accounting for prior academic performance. The results, shown in the Table 3 below, compare the basic model with an interactive model. For CE483, incoming GPA had a significant association with final exam performance when controlling for other factors, whereas no other factor was statistically significant when controlling for Incoming GPA. This could indicate that, as an advanced course, understanding of previous concepts is a better indicator of overall performance than any single graded event in the class leading up to the final exam. Ultimately,

there is no evidence in this sample that participating in an escape room review session had any impact on final exam performance.

Table 3 Mechanics of Materials Linear Regression Results for Association with Final Exam Grades

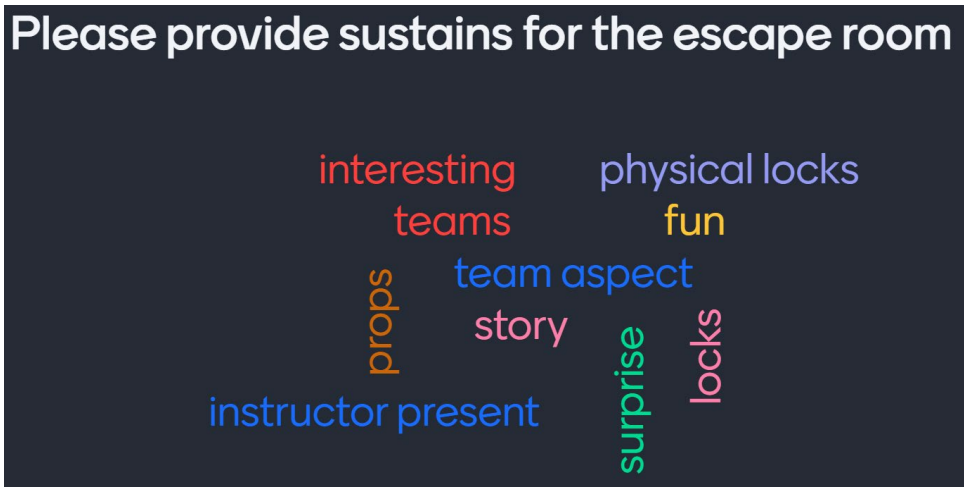
	Final Exam Grade				**Final Exam Grade**			
Predictors	*Estimates*	*std. Error*	*Statistic*	*p*	*Estimates*	*std. Error*	*Statistic*	*p*
(Intercept)	-0.08531	0.07146	-1.19381	0.235	-0.10502	0.14801	-0.70959	0.479
WPR1	0.43099	0.07673	5.61679	**<0.001**	0.39423	0.08350	4.72121	**<0.001**
WPR2	0.29077	0.06707	4.33538	**<0.001**	0.32449	0.07519	4.31557	**<0.001**
WPR3	0.34723	0.09754	3.56007	**0.001**	0.39899	0.10108	3.94740	**<0.001**
Escape [1]	0.00459	0.01372	0.33455	0.738	-0.20915	0.27714	-0.75466	0.452
RQ					0.16851	0.10631	1.58501	0.115
LAB					-0.18548	0.16815	-1.10308	0.272
RQ × Escape [1]					-0.49618	0.20506	-2.41968	**0.017**
LAB × Escape [1]					0.89125	0.35233	2.52955	**0.013**
WPR2 × Escape [1]					-0.21051	0.14375	-1.46443	0.145
Observations	145				145			
R^2 / R^2 adjusted	0.599 / 0.587				0.641 / 0.617			

Table 4 Design of Reinfroced Concrete Linear Regression Results for Association with Final Exam Grades

	Final Exam Grade				**Final Exam Grade**			
Predictors	*Estimates*	*std. Error*	*Statistic*	*p*	*Estimates*	*std. Error*	*Statistic*	*p*
(Intercept)	0.31861	0.09860	3.23149	**0.002**	0.43659	0.09281	4.70401	**<0.001**
Incoming QPA	0.08634	0.03073	2.80974	**0.007**	0.09018	0.02951	3.05554	**0.003**
Escape [1]	-0.02351	0.02250	-1.04501	0.300	-0.23261	0.15223	-1.52802	0.132
WPR1	0.14993	0.11340	1.32207	0.191	0.09669	0.12105	0.79876	0.428
WPR2	0.10440	0.13154	0.79365	0.430				
WPR1 × Escape [1]					0.24976	0.17615	1.41786	0.161
Observations	66				66			
R^2 / R^2 adjusted	0.346 / 0.303				0.360 / 0.318			

These findings indicate that escape rooms on their own did not significantly improve performance on the final exam. However, statistically significant interactions in our complex model might indicate that the escape room exercise enhanced prior laboratory work recollection, something that should be explored in future research with a broader sample.

While there is no statistical significance that can be seen in the students' final exam grades, there is still value in executing the escape room as a course review exercise, which is demonstrated through student feedback. Looking at the word clouds shown in Figure 5, multiple students mentioned team aspects. 80% of students who participated in the escape room either agreed or strongly agreed that the escape room required teamwork to be completed. ABET's 5th student outcome states that students should "have the ability to function effectively on a team [27]." Figure 6 shows the students perceived the escape room as a good method for preparation for the final exam and as a valuable team building activity. In additional to the educational outcomes, the student feedback also indicated that the escape room was a "fun" and "engaging" activity, which may inspire the students to pursue further learning. Figure 7 shows that overwhelmingly students found the escape room to be a "fun" (MC364) and "engaging" (CE483) activity.



(a)

(b)

Figure 5: Visualization of Open-Ended Survey Responses: (a) Mechanics of Materials and (b) Design of Reinforced Concrete

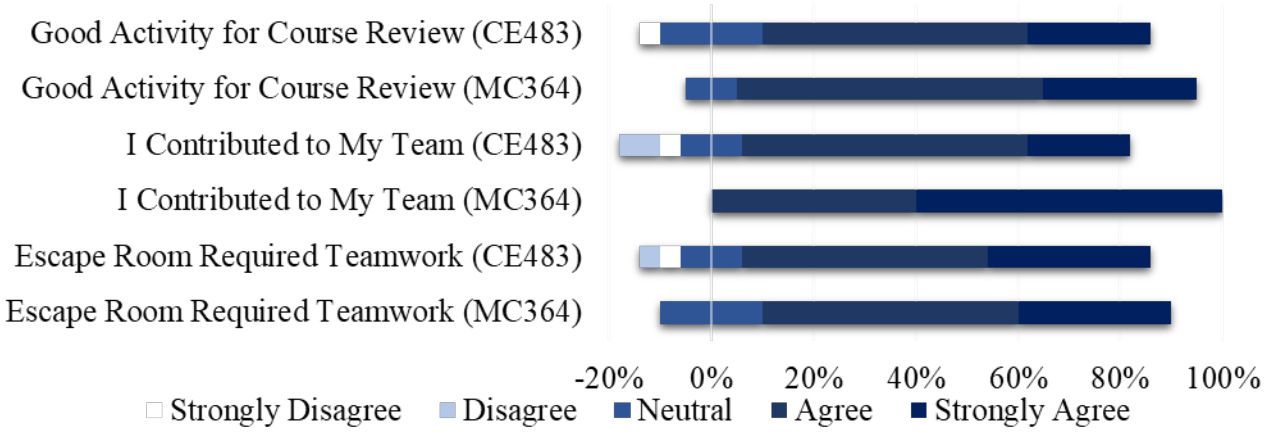


Figure 6: Student Survey Results on Teamwork and Course Review

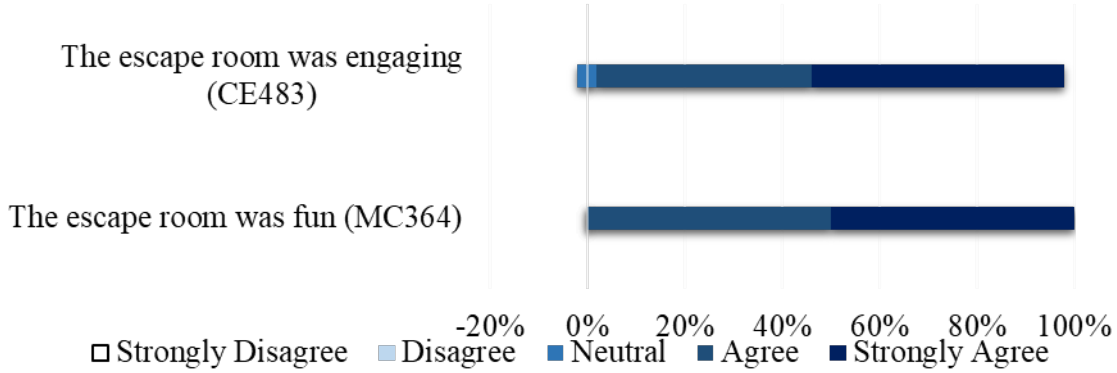


Figure 7: Student Survey Results on the Amusement of the Escape Rooms

Conclusion

The goal of this study was to investigate the impacts of implementing an escape room activity as a course end review. The use of educational escape rooms was an out of the box method for conducting an end of course review. The competitive nature of the game encouraged engagement frommore students compared to a simple problem-solving session. While both an escape room and a problem-solving session require students to work problems centered on the course concepts, the puzzles and limited time that are tied to the escape room provides additional motivation for the students.

The research question that this paper sought to answer was: *did participation in the escape room improve students' ability to achieve the course objectives?* Based on the student performance on the final exam, the escape room did not have a statistically significant effect on the students' grade. However, the authors acknowledge that confounding factors may have influenced the data as a result of the small sample size. Collection of additional data may improve the analysis. Although there was no effect on final exam scores, there were still benefits to the use of the

escape room which included teamwork and the enjoyment of the students. The lack of step-by-step instructions in completing the escape rooms required students to identify connections and potentially try multiple approaches to solve the puzzle. The complexity of the puzzles, combined with the time requirement increased the level of teamwork observed. With a small group of four to six students, an educational escape room was found to be an outstanding activity for team building. Additionally, the overall experience was found to be more memorable for the students. The fun, engaging, and collaborative nature of the escape room has the potential to inspire the students to seek additional learning opportunities.

The escape rooms presented in this paper will continue to be used in both the Mechanics of Materials and Design or Reinforced Concrete Structures courses. This will allow for additional data to be collected to assess if the educational escape rooms are an effective end of course review. Additionally, in the next course offering of Design of Reinforced Concrete Structures, a portion of the students will have completed both the escape rooms (MC364 and CE483). This will provide an opportunity to analyze if there is an advantage to having experience completing multiple educational escape rooms.

Acknowledgements

The authors would like to acknowledge the contributions of their students in execution of the escape room activities. The authors would also like to thank COL Jakob Bruhl for assisting in the trial competition of the CE483 escape room. This study was approved by the Institutional Review Board of United States Military Academy (CA-2023-61). The views expressed in this work are those of the author and do not necessarily reflect the official policy or position of the United States Military Academy, Department of the Army, DoD, or U.S. Government.

References

[1] S. Nicholson, “Creating Engaging Escape Games for the Classroom,” *Child. Educ.*, vol. 94, no. 1, pp. 44–49, 2018, [Online]. Available: https://doi.org/10.1080/00094056.2018.14203.

[2] E. Ozcelik, N. E. Cagiltay, and N. S. Ozcelik, “The effect of uncertainty on learning in game-like environments,” *Comput. Educ.*, vol. 67, pp. 12–20, 2013, doi: 10.1016/j.compedu.2013.02.009.

[3] R. Garris, R. Ahlers, and J. E. Driskell, “Games , motivation , and learning : A research and practice model,” *Simul. Gaming*, vol. 33, no. 4, pp. 441–467, 2002, doi: 10.1177/1046878102238607.

[4] D. U. Mall, “Escape Rooms in Syracuse, NY,” *All in Adventures*, 2023. https://mysteryroom.com/locations/syracuse-ny/.

[5] E. the Crate, “Subscription Box Adventure,” 2023. https://www.escape-the-crate.com/.

[6] M. Wiemker, E. Elumir, and A. Clare, “Escape Room Games: Can you transform an unpleasant situation into a pleasant one?,” 2015.

[7] S. Nicholson, “Peeking Behind the Locked Door : A Survey of Escape Room Facilities,” *White Pap.*, pp. 1–35, 2015.

[8] D. Watermeier and B. Salzameda, “Escaping Boredom in First Semester General

Chemistry," *J. Chem. Educ.*, vol. 96, pp. 961–964, 2019, doi: 10.1021/acs.jchemed.8b00831.

[9] A. Manzano-León *et al.*, "Escape rooms as a learning strategy for special education master's degree students," *Int. J. Environ. Res. Public Health*, vol. 18, no. 14, 2021, doi: 10.3390/ijerph18147304.

[10] C. Crawford, *Chris Crawford on game design*. Indianapolis, IN: New Riders Publishing, 2003.

[11] K. Salen and E. Zimmerman, *Rules of Play: Game Design Fundamentals*. Cambridge, MA: MIT Press, 2003.

[12] S. Clarke *et al.*, "escapED : A Framework for Creating Educational Escape Rooms and Interactive Games For Higher / Further Education .," *Int. J. Serious Games*, vol. 4, no. 3, pp. 73–86, 2017, doi: http://dx.doi.org/10.17083/ijsg.v4i3.180.

[13] N. Dietrich, "Escape Classroom: The Leblanc Process -An Educational ' Escape Game ,'" *J. Chem. Educ.*, vol. 95, pp. 996–999, 2018, doi: 10.1021/acs.jchemed.7b00690.

[14] M. A. Butkus, K. B. Newhart, and A. R. Pfluger, "The Green Escape Room: Part 1 - A Race to Solve an Environmental Engineering Problem by Applying Engineering Principles and Deciphering Clues and Puzzles," 2022.

[15] K. B. Newhart, A. R. Pfluger, and M. A. Butkus, "The Green Escape Room: Part 2 - Teaching Students Professional Engineering Ethics by Applying Environmental Engineering Principles and Deciphering Clues and Puzzles," 2022.

[16] D. De la Flor, J. A. Calles, J. J. Espada, and R. Rodríguez, "Application of escape lab-room to heat transfer evaluation for chemical engineers," *Educ. Chem. Eng.*, vol. 33, pp. 9–16, 2020, doi: 10.1016/j.ece.2020.06.002.

[17] C. Borrego, C. Fernández, I. Blanes, and S. Robles, "ROOM ESCAPE AT CLASS : ESCAPE GAMES ACTIVITIES TO FACILITATE THE MOTIVATION AND LEARNING IN COMPUTER SCIENCE," *J. Technol. Sci. Educ.*, vol. 7, no. 2, pp. 162–171, 2017, doi: https://doi.org/10.3926/jotse.247.

[18] A. Kinio, L. Dufresne, T. Brandys, and P. Jetty, "Break out of the Classroom : The Use of Escape Rooms as an Alternative Teaching Strategy in Surgical Education," *J. Surg. Educ.*, vol. 76, no. 1, pp. 134–139, 2019, doi: 10.1016/j.jsurg.2018.06.030.

[19] V. Adams, S. Burger, K. Crawford, and R. Setter, "Can You Escape? Creating an Escape Room to Facilitate Active Learning," *J. Nurses Prof. Dev.*, vol. 34, no. 2, pp. E1–E5, 2018, doi: doi: 10.1097/NND.0000000000000433.

[20] J. Cain, "Exploratory implementation of a blended format escape room in a large enrollment pharmacy management class," *Curr. Pharm. Teach. Learn.*, vol. 11, no. 1, pp. 44–50, 2019, doi: 10.1016/j.cptl.2018.09.010.

[21] H. N. Eukel, J. E. Frenzel, and D. Cernusca, "Educational Gaming for Pharmacy Students - Design and Evaluation of a Diabetes-themed Escape Room," *Am. J. Pharamaceutical Educ.*, vol. 81, no. 7, 2017, doi: 10.5688/ajpe8176265.

[22] C. A. Bodnar, D. Anastasio, J. A. Enszer, and D. D. Burkey, "Engineers at Play: Games as Teaching Tools for Undergraduate Engineering Students," *J. Eng. Educ.*, vol. 105, no. 1,

pp. 147–200, 2016, doi: 10.1002/jee.20106.

[23] T. Philpot and J. Thomas, *Mechanics of Materials: An Integrated Learning System*, 5th ed. Hoboken, NJ: John Wiley & Sons, Inc, 2020.

[24] A. C. I. ACI, *Building Code Requirements for Structural Concrete*. 2019.

[25] H. Lew, N. Fattal, and S. Batts, "Investigation of Construction Failure of Harbour Cay Condominium in Cocoa Beach, Florida," 1982.

[26] A. Veldkamp, L. van de Grint, M. Knippels, and W. van Joolingen, "Escape education: A systematic review on escape rooms in education," *Educ. Res. Rev.*, vol. 31, no. September, 2020, doi: 10.1016/j.edurev.2020.100364.

[27] ABET, *Criteria for Accrediting Engineering Programs*. Baltimore, MD: Engineering Accreditation Commission, 2022.