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Learning through Escape: Developing Collaboration, Communication, and Confidence in a Biomedical Engineering Laboratory Escape Room

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Abstract:

Escape rooms are growing in popularity in higher education because they can be used to promote hands-on technical skills and soft skills like communication and collaboration. In addition, they provide an opportunity for students to develop mastery in these skills and improve confidence. This work describes the use of a laboratory-based escape room to test the teamwork ability of upper-level undergraduate student groups while employing technical skills and problem solving in a laboratory environment. Students use ultrasound, mechanical tests frames, spectrophotometers, micropipettes, scales, and other laboratory tools to solve puzzles within 55 minutes.

We evaluated the use of a previously described biomedical engineering laboratory escape room to evaluate how the perceptions of teamwork and communication are affected for an upper-level biomedical engineering laboratory course. We evaluated the effectiveness of assigning group members specific team roles and their effect on teamwork through these several parameters of success in the escape room. In addition, we present qualitative results from student survey responses (in an IRB determined exempt study) about their perceptions of teamwork, communication, and confidence during the activity.

When asked what students will take away from the learning experience, the most common theme was an emphasis on the importance of effective communication during a group task. The importance of assigned roles was the next most common theme, but it was divided by whether students thought it was a positive or a negative effect on the success of the escape room. In either case, students enjoyed the experience, claimed to learn about communication and teamwork, and that it improved their confidence.

Introduction:

The appeal of an escape room for educational contexts is that students are immersed in a problem-solving scenario in which completing puzzles as a team while utilizing skills in communication is a primary focus. Educational escape rooms may be effective because they create an interesting opportunity for increased teambuilding and promote positive social interactions [1], [2] as well as provide a unique method for testing the ability of students to communicate [3], [4]. Escape rooms use the pedagogical viewpoint of the social-constructivist [5], where learning develops as a result of social interaction and collaboration. Participants construct knowledge by interacting with the puzzles, which may, by design, require collaboration with other participants. The design of escape rooms often encourages collaboration and communication because either the puzzles are complex, benefit from multiple perspectives, or perhaps the puzzles require two or more people to physically interact with an object or set of objects.

People have preconceived notions about the effectiveness of teams based on the number of people in those teams. As the number of team members increase, coordination and communication amongst the group is even more important. For an escape room, the average recreational escape room has about 5 players in a team [3]. Educational escape rooms range from 2 to 16 players, with the most common team sizes around 3 to 6 players [6]. A recommended team size is in the range of ~5 players in part because it allows all players to be actively engaged [6]. In addition, larger group sizes have been shown to be less effective in escape rooms because communication or coordination was more difficult [7].

How effective a team performs is not just affected by the number of people in the group, but how they work together. Team cognition represents the process whereby teams combine their ideas as individuals to contribute to a team's goal. Team cognition is not just affected by interindividual factors (e.g., a specific person's skills) but also intraindividual factors [8] like delegation and communication. Team cognition is most effective when the team members interact with each other more and have had an opportunity to get to know each other [8]. Since, in this study, the escape room is positioned about mid-way through the semester, before a group project at the end of the semester, the escape room could be used to increase team cognition. The teams in an escape room could potentially be leveraged to help increase social interaction needed to build team cognition.

Some gamified learning implementations use aspects of game design to improve student's confidence and in turn their academic performance [9]. A potential concern of an overly difficult escape room is a decrease in student's confidence to succeed [10]. Although setting challenging proximal goals is also useful in developing self-efficacy [11]. One goal of this escape room was to provide an additional opportunity for students to practice skills and use equipment before they begin an open-ended project at an appropriate challenge level [12]. Since self-efficacy (i.e., task-specific and situational confidence) can be increased with authentic mastery experiences [11], the escape room provides an opportunity to practice or demonstrate mastery of laboratory skills.

The escape room in this study was placed just before the end-of-semester group project, and 2-3 groups working on the project together were assigned to complete the escape room as a team of 6-8 people. This timing was decided with the hope that the escape room could provide an opportunity for social interaction and team building before the final group project in the course and also serve as a refresher of several laboratory skills gained throughout the semester. The escape room requires several skills that the students have learned earlier in the semester and provides another opportunity to practice or show mastery, which may help to build confidence as well. This study attempts to answer the following research questions:

Research Question 1: In what ways are student's perceptions of teamwork and communication affected after participating in the laboratory escape room?

Research Question 2: Can the experience of the escape room help students feel more confident in the mastery of laboratory skills?

Methods:

Curriculum Context and Implementation of Escape Room:

The escape room activity occurs in the 7th week of a semester-long upper-level BME laboratory course, preceding an open-ended final group project where small groups of a few students design experiments to address a hypothesis of their own. As a part of the laboratory course curriculum, students gain experience in a broad range of technical and laboratory skills such as mechanical testing, micropipetting, ultrasound imaging, aseptic technique, and cell culture skills. The escape room puzzles were designed to incorporate major techniques students learned in the course [12]. Briefly, the activity was designed to be completed in groups of 8 or fewer participants and within 55 minutes. Participants were first introduced at the beginning of the activity with a short narrative delivered by the instructor. In short, a breakthrough in an infectious diseases research facility recently resulted in the discovery of a cure for a [fictitious] strain of COVID. However, a malevolent infiltrator breached the laboratory security, putting our scientists out of commission and sabotaging their results. The students are asked to follow the clues left behind to recover the data that will lead to the cure.

Within each group, students were randomly assigned one of six possible team roles including: (1) project manager, (2) reader, (3) searcher, (4) brain, (5) quartermaster, and (6) worker [13]. In groups with more than 6 students, an additional worker and/or brain assignment was added. Briefly, the project manager acts as the communication hub to provide leadership and direction for the group. The reader is tasked with careful review and interpretation of relevant written clues. The searcher should scout the environment, identifying unsolved puzzles and clues to assist the brain who works to solve the puzzles. The quartermaster needs to maintain organization and keep track of used material. The worker acts as a floater, with a focus on trial-and-error when working through difficult obstacles. Students were handed a role card with the description of the responsibilities for each role and given 5 minutes to plan amongst themselves. Students were then allowed to enter the escape room before the 55-minute timer began counting down (Figure 1). The puzzles were organized into multiple concurrent pathways to provide students with the options for exploration, collaboration, and to prevent potential bottlenecks at more challenging puzzles. Successful completion of each of four pathways will provide students with one of four digits to a bottle labeled as “The Cure”. Successful escape occurs when all four numbers are entered in the right sequence before the timer runs out.

Figure 1: (Left) Two students attempting to solve a fluorescence-related puzzle. The student on the right (wearing a blue badge marked as the “Reader”) is reviewing notes found in the escape room. (Right) Groups of students collaborate to solve puzzles.

Escape Room Assessment:

Instructors were present within the escape room to observe students during the completion of the activity and recorded observations about the number of clues needed, which puzzles were

solved, and timing of completing certain achievements. At the end, an anonymous survey was sent electronically to participants (Appendix 1). The survey questions were adapted from four other studies on educational escape rooms [14]–[17]. Students were asked to self-report their assigned roles and whether they strictly followed their assignments for the escape room. Student responses to survey questions regarding the effectiveness of assigning team roles were tabulated to describe the level of agreement expressed for each statement. Students were asked to report whether their group successfully escaped within the time limit, and their survey responses were grouped accordingly for further analysis.

The survey questionnaire related to the escape room and student group dynamics for this study was approved by the Institutional Review Board of The Ohio State University and determined as exempt (study ID 2022E0178). In addition, record review of responses from a course survey implemented by the department was also determined as exempt (study ID 2023E0052).

Methods for Qual Analysis*:*

Open-ended responses to the question "Was there anything that you would take away from this experience and apply to future projects or group work? If so what?" in the survey was analyzed and validated in two ways. Salient themes were identified by the authors and the frequency of those themes were tabulated to count the number of occurrences specific features were identified from students. Responses were coded into the following 8 themes: Communication, assigned roles, motivation, lab skills/course content, collaboration/teamwork, leadership, enjoyment, and delegation/group organization. In addition, the responses were input into an artificial intelligence natural language processing tool (ChatGPT, OpenAI) to identify themes from responses in an unbiased manner. This method was used to validate themes identified by the authors.

Study Participants:

Informed consent was obtained from all individual participants included in the survey specific to the escape room. A total of n=70 undergraduate students (n=34 in Spring '22 and n=36 in Fall '22) who were enrolled in the upper-level course (mostly juniors) agreed to participate in the survey. All participants were confirmed to be at least 18 years old. While demographic data was not collected as a part of the study, student demographics are expected to be representative of the Biomedical Engineering department since the escape room activity was placed in a required course and all undergraduates were from the BME department. Between 2019 and 2022, 46% of BME students identify as female, and 8% of students identify as Black, African American, Hispanic, American Indian, Native Hawaiian, or Pacific Islander.

Results & Discussion:

A total of 18 groups of students participated in the escape room, of which 6 groups were able to successfully escape. A 30% success rate suggests that the escape room activity provided a challenge for the students at an appropriate difficulty. This is also comparable to commercial escape rooms which have reported a similar success rate of 26% [3].

Effect of experience on communication and collaboration:

Students were asked to reflect and rate the effectiveness of their teamwork and communication. The responses in the survey were divided by students who reported succeeding in the escape room vs not succeeding (Figure 2). Students who successfully escaped were more likely to rate their teamwork and communication as excellent or good vs students that did not escape.

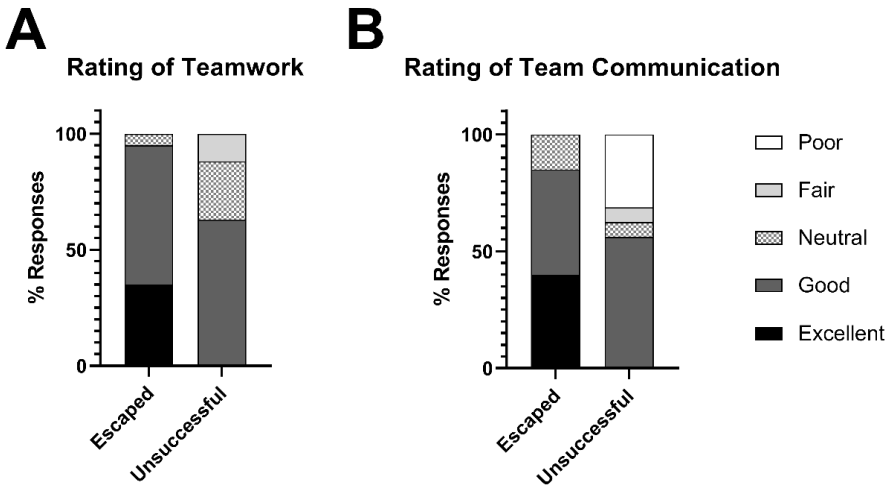

Figure 2:Student responses to the questions "How would you rate the effectiveness of your group's teamwork?" (A), "How would you rate the effectiveness of your group's communication during the escape room?" (B).

It is unclear, whether successful students were more likely to have good teamwork and communication or whether the students that were unsuccessful rated themselves poorly because of the failed attempt in the escape room. Questions about their anticipated teamwork and communication before realizing the result of the escape room could help discern if students are filtering their responses through their recent success or failure.

Effect of team role assignments:

The participants were asked to report the role they picked and respond about their role and how it affected teamwork. The distribution of the reported roles is closely aligned to the expected 1/8 or 12.5% for each role, suggesting that the participants of the survey may provide representative responses for the escape room experience (Figure 3A). 83% of students reported that while they utilized their assigned roles, many chose to be flexible with their responsibilities (Figure 3B). Interestingly, 6% of students reported not following their assigned roles at all. Each of these students also reported an unsuccessful escape attempt. One of these students mentioned in their free response:

> *"I wish that we were allowed to choose our roles instead of randomly choosing them. The members of our team all had different strengths and the ability to choose the role that we thought we would thrive in would allow us to play to our strengths and be more successful".*

Although the roles were randomly handed out, they were not strictly assigned to a student and groups were told that they may use them how they wish. Participants were asked if they liked their assigned role, to which 44% responded positively (Figure 3C). Furthermore, 47% of students agreed/strongly agreed that having assigned roles made their teamwork more effective. Conversely, 14% of students selected Disagree/Strongly disagree to the same question. When dividing respondents up by successful or unsuccessful escape (Figure 3D), students who were successful were more positive about the effect of assigned roles on teamwork.

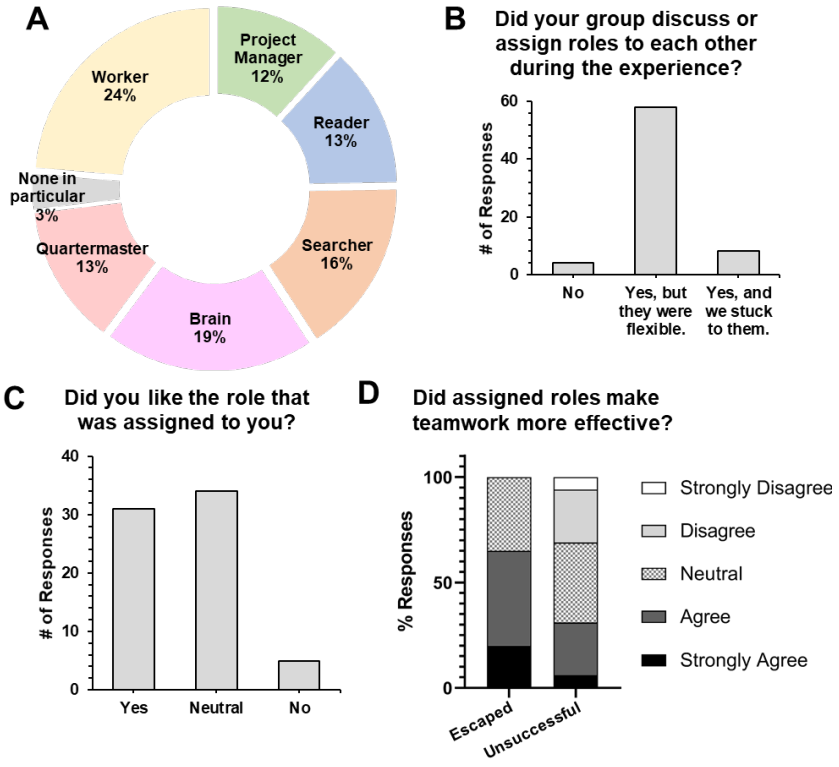

Figure 3: Student-reported assigned roles follow expected distribution (A). Student responses to survey questions detailing their experiences in their assigned team roles (B-D).

Effect of experience on confidence:

Over the two semesters included in this study, students were asked to answer questions as part of a department survey. One question of the survey was "As a result of taking this course are you more or less confident about your ability to succeed in this field?" Of the 59 students that responded to the survey, 57 students agreed that confidence was boosted. A follow-up question for students who answered they were more confident requested "Please give more details about why you feel this way and any thoughts on what could have made you feel more confident." Of the 49 students that responded to that question, 13 mentioned the escape room as one of the things contributing. For instance, one student responded:

> *"I really enjoyed the lab procedures that led up to the escape room. They allowed me to work with parts of the lab that I normally wouldn't and led up to the escape room which was really rewarding to see all of the techniques we worked on at once."*

Another student said

> "*The lab work made me more confident in my ability to use proper lab technique. The escape room at the end of the course really tested whether or not you retained the skills learned previously.*"

When students were asked how strongly they agree with the statement "I felt confident performing the required skills for the activity", the portion of students that successfully escaped all answered Agree or Strongly agree (Figure 4). However, there was more of a mixture of answers from the groups of students that reported they were not successful in the escape room (Figure 4). It is unclear from these data if only students that escaped had these confidence gains, or if students who were not successful in the escape room had their confidence affected. A pre-post survey could help elucidate this effect in future work.

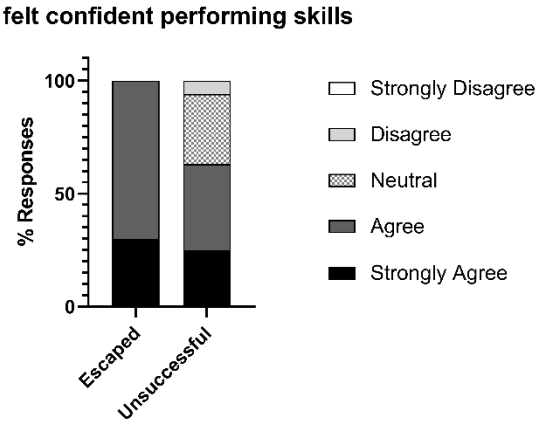

Figure 4: Student responses to the question "I felt confident performing the required skills for the activity" show that a larger portion of students in winning teams agreed with the statement than teams that were unsuccessful.

Student takeaways from this experience:

To help answer the research question of "In what ways are student's perceptions of teamwork and communication affected after participating in the laboratory escape room?", we asked students "Was there anything that you would take away from this experience and apply to future projects or group work? If so what?". There were 26 responses to this question (out of 36 respondents). The 8 themes identified from increasing frequency to lowest are shown in Figure 5. From the 26 responses, students described their takeaways in terms of communication (50%), delegation/group organization (35%), assigned roles (35%), collaboration/teamwork (23%), lab skills/course content (23%), leadership (12%), enjoyment (12%), and motivation (8%).

The key themes from student responses identified by the natural language processing tool were consistent with the themes identified by the analysis done by the authors:

"On theme was the importance of effective communication and delegation of tasks among group members. Respondents noted that improved communication and division of tasks led to more efficient and effective group work. Another theme is the importance of having a confident and communicative leader in the group, respondents noted that lack of communication and direction from the leader caused confusion and inefficiencies within the group. Additionally, several respondents emphasized the importance of having defined roles and responsibilities within the group, which helped to focus the group's efforts and improve organization. Finally, some respondents highlighted the importance of being motivated and having fun as a team, which made the experience more enjoyable and productive."

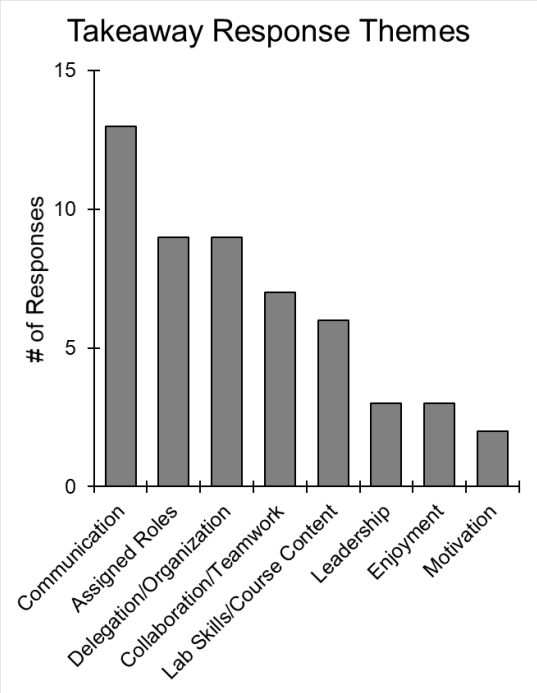

Figure 5: Students responses to the question "Was there anything that you would take away from this experience and apply to future projects or group work? If so what?". The top three takeaways include effective communication, assigned roles, and delegation/organization.

Conclusions:

Many students report increased confidence, but it is unclear if gains are only experienced by "winning" in the escape room by being able to complete the experience in the allotted time. Future work would be needed to investigate this. Whether or not students were successful, many students' main takeaway from the experience was the necessity for effective communication when working within a group. Teamwork and collaboration were another takeaway, but not all students were convinced that assigning roles was the most effective way to improve teamwork. In addition, tracking of communication and teamwork before the escape room in the laboratory activities and after the escape room experience during the final group projects could help identify the escape room activity's role in the students' perceptions and abilities.

One limitation of this work is that it focuses primarily on student's perception of their own teamwork and communication and not necessarily an objective evaluation of their effectiveness beyond whether or not they "escaped". It is possible that the students' evaluation of teamwork and communication is filtered through whether or not their team escaped. Alternatively, it may be accurate, in that teams that truly had better teamwork were the ones that were more likely to escape (Figure 2). Similarly, self-efficacy may be affected by the escape room success or not. Students who were not confident in their skills may be less likely to succeed in the escape room. However, students who failed in the escape room may have had their confidence shaken. For instance, if students were asked to report their confidence levels on certain laboratory techniques just before the escape room, their evaluation would not be filtered through their success or lack thereof.

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Appendix 1: Survey Questions

1) Have you ever participated in an escape room before?
   a) No, never.
   b) Yes, but in a different format (e.g., board game or virtual)
   c) Yes, in a similar in-person format.

2) Did you watch the assigned YouTube video before participating in the escape room?
   a) Yes
   b) No

3) Did your group successfully complete the escape room in the time limit?
   a) Yes
   b) No

4) The time needed to complete the escape room (minutes)

0 5 10 15 20 25 30 35 40 45 50 55 60+

Approximate time (minutes) ()	

5) Which role[s] did you play during the experience?
   a) Project Manager – communication hub
   b) Searcher – looks for puzzles pieces and clues
   c) Quartermaster – keeps track of stuff, items, equipment
   d) Brain/Puzzler – completes puzzles
   e) Reader – carefully reads all materials
   f) Worker – tries stuff out
   g) None in particular
   h) Other

6) Did you group discuss or assign roles to each other during the experience?
   a) No
   b) Yes, but they were flexible
   c) Yes, and we stuck to them

7) Did you like the role that was assigned to you?
   a) Yes
   b) Neutral
   c) No

8) Do you think assigned roles made teamwork more effective?
   a) Strongly agree
   b) Agree
   c) Neutral

d) Disagree
e) Strongly disagree

9) How would you rate:
Poor (1) Fair (2) Neutral (3) Good (4) Excellent (5)
- The effectiveness of your group's teamwork?
- The effectiveness of your group's communication during the escape room?

10) Please rate the level of your agreement with each statement below:
Strongly Disagree (1) Disagree (2) Neutral (3) Agree (4) Strongly Agree (5)
- I wanted to successfully complete the activity
- I enjoyed this activity
- I enjoyed the storyline aspect of the activity
- I needed additional clues from the moderator to complete the activity
- This format was an effective method for testing my knowledge
- I felt confident performing the required skills for the activity

11) Please rate the level of your agreement with each statement below:
Strongly Disagree (1) Disagree (2) Neutral (3) Agree (4) Strongly Agree (5)
- Members of the team were open and supportive of my ideas
- My team members contributed equally to the activity
- My team was committed to completing the activity together
- This activity encouraged communication between team members
- This activity encouraged collaboration between team members
- This activity encouraged the use of leadership skills
- This activity would not be possible to complete in the time limit by myself

12) Please rate the level of your agreement with each statement below:
Strongly Disagree (1) Disagree (2) Neutral (3) Agree (4) Strongly Agree (5)
- This format motivated me to apply and retain course information
- This activity provided an opportunity for me to demonstrate my knowledge
- The escape room experience was directly related to course content
- I had the necessary background knowledge to be successful in this experience.

10) What recommendations do you have to improve the escape room experience?

11) What were the best parts of the escape room experience?