ESCAPE Puzzles: Bringing Physics to Fruition Through Classroom-Based Making

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Abstract: Often, in secondary science classrooms, hands-on learning engages students in projects that are 1) conceived of by the teacher and 2) deconstructed at the end of class so that future students can use materials. These factors create a lack of ownership and engagement for students. Maker technologies create opportunities to disrupt the narrative around who can engage in STEM as well as typical classroom teacher-student discourse. In this paper, we examine the experiences of 57 AP physics students engaged in designing and constructing their own physics-based ESCAPE puzzles, inspired by the popular escape room activity games. Findings indicate that these projects had particular meaning to students because of the 1) physical manifestation of their ability to bring an idea of their own creation to fruition and 2) the permanence and usability of the final project, as illustrated when students shared their puzzles with others in the class.

Keywords: making, STEM, computing, ownership, physics

Introduction

Makerspaces have primarily been an out-of-school space and experience for many. Only since the last decade have schools included making and maker spaces as a learning tool for in-school activities. One promising aspect of making in a formal in-classroom setting is its ability to integrate Science, Technology, Engineering, and Math (STEM) in novel and engaging ways (Marshall & Harron, 2018). This integration is evident in high school and middle school science classrooms where teachers engage making to integrate curriculum (Litts, Kafai, Lui, Walker, & Widman, 2017; Tofel-Grehl et al., 2017).

Formalizing *making* for the classroom requires a framework for evaluating and leveraging *making* as an in-classroom instructional strategy (Cohen, Jones, Smith, & Calandra, 2017; Marshall & Harron, 2018). Marshall and Harron (2018) propose elements within their making evaluation framework of ownership/empowerment, maker habits, production of an artifact, collaboration, and use of STEM tools. The idea of ownership recognizes that successful making projects are personally meaningful and original.

Fruition of idea and motivation through design

In this paper, we use the term *fruition* to mean the development and enactment of an idea into physical manifestation, either through artifact or actionable effort. For example, a student could write code for a microprocessor that sends signals to a speaker to produce sound, and to an LED to produce flashes of light. Other examples might include developing a more tangible item, such as a cardboard-cutout replica or a toy made from material.

Two of the primary elements of making include fruition of an idea in the form of a physical product, and the ownership that comes with personalizing or identifying with the creation out of a sense of pride (Marshall & Harron, 2018). These making factors are important because students are afforded hands-on learning opportunities to develop their ideas into something more functional as tangible, visible, or audible formats. The factor of ownership has the ability to help students identify with their work appealing to a wide array of students from different cultural backgrounds (Searle & Kafai, 2015). Furthermore, the motivation of student learning increases as students' sense of ownership increases (Savery, 2006).

Theoretical framework

This work uses the theoretical framework of *student ownership of learning* for physics as conceptualized by Enghag & Niedderer (2008). Through the student ownership of learning lens, students achieve ownership through sense-making in the process of working in groups. Under this framework, a task is usually assigned to groups by the teacher. Students develop how the task will be managed, generate insightful ideas and questions iteratively, and determine how the final product will be presented. Students achieve this motivation through both group work and a physical manifestation of making a product that is shared and presented to peers.

This study investigates the experiences of high school students in an Advanced Placement (AP) physics class involved in a five-day Escape Room Project (ERP). Students teamed up to design and construct puzzles; puzzle design was constrained by the teacher's guidelines that solutions must apply the physics content knowledge taught that year. Each puzzle also needed to engage a microprocessor that students were required to program. Groups of three students designed and constructed their puzzles.

With this as the learning phenomena of study, we ask the following research questions:

1. How does constructing physics puzzles influence students' ownership in their physics learning?
2. How did designing puzzles for others to solve influence students 'experiences of making?

Methods

Data were collected in three sections of AP physics taught by one teacher. Data were analyzed using Saldana's (2015) open approach to qualitative data analysis. Open coding analysis was done in two cycles. The first cycle involved identifying first impression responses to student journal questions while memoing emerging codes. Because there was an interest in how students developed ownership over their learning, the analyzed journal questions all centered around the rewards and challenges of the ERP to determine the motivational factors that lead to student-learning ownership. First impression codes were then developed into codes that revolved around similar concepts. Several of these second-cycle codes include *collaboration*, *fruition of ideas*, *physics connections*, *physical construction*, *creative aspect*, *learning to code new things*, and *Microbit sensors* as rewarding or challenging factors throughout the ERP.

The teacher was in his sixth year of teaching high school physics and his third-year teaching AP physics. Based on his prior years' student scores on the AP exam, Mr. Feynman is considered one of the state's best AP physics teachers.

Students participating in this study enrolled in AP physics and were assigned to Mr. Feynman's classes. Of the approximate 85 students enrolled in AP physics, 57 students assented to participate in the study.

Westside High School serves approximately 2,286 students in a suburban school district in the intermountain West. 32% of students at the school receive free and reduced lunch services.

Data collected as part of this study were routine class assignments and teacher observational notes and reflections. Students' reflective project journals served as the main data source. Photographs of design documents and projects were also provided as part of classroom instruction and were collected.

Model escape room puzzles (ERPs), presented to students at the outset for solving, were revised and expanded from previously developed puzzle projects such as the "circuit forest" and "magnetism vocabulary" (Tofel-Grehl, Ball, Searle, and Cannell, 2019). All projects invoke computational elements such as sequencing, conditional and Boolean logic, and data storage and use, which manifests in the instruction of several foundational programming concepts: sensing, conditionals, operators, embedded loops, and functions.

Findings

While many findings emerged throughout the student design and construction processes, one key overarching value to the work shared by all student groups was the importance of a broad sense of valuing *fruition*. Students worked collaboratively in groups to design and build their puzzles. While several challenges and questions arose from this collaborative process, all student groups felt that moving from an idea to a physical object or a new piece of code was paramount in value. These notions, rooted in the physicality of the object and project completion, were coded broadly as "fruition." Within the fruition code, two themes emerged. The first theme is the satisfaction of completing the project task. The second theme was student pride.

Student satisfaction

Students were proud when they saw ideas "work". They found value in having completed a functional project that served as a manifestation of their physics knowledge. Many students commented on how thrilled they were to see their ideas spring to life through working code that engaged the Microbit to display an output of letters, pictures, numbers, or even make a sound through a connected speaker. When asked which aspects of the entire project, in general, were most rewarding, Alejandro commented " It was most rewarding to see something on paper come to life! We worked hard to form an idea but carrying it out meant so much more!" (Alejandro's Journal, Day 5).

While many students felt that it was challenging to design an idea cooperatively, they also felt that the process was worthwhile when they were able to see the idea come to life. This notion of functionality was not limited to the physical objects created; students articulated equal pride in the designing and developing of working code. Rachel stated, "It was rewarding to see when our code worked, and we could hear the music because we accomplished something a lot of kids couldn't do" (Rachel's Journal, Day 3). Students' satisfaction was greatly manifest in seeing puzzles and code go from nothing to something because of their creativity and collaborative abilities. With regards to bringing the code to life, Carrie said, “watching code work out in real life” was her most rewarding moment across the duration of the project (Carrie’s Journal, Day 3). Others noted how “seeing the LED’s light up” or getting the Microbit to display words like “battleship” and “you win” flash across the LED’ matrix screen when students achieved win conditions as gratifying moments. Even simple gestures displayed, or sounds produced, were rewarding to students. For example, Ty said, “It was awesome to see that our work payed off, even if it was just a check mark on a Microbit” (Ty’s Journal, Day 5).

Students enjoyed seeing an idea transform into something more tangible in the form of lit LEDs or self-generated melodious tunes played. As one student put it, “Having the display work was the most rewarding because it's *physical evidence* that what we did works” (Lexi’s Journal, Day 5). Having a working product materialize was satisfying, as evidenced by a student who felt “it was satisfying to see the finished product” (Santi’s Journal, Day 5). Students cared that they could design and build something that worked. Ownership of the learning and product is made evident in this statement from another student who said, “I found that building something with my hands and being able to see something develop due to my own work and that of my teammates was especially rewarding” (Karmen’s Journal, Day 5). Student reflective journals reflected this sense of ownership over their learning. Figure 1 provides examples of the student-created content-based puzzles.

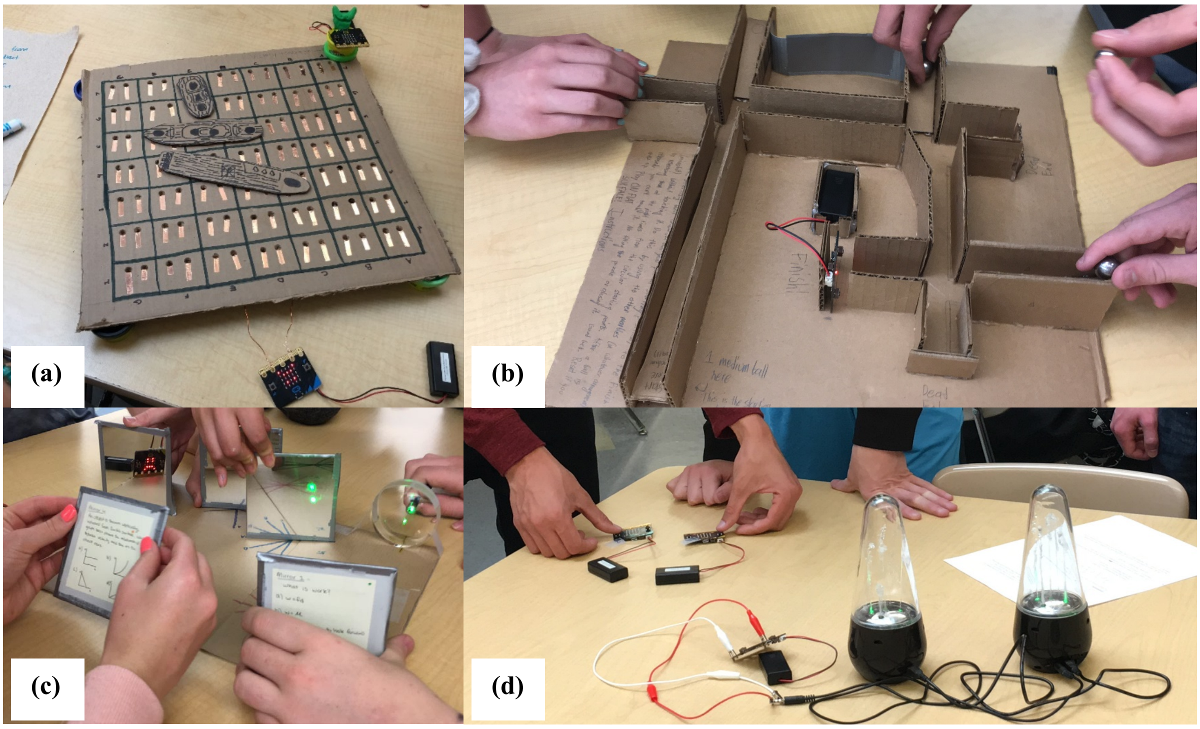

Figure 1. Student-constructed ESCAPE puzzles: (a) copper tape circuit puzzle, (b) accelerated ball and ramp puzzle, (c) optics and light level-detection puzzle, (d) Microbit-generated sound puzzle.

Student pride

Students articulated a sense of fulfillment from both the solving of other folks’ puzzles and watching peers solve their puzzles. The puzzles mattered to the students as they became a reality. Students also shared this sense of pride in their work while watching others solve their puzzles. Paige articulates this pride, stating, “I think the most rewarding aspect of the project was seeing what we were able to finish and to be proud of the puzzle we created” (Paige’s Journal, Day 5). Such pride was not only manifest in a working puzzle but also the aesthetics of the puzzle when Abby said, “the most rewarding part to me was how good our puzzle looked; it looked very professional and clean” (Abby’s Journal, Day 5). This sense of pride in their work product is not typical in physics classrooms. The classroom teacher noted that students do not typically articulate feelings of pride during other projects.

Students’ sense of pride was also manifest as a result of others solving their working puzzle in the form of entertainment for others. Of the 57 participant responses, 20 commented on the satisfaction of watching others solve their team's puzzle as being the most rewarding aspect of the entire escape room project. Sidney declared, "I liked seeing people excited when they solved our puzzle because it made me happy to know that they enjoyed it" (Sidney's Journal, Day 5). As students watched others solve their puzzles and received feedback, they felt as if the challenges that their project team faced were worth it. As Amy explained, "The most rewarding aspects of our project was having people solve it and coming together to make a cohesive puzzle board with my team. When people solved it, they'd get all smiley and happy making the trouble worth it" (Amy's Journal, Day 5).

Discussion

Across science classrooms, while students frequently engage in activities, engagement in activities over which they have decision making power is less common. Finding ways to engage students in more personally driven physics learning may hold the key to better engagement and early interest. Students involved in the Escape Room Puzzles were engaged, interested, and driven to complete meaningful and interesting puzzles for their classmates. Findings indicate that students felt tremendous pride in their ability to design and persist through tasks to a successful product.

The escape room project engages students in personally relevant design through content and standards-driven projects. Students in this project articulated a strong sense of ownership and pride in their work. This pride created keen interest and caring from students. With making, possessing affordances strongly linked to increased interest and engagement in science and mathematics classes (Tofel-Grehl et al., 2017), finding additional ways to engage students in making for physics is warranted. However, with the process of engaging making in the classroom in service to standards-based instruction, comes questions of assessment. Projects such as physics-driven ESCAPE puzzles may hold the answers to such assessment questions. If students have mastery of the concepts needed to design and build ESCAPE puzzles based on content knowledge learned in physics class, it ought to be that students design an escape room to allow teachers to assess student knowledge and ability to apply that knowledge. If escape room puzzle solutions can act as assessments of student learning, more authentic maker education in classrooms can engage maker-based assessments for that learning.

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