Engaging Students in an Educational Escape Box Design Project

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***Abstract*—This innovative practice full paper describes a student project that occurred during the 2023-24 academic year at Michigan Technological University. Students in the second semester engineering class developed an educational escape box as part of a semester-long design experience. Students began by selecting a target audience for the escape box (middle, high school, or college students), identified the topic or skills they wished to highlight, and researched educational strategies to facilitate effective learning. The escape box projects were used to reinforce the common content of the course (spatial visualization, 3D modeling, programming, and design) and the incorporation of an Arduino Uno to collect data from the environment (e.g., sensors) or students (e.g, buttons) and provide information back to the user (e.g., on/off lighting, visual display, program output) to indicate they have/have not successfully completed the challenge. This paper will focus on the development of this unique design project for first-year engineering students and lessons learned throughout the first two iterations of this in the classroom.**

Keywords—first-year, engineering, escape room, design project

I. Introduction

Instructors are always looking for new and exciting ways to engage students with course content. Since the introduction of escape rooms in 2007 [1], instructors have investigated ways to use this popular concept to engage students with the material in their classroom [2, 3]. Escape rooms have been shown to be a successful method to engage students in team-based, experiential learning [4]. A 2021 study by Moore and Campbell indicated that in a group of university students participating in an educational escape room, 90% of them preferred that experience to traditional strategies such as lecture, reading, or tutorials [5]. Many of the current studies on incorporating escape rooms into the classroom focus on these four areas: scenario, curriculum, 21st-century skills, and motivation [1].

Northeastern University has student teams create a tabletop escape room experience as well as a class project to create a large, traditional escape room for the community with components designed by student groups [6]. Michigan Technological University has several escape rooms used for various purposes. Career Services offers an escape room that is aimed at improving student's teamwork, problem-solving, critical thinking, and communication skills [7]. The Center for Educational Outreach harnessed and adapted the escape room idea in their Unboxed™ Challenges. The program has designed several scenario-based puzzles (e.g, treasure hunt, CIA, natural disaster, museum heist, influencer, operation, galaxy, circular economy) that are designed to help students apply STEM concepts to real-world problems and 21st-century skills [8].

At Michigan Tech, engineering students engage in a two semester engineering course sequence their first year (ENG1101 and ENG1102). In their first semester course (ENG1101), students are introduced to problem solving methods and analysis techniques essential to engineering practice. They demonstrate these skills through the completion of team activities and several 2-3 week long team projects throughout the semester. In the second semester class (ENG1102), the students complete an integrated, semester-long project around a central theme. Previous themes have included: autonomous robots, biofuels, Engineering Without Borders (EWB) team challenge, human-powered designs, microbrewing, New Orleans flooding, product design, prop design, prosthetics, solar towers, supermileage vehicles, and sustainable autonomous growing pods. Each project takes an engineering team through the phases of design thinking: empathy, define, ideate, prototype, and test. Each project includes an empathy investigation, project ideation and proposal pitch, a project management plan, development of a 3D model and mathematical simulation, an investigation of design hazards, a resource budget, iterative prototyping and testing, and final project communication. Additionally, from spring 2023, students were challenged with integrating an Arduino Uno into their final project which would require students to apply their understanding of MATLAB programming as an interface with common circuit components.

II. Escape Box project Overview

In the 2023-2024 academic year, freshman engineering students in ENG1102 embarked on an exciting semester-long design project with the goal of developing an educational escape box as their final product. The major goals for this project were to a) create an interactive, engaging new project for our first-year engineering students, and b) help the students develop their humanistic and technical skills to succeed in their future engineering courses. This semester-long endeavor was rooted in the design thinking model and not only challenged students' creativity, but also allowed them to apply key engineering design concepts. Students explored such concepts as Failure Modes and Effects Analysis, integration of MATLAB and Arduino functionality, physical prototyping, and CAD design assembly. Students had design project

deliverables throughout the semester beginning with an empathy investigation along with a project proposal and a low-resolution prototype. By mid-semester they had the opportunity to develop and test a more mid-resolution physical prototype, eventually developing a 3D model using OnShape, and a final physical prototype they tested with their teammates and high-school students during the last few weeks of the semester.

This project was implemented in both the Fall 2023 and Spring 2024 semesters. Three sections (67 students, 17 teams) participated in this project in Fall 2023 and two sections (41 students, 11 teams) participated in this project in Spring 2024. There were several instructional issues noticed during the Fall semester, which were addressed during the spring semester. First, with such a freeform project, it was important for the course instructor to know what each team's goal was for the project and where additional instruction and supplies might be needed to help them achieve their goals. In Spring 2024, the low-resolution prototype review was done with the instructors to gain this understanding. Each team set up a 30-minute meeting with the instructors to explain their prototype and semester plan. Additionally, the second prototype, which demonstrated the Arduino / MATLAB interface, was moved toward the middle of the semester to encourage teams to complete a draft of their Arduino puzzle elements sooner instead of waiting until the week before the final prototypes were due to get feedback.

Next, the final project deliverable asked the students to reflect on the humanistic and technical skills they developed over the course of the project, which the fall cohort had difficulty articulating in their final reflection. In the spring semester, additional information was provided to the students at the beginning of the semester on what constitutes a humanistic or technical skill and the students were asked to identify specific skills they wished to develop throughout the semester. They reflected on their progress toward their goals as part of their final deliverable in the spring semester. Finally, there was time allowed each week for teams to meet and discuss the progress each team member made toward the project during the week and assign new tasks to improve team communication and accountability. The next few sections will explore the project components and design thinking process elements of the project in more detail.

A. Empathy

To kick off the project, students were given an incomplete definition statement "How might we help (define a group) learn about/learn to (insert skill) by using a 30 minute Arduino-based escape box?". Each teammate completed an empathy investigation for a different aspect of the project's initial research and summarized their work in a memo report. For example, one student might be in charge of researching a specific student population (e.g., middle school, high school), another may research different puzzle types, one team member may research strategies to help teach collaboration, and the final team member may research how to design educational escape boxes. Then each team member would share their findings with their teammates.

One other key element of their empathy investigation was that teams tried completing an example escape box from our Educational Outreach Program at the beginning of the semester. In the Fall 2023 group, the students completed the Natural Disaster project. This project is geared for 9th and 10th grade students and targets manufacturing concepts as students determine how many water filters they need to produce for a community stricken by a severe weather event [8]. In Spring 2024, teams completed the CIA project, which was geared for 10th - 12th graders, and involved finding a leak within the CIA Headquarters [8]. This was an impactful activity as students not only completed an escape box similar to what they would design for their project, they were also able to interview the designer who explained the key considerations they need to think about when designing their own escape box experience: timing, puzzle difficulty, importance of storytelling and designing around a theme, designing for specific age groups, designing for collaboration, and building soft skills as well as utilizing technical skills.

B. Define

After completing their empathy investigation, the students expanded on their problem definition statement by identifying their target audience and the humanistic and technical skills they wanted to focus on developing through their escape box experience. Out of 28 projects, one team chose to focus their project on upper elementary school students (3rd - 5th grade), ten teams chose to focus their support on middle school students (6th - 8th grade), 13 teams focused on high school students (9th - 12th grade) and four team focused on late high school/early college students (12th grade - 1st year). The skill sets chosen for each group are defined in Table I below.

TABLE I. TARGETED SKILL SETS FOR ENGXXXX ESCAPE BOXES BY STUDENT AUDIENCE

Audience	Humanistic and Technical Skills
Elementary School	Spatial visualization skills, pattern recognition
Middle School	Problem solving, teamwork, math skills, cooperative skills, engagement, team coordination, basic circuitry, time management, science, leadership
High School	Problem solving, analytical thinking, cooperation, communication, teamwork, time management, pattern recognition, critical thinking, math skills, science
Early college	Problem solving, pattern recognition, critical thinking, time management, communication, teamwork

C. Ideate

The teams began their initial ideation process by brainstorming themes and puzzle ideas for their project and narrowing these ideas through the use of a decision matrix. Project themes were varied with some similar to those created by Educational Outreach (e.g., bank heist, bomb defusal, hunting for treasure, solving a mystery), whereas some were more focused elements from popular culture (e.g., Oceangate, Survivor, Frozen, Penguins of Madagascar, Barbie / Oppenheimer, Jeopardy). Puzzle idea examples included logic puzzles, math problems, code breaking, creating circuits,

problem solving, analyzing information for clues, and following directions. Next they developed a team memo that summarized their plan for the semester: initial research, project definition statement, evaluation of initial designs, proposed design, and a project management plan. The students returned to the ideation phase several times throughout the semester. They created several prototypes throughout the semester and received feedback on each, which made them revise and rethink their ideas as well as come up with alternative approaches.

D. Prototyping

Students developed several prototypes throughout the semester. They began with a low-resolution prototype developed from inexpensive and readily available materials such as paper and cardboard. Examples can be found in Fig. 1 and 2 respectively.

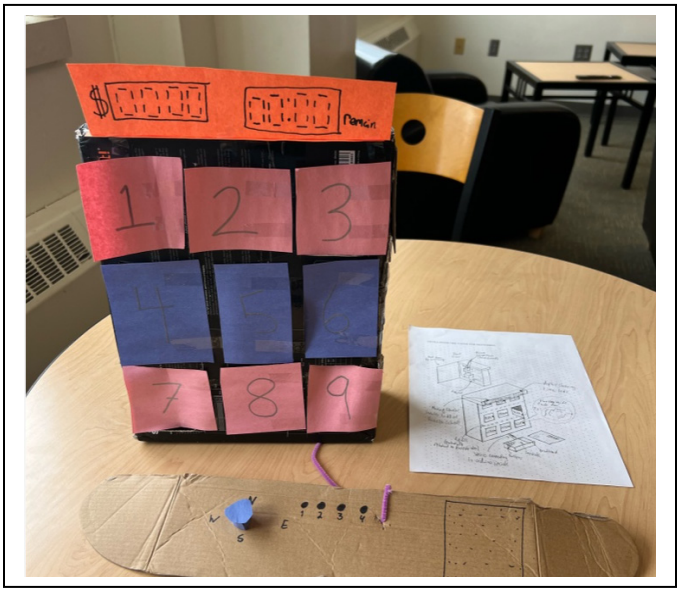

Fig. 1. Game show Low-Resolution Prototype

Fig. 2. Sauna Escape Initial Prototype

Students progressed in their design with a mid-resolution physical prototype that demonstrated their incorporation of MATLAB code and Arduino components. Students also created a 3D prototype in OnShape. The OnShape components were brought together to develop a final assembly of the prototype and a working drawing packet containing all individual drawings, assembly drawings, and a bill of materials. Later in the semester, teams brainstormed possible failure modes associated with their design and evaluated the ethical impacts and hazards in their design based on the methods described in an Failure Mode and Effect Analysis. Potential hazards were addressed for their final prototype. Towards the end of the project design, students developed a spreadsheet that quantifies the materials, energy, and labor necessary for the production of their final prototype.

A final high-resolution prototype of their completed escape box model was brought to class at the end of semester for testing. Examples can be found in Fig 3 and 4 below. Fig 3 shows a Jeopardy type escape box where teams choose a door with a challenge behind it. If they successfully complete the challenge, the team earns the amount of money on the door and can choose a new challenge. The box is designed so that teams must complete at least three challenges to successfully complete the box.

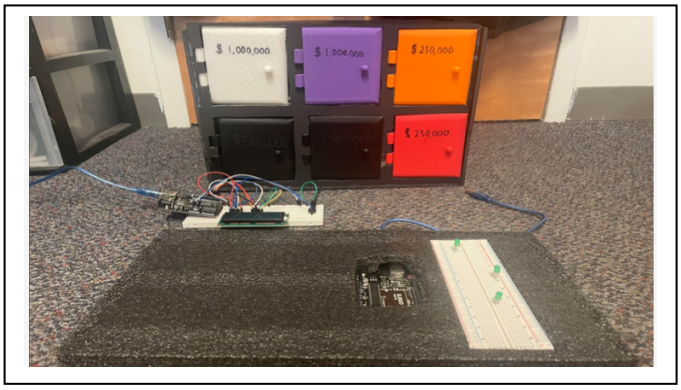

Fig. 3. Game Show Final Prototype

Fig. 4 shows a popular culture escape box built around the movie Frozen. In this scenario, Olaf has locked himself in the Sauna and teams have 30 minutes to successfully complete the challenges to open the sauna and escape. The correct answer for each challenge provides the code to unlock the next challenge.

Fig. 4. Sauna Escape Final Prototype

E. *Testing*

There are multiple opportunities throughout the semester for students to test their design. Once students had completed their low-resolution prototype with the instructors and received feedback on their initial plans, they had an opportunity to share their mid-resolution prototype which included their MATLAB code and Arduino components with other teams and get their feedback. At another point in the semester, when teams had developed the instructions that would be provided to the students completing your escape box, they also received feedback on the clarity and appropriateness of your instructions for their target audience. Students continued to refine their project and at the end of the semester, teams rotated through testing of each other's final prototype. Additionally, representatives from Educational Outreach, first-year faculty instructors, and high school students were invited to join teams as testers for the final prototypes.

III. Project Outcomes

As stated previously, the major goals for this project were to a) create an interactive, engaging new project for our first-year engineering students, and b) help the students develop their humanistic and technical skills to succeed in their future engineering courses. We will be looking at the most current iteration of this project to help answer these questions. At the beginning of the semester, we asked the students to set goals for themselves in terms of humanistic and technical skills they wanted to develop over the course of the semester. At the end of the semester, we asked the students to reflect on the skills they developed throughout the project in their final project deliverable. We also asked a few open ended questions in an end of semester survey on the most valuable and challenging aspects of the project and suggestions for improving the project for the future.

Table II shows the initial student goals set during the first session of the semester. Some students set more than one goal for themselves. There was a wide variety of humanistic skills the students were focused on, with the primary goals being interpersonal communication (e.g., learning how to confidently ask questions or work with their teammates) and technical communication (e.g., overcoming stage fright, being more confident in discussing technical data, writing stronger reports). This course is primarily focused on the semester design project, programming, spatial visualization skills, and 3D modeling, so it makes sense that the technical skills are focused on those areas.

TABLE II. ENG1102 Student Goals (N = 40)

Humanistic Skills	% of Students	Technical Skills	% of Students
Collaboration	7.5	Arduinos	15
Creativity	10.0	3D Modeling	60
Critical Thinking	2.5	3D printing	2.5
Empathy	5.0	Programming	37.5
Interpersonal Communication	22.5		
Leadership	5.0		
Resiliency	2.5		
Technical Communication	45.0		
Time Management	5.0		

Table III shows the final student-reported humanistic and technical skills they developed over the course of the semester. As with the initial goals, some students reported more than one skill they developed during the semester project, but there were some students who did not identify either humanistic skills or technical skill or both. Overall, the student-reported skills developed throughout the semester match very well with their initial goals. More students reported gaining skill in the area of collaboration and interpersonal communication throughout the project experience. There were also more students who reported gains in almost all technical skills.

TABLE III. ENG1102 Student Skills Growth (N = 40)

Humanistic Skills	% of Students	Technical Skills	% of Students
Collaboration	32.5	Arduinos	20.0
Creativity	7.5	3D Modeling	55.0
Empathy	5.0	3D printing	2.5
Interpersonal Communication	35.0	Programming	50.0
Leadership	7.5	Sketching	12.5
Problem Solving	2.5		
Technical Communication	27.5		
Time Management	2.5		

At the end of the semester after the project was complete, students completed a self-reflection assignment where they took time to reflect on the various major aspects of the project as well as their own growth during the semester. This portfolio assignment allowed the students to capture the key details of their projects along with artifacts of the project which they can reference later in their education or when seeking employment.

When asked the question of what is the most valuable thing learned from the escape box project, students found value in the technical skills introduced during the semester such as 3D modeling, engineering drawings, coding, and Arduinos made

the top of the list. Many students mentioned the wealth of humanistic skills that they acquired from being involved in the project. For instance several students stressed the importance of teamwork and not procrastinating. So time management skills were also noted by many of the students. The majority of students noted the value and their personal growth in communicating with others which included applying feedback and talking through the project timeline. Overall, students shared the pride they had in what they accomplished on the physical project as well as their own personal goals for growth.

Students reported several challenges completing the project with the most common related to time management. Many students felt that they did not do a good job of time management throughout the project and felt rushed at the end of the semester. They also mentioned it was difficult finding time to work on things as a group and wished there was more time to work together in class on the project. They also underestimated the time necessary to 3D print portions of their escape box with many teams struggling to put their final parts together in the last few days before the final testing. Other challenges students mentioned were with coding the Arduinos and just being ready to fix unexpected problems as they came up.

IV. Conclusions

This project was a lot of fun from both the student and instructor side. The student enjoyed the freedom of creating a theme and puzzles for a specific target audience and enjoyed seeing people go through the experiences they created. The students were able to clearly identify skills they wanted to gain throughout the semester and reflect on their growth and where there was room for improvement. Many of the most valuable things they learned reflected the growth in their humanistic and technical skills.

Overall this project was challenging from the instructor side due to the amount of freedom and leeway in this open-ended project. It was challenging from the student side primarily in terms of time management. Student suggestions on improving this project primarily focused on this area, with some students asking for additional smaller deliverables earlier to help keep on task, more time to work in class, an additional testing day sooner, or setting up additional meetings with the instructor. Several changes were made from the fall iteration to the spring semester to help address these with moving the physical prototype sooner and adding a physical touchpoint with the instructor on the low-resolution prototype, but it appears the students would like more guidance in this area.

There is a fine line on the instructional side to find the balance between allowing the students the freedom to create, but enough structure to help students stay focused on developing the project throughout the semester. Some easy changes will be implemented in the next iteration such as changing the mid-resolution prototype to a small scale testing instead of demonstration and adding an assignment for 3D printing so students submit the parts they wish to have 3D printed early, so they have time to build their final prototype sooner. Additionally, we will explore partnerships with the local middle and high schools to see if we can bring in some students to test these prototypes with a more targeted audience.

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