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Towards Teaching Digital Electronics Using Escape Rooms

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ABSTRACT

Teaching second year undergraduate digital electronics is a serious business, designed to impart individual technical mastery. In this paper we attempt to embed several key digital logic concepts within an escape room game. We report results of iteratively piloting our game with academic engineering staff and then used them with students showing promise for using escape rooms to support undergraduate engineering education.

Key words: Digital Electronics, Game Based Learning, Student Engagement

INTRODUCTION

Gamification, infusing game mechanics into products and services, was touted by (Pettey and van der Meulen, 2012) as a next-generation method for engagement, given humans seem "hard-wired" to enjoy games (Hamari,Koivisto, and Sarsa, 2014). We see this in a multi-billion dollar gaming industry which encompasses electronic games, board games and gambling games (Kücklich, 2005). A gamification stampede ensued in business and other training areas. However, in 2012, Gartner said that by 2014, 80% of current gamified applications will fail to meet business objectives due to poor design (Pettey and van der Meulen, 2012). Games designed by professional game designers, are, as it turns out, better than games designed from scratch by novice game designers. A better strategy for novices, which we follow, is to adapt an existing game concept; in this paper we adapt escape rooms for use in the engineering classroom.

In escape room games participants play the role of story characters locked in a room. They use whatever is in the room to solve puzzles, finding keys to escape (Wiemker, Elumir, and Clare, 2015). The concept has seen strong commercial success, with many escape room venues opening around the world. Nicholson's survey suggests that escape rooms appeal to males and females equally with common participant groups comprising of corporate, families and dating couples (Nicholson, 2015).

While traditional escape rooms temporarily lock up the participants within custom-designed rooms, other versions (online games and board games [e.g. EXIT, Escape Room the game]) do not require such rooms and instead give a more compact and cost effective table-top experience. Hence, there is no requirement for educational variants to provide actual rooms to stay true to the escape room genre. Our table-top adaptation helps create a scalable experience which better suits an educational context (rather than creating lots of small rooms and trying to supervise or schedule them all).

The escape room concept of finding keys is suitable for adaptation to digital electronics as electronic devices can represent numbers and operations thereon. The key is produced simply by correctly applying domain knowledge. Successful escape gives immediate formative feedback. In addition, the escape room concept of finding keys collaboratively is also worth mentioning. Engineers after all need to verbally communicate their discipline specific knowledge which is core to most accreditation requirements. Keys can be created that require a certain amount of activity too great for a lone super player to perform in a certain amount of time. The work must at least be divided and aggregated at speed to compete.

Ideally, all players will be immersed in that game-player state of mind known as flow somewhere between frustration and boredom (Weber, Huskey, and Craighead, 2016). Gamification in educational products and services is not new. In the online space, Khan Academy gamifies mathematics education, and Codecademy gamifies computer programming education. In traditional education, one pilot school called Quest to Learn delivers the entire 6-12 curriculum through a gaming approach (Tekinbas, Torres, Wolozin, Rufo-Tepper, and Shapiro, 2010). Nonetheless, education gamification is currently some way from becoming ubiquitous. There is, however, a considerable amount of interest in developing novel interactive methods for improving the teaching of digital logic design, including practical examples (Hoffbeck, 2014) and even a Lego-style game (Kharma, Caro, and Venkatesh, 2002).

This paper is structured into four sections. In Section 2, we discuss the requirements for designing an escape room game. In Section 3 we present the digital electronics puzzles that we created and refined. We present feedback on our pilot escape room from engineering faculty and students at La Trobe University in Section 4. Finally, in Section 5 we reflect on the extent to which our requirements were met and discuss future work.

Table 1. Analysis of Product Quality.

Characteristic	Sub-Characteristic	Requirements
Functional Stability	Functional Completeness	Improve student performance and engagement
	Functional Appropriateness	The educational content does not detract from the escape room
Performance Efficiency	Time-Behaviour	Teams can escape within an hour
	Capacity	Can be run with large cohorts
Compatibility	Interoperability	Supports other learning materials and can be utilized in a traditional tutorial
Usability	Learnability	Game play must be easily understandable
Reliability	Fault Tolerance	No-one gets stuck indefinitely
	Maturity	Design process goes through several iterations
	Confidentiality	The escape room must be a safe place for students to fail
Maintainability	Reusability	The escape room must be trivial to redesign for subsequent use
	Testability	At least one team member must have domain knowledge

Requirements

After the initial puzzles and narrative were created (version 1) and play-tested, a two-part system quality framework (ISO/IEC 25010:2011) (ISO/IEC, 2011) was applied to guide development and refinement. The product quality model has eight characteristics of static and dynamic system properties (Table 1). The quality in use model has five characteristics related to interactions with the system (Table 2). Some of the characteristics were less relevant or had significant overlap for this domain and hence have been omitted.

Table 2. Analysis of Quality in Use.

Characteristics	Sub-Characteristics	Requirement
Effectiveness		Reinforces key digital electronics concepts
Effectiveness		Improves student performance and engagement
Satisfaction	Usefulness	Students benefit from participating in the escape room
	Trust	Developed by faculty
	Pleasure	The escape room increases positive interactions
	Comfort	Players are comfortable in the escape room
Freedom from risk	Economic Risk Mitigation	Comparable cost to running a tutorial.
	Health and Safety Risk Mitigation	The escape room has no adverse impacts on students
Context coverage	Context Completeness	Trialing on different student cohorts
	Flexibility	Could be adapted to other engineering subjects

Note that our functional correctness requirement, that is, offering this escape room to people best suited to gain from the educational experience, assumes that escape rooms might work better for some learners than for others. Different learners have different preferences related to how they are presented with, digest and learn information. In particular some learners significantly dislike team-based activities, which typically often stem from unequal contributions from group members with assessment which doesn't encourage individual accountability (Tucker and Abbasi, 2016). Given the short duration of this activity we expect the negative (e.g. social loafing) aspects of teamwork will be minimized.

Note that our requirement to reinforce key digital electronics concepts (unrealistically) assumes that all players will already have some degree of competency with using these concepts. The game should work provided each team has at least one competent player (both in terms of technical and communication ability). Also, we believe that it is more valuable to experiment with escape rooms in engineering education by infusing them with engineering concepts that we know from experience that students find hard. If the escape room shows promise with any hard concepts, we might be able to mount an argument for selective implementation elsewhere within our engineering program.

CREATING AND REFINING PUZZLES

According to (Wiemker et al., 2015), an escape room uses a simple game loop:

1. A challenge to overcome (e.g. Finding a key)
2. A solution (may be concealed) (e.g. Opening a lock)
3. A reward for overcoming the challenge (e.g. Progress)

Rather than trying to design a series of physical rooms, which is not very cost effective or scalable, our escape-room approach takes the table-top board game model. Each group of participants sit on a separate table and have 3 sealed envelopes, a story narrative and the decoder box. At the start of the activity the participants read the introductory narrative, we turn (and remove) the key on the decoder box and participants open the first envelope. The puzzles in the first envelope (coding) we randomly chopped up to give an extra challenge to participants.

We iteratively designed three versions of an escape room targeted towards digital electronics education.

Version 1 of the escape room had three linear puzzles.

Puzzle 1.1:

1. Number and bit-bashing operation (e.g. XOR) printed on opposite sides of paper (supposed to foster teamwork when they held up the paper and realized it was double sided)

2. Resulting number converted from Octal to Char using ASCII table
3. Combining Chars gave a word which spelt four numerical keys eg. ONE, FIVE

Puzzle 1.2:

1. A series of digital oscilloscope waveforms, each wave form corresponded to a hexadecimal number.
2. Resulting combined number related to its corresponding letter place in the alphabet (A=1, B=2).
3. Combining Chars gave a word which spelt four numerical keys e.g. ONE, FIVE

Puzzle 1.3:

1. Number and negation option (0 or 1) on opposite sides of the page (like P1.1)
2. These numbers corresponded to digital logic settings of pins on a microcontroller connected to an LED display
3. The display spelt out “NOTHEAVEN” for which the four numerical keys for the answers were supposed to be 7734, which upside down on a calculator spells HELL.

Coincidentally, Version 1 was deemed “devilishly hard” by an anonymous reviewer (a faculty staff member), who failed to complete a single puzzle within a two hour timeslot. The feedback was that the logical leaps required were too hard, the puzzles were abstracted from the real word and were too cryptic.

Version 2 was more straightforward with the following changes that were made to each puzzle:

1. We put the original number together with the operation on the same page and added the clue about an octopus to indicate that we were using the ASCII table outside typical hexadecimal usage
2. Each waveform corresponded to a reversed hexadecimal number and the resulting number was converted directly from Decimal to Char using the ASCII table.
3. We eliminated the requirement to calculate a code, instead we selected combinations of pins which would drive the display to show a number directly (7734).

Version 2 was reviewed by two faculty staff members, who were able to complete all puzzles. However, they had several recommendations which we incorporated into Version 3 as follows:

1. We migrated the numbers and operation directly into embedded C, and further increased the number of operations.
2. We added a clue which showed how to decode an example waveform.
3. We directly referred to pins on the microcontroller in hexadecimal and added the (realistic) concept that pins needed to be off for each LED to be on. We added a clue that “Two sevens will get you out of here”, alluding back to 7734.

As part of Version 1, a simple science-fiction narrative was created as a back-story to explain that players needed to find codes to release them from a holding cell. This narrative was used in all subsequent versions as no changes were suggested.

We now give partial examples for each of our version 3 puzzles which were used with the whole faculty and with students:

Puzzle 1 Partial Question:

```
unsigned char number_1 = 168;
number_1>>=1;
```

Puzzle 1 Solution:

168>>1 = 84
84 (decimal) in an ASCII table is ‘T’. The other parts
of the question result in ‘WO’, spelling TWO.

Puzzle 2 Partial Question (Figure 1):

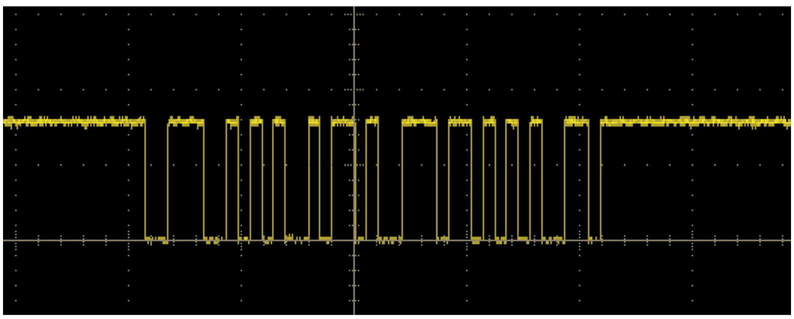

Figure 1. Waveform for Puzzle 2.

Puzzle 2 Solution:

The waveform in Figure 1 is decoded as 0x4E 0x49 0x4E 0x45 which translate to NINE when using an ASCII table.

Puzzle 3 Partial Question (Figure 2) where students are given multiple digits in the form P1OUT = 0x?? (e.g. P1OUT = 0xD3):

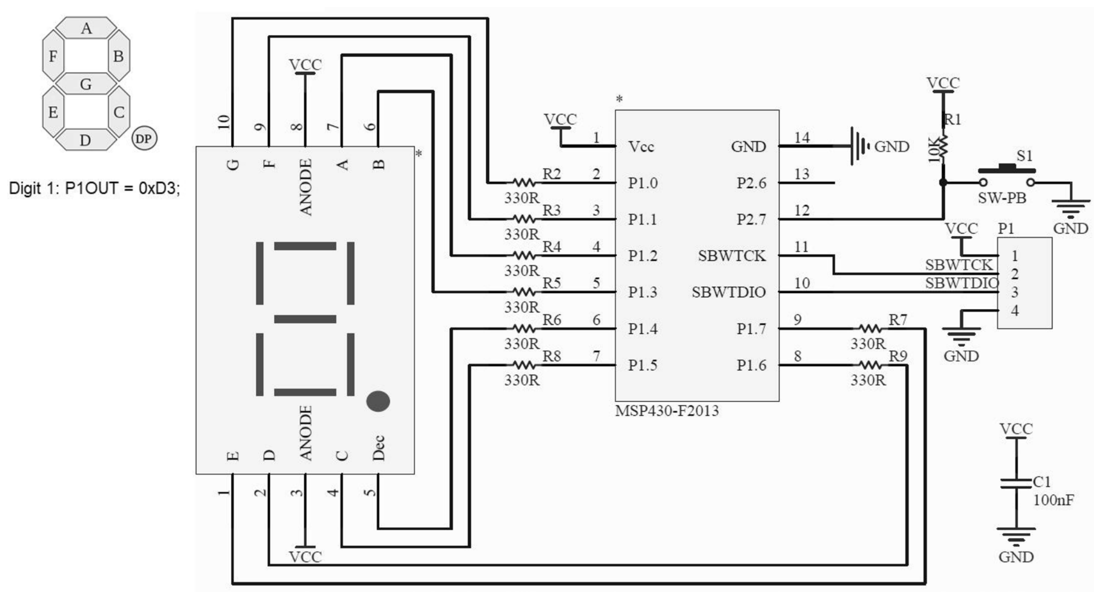

Figure 2. Schematic for Puzzle 3.

Puzzle 3 Solution:

0xD3 corresponds to 11010011b which students work out (using the schematic) turns lights up segments A,

B and C of the 7-Segment display (displaying a 7).

Clearly, some domain knowledge is required to solve these and so without prior background in programming and electronics fields participants would struggle.

Having iteratively refined our puzzles with faculty we then piloted our escape room firstly with the engineering faculty and then with students.

We ran the activity as follows:

- Each team consisted of 3–5 team members
- Each team worked around a single table
- Teams were allowed to use the internet and were given paper and pens
- Each team had their own decoder box to validate their answers (described further in (Ross, 2019))
- Each round of clues was stored in a separate sealed envelope
- Participants were timed for their progress through each round of the activity
- Participants would type in their numerical answer into the decoder box

RESULTS AND EVALUATION

This section evaluates our activity, first with engineering faculty staff (using the version 2 puzzles) and then with students (using the version 3 puzzles).

Faculty Results

Our escape room was piloted with a group of seventeen faculty staff members from the School of Engineering and Mathematical Sciences at La Trobe University, from disciplines including electronic, mechanical and civil engineering. Each table was organized to include at least one electronic engineer.

We had explained that this was an experiment and that while we had one hour scheduled for the game, we did not know if all questions could be completed in time, so we would be timing teams on each question. When a team believed that they had figured out a key they could test it (by entering it in the decoder box). They would only be informed if their answer was right or wrong, not if their answer was partially correct.

Each key was 4 digits (participants were informed of this), so the probability of a team guessing an answer was 104 or 1 in 10000. We evaluated the participants views on the activity through a short survey at the end of the activity and a focus group conducted 10 days after the activity.

We timed each of our teams, who were labelled A, B, C, D. Table 3 shows the times for each team (in minutes) as well as the average time per question. Team D was the clear time-based winner, completing all questions in 37 minutes, although we consider all participants who have learnt something 'winners'.

Table 3. Timing teams in our escape room (minutes).

Puzzle	Team A	Team B	Team C	Team D	Average
1	20	24	24	10	19
2	28	17	21	19	21
3	8	7	6	8	7
Totals	56	48	51	37	48

Team A was unable to complete the second question (after 28 minutes they were given the answer so they could progress). The fastest possible path through all the questions (blue) was a total of 33 minutes. The slowest possible path (orange) was exactly 1 hour.

Some of the approaches to solving keys were unanticipated. Several teams narrowed the search space by working out 3 out of 4 keys then making (up-to) 10 guesses 0-9 to solve the final digit.

Based on this behaviour and feedback from academics we introduced a penalty based system for students where wrong guesses would incur a one minute time penalty. Hence, students were far more conservative with their guesses.

There were notable differences between running this escape room with staff and running this with students. Most staff members had PhDs, and many years' experience. They were motivated, communicative, and cooperative, and were not undertaking this as part of a course.

Given our requirements of reinforcing key digital electronics concepts and improving performance, our questions for staff were split into two parts: asking about prior experience and asking about any improvements in understanding. We had sixteen respondents to the survey. In terms of prior experience, staff were largely unfamiliar with the concept of escape rooms (75% had not done one). In contrast 81% of staff had some prior experience with digital electronics (although for some of these it was decades ago during their undergraduate studies or secondary schooling).

Prior experience with digital electronics design corresponds (as expected) with staff familiarity with specific areas of content expertise (ASCII tables, waveforms, and 7-Segment LED displays) shown in Figure 3.

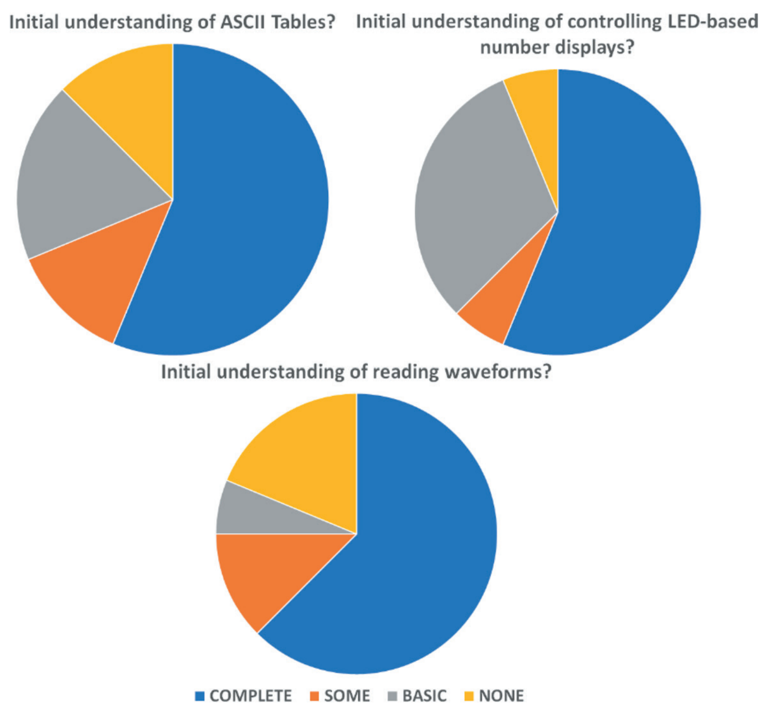

Figure 3. Prior Experience (Content Specific).

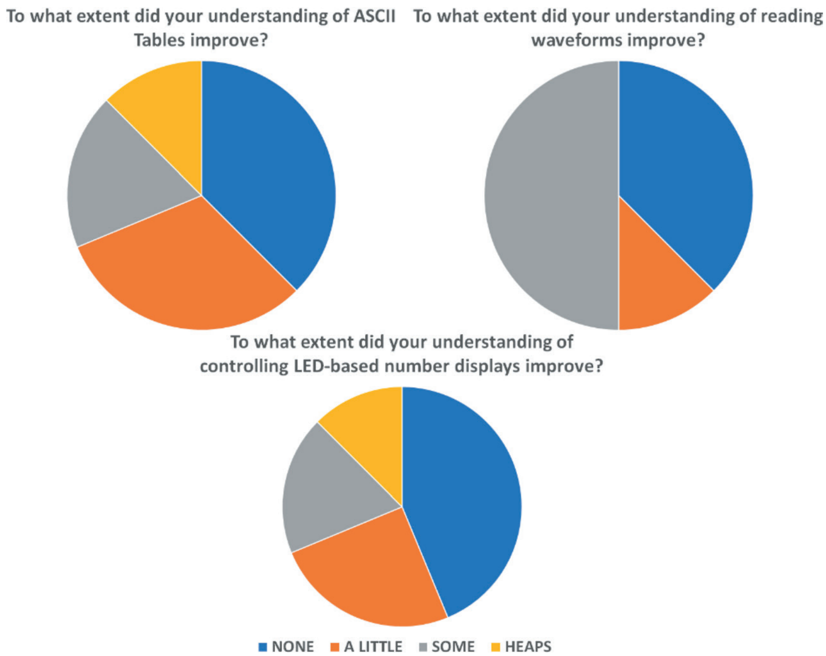

Figure 4. Improved Understanding (Content Specific).

We also surveyed improved understanding in each of these three areas of content expertise as shown in Figure 4 and are self-reported.

The blue sectors are a similar size between prior knowledge and improved understanding, which should be expected since staff claiming to have complete knowledge would not improve understanding of content whatsoever. In fact, four staff members (25%) claimed to have complete initial understanding across all three areas and their understanding did not improve as part of the escape room. Across the board, at least 50% of those participating in the escape room improved their understanding of content, even if only a little.

These results showed that the escape room did not work for all staff members–particularly those well outside the discipline area. In the worst case, one participant started with no digital electronics design experience yet had some basic knowledge of ASCII Tables and LED displays, but they claimed their understanding did not improve whatsoever. Given the anonymous nature of the survey we were unable to explore the source of this failure, but this result does align with our expectation that this format will not work for everybody.

We wanted to get more feedback from educators on their experience and how they might use something similar in the classroom. Hence, following our escape room, we invited staff to participate in a focus group to discuss the escape room. We had eight staff members attend this group

10 days later. We initially split the group in two: those who had learnt something from the escape room game, who had no prior expertise (Group A, 3 participants); and those subject matter experts who had learnt nothing from the game (Group B, 5 participants).

We wanted to test Group A to see what they had retained anything from their escape room experience in terms of domain knowledge. Consequently, we asked them the three partial questions described in the design section of this paper. Their answers were as follows:

Puzzle 1 (ASCII question):

Two people remembered the operation and converting the code through the ASCII table to a letter.

Puzzle 2 (Waveform question):

All respondents remembered the waveform relationship with binary, that the numbers were reversed and translated through the ASCII table.

Puzzle 3 (Waveform question):

Nobody remembered how to solve puzzle 3.

The result was interesting, even from our tiny sample size. In terms of timing, Puzzle 3 had taken under 10 minutes to complete, while Puzzle 1 and 2 took on average 20 minutes to complete. Perhaps Puzzle 3 was less memorable because it followed the other puzzles (and participants couldn't take much more in) or maybe it was so easy to solve that it was less memorable than the other puzzles.

Meanwhile, we asked Group B to put on their designer hats and tell us how to improve the puzzles. They focused on Puzzle 1, suggesting that keys could be even more clearly written, and their preference was for decimal over octal conversion as it aligns with how the numbers are encoded. They deemed the selection of octal to be random, which was a reasonable charge. Given the fact that it had taken them 20 minutes to solve Puzzle 1, largely due to this hurdle, we felt that it was worth making this change in a future version (which we used with the students).

Following the initial running of the escape room, one staff member from Team D had stated "If you think the students will solve this you're dreaming". Interestingly all of our student groups escaped (albeit with automated clues delivered at 5 minute intervals that academics didn't receive). We suggest this highlights the role of recent familiarity with the subject content and the helpfulness in receiving the clues. We were interested in exploring this statement by drilling deeper with our focus group. We discussed the following 14 questions:

1. What if teams simply give up?
2. What if specific individuals are dominating?

3. What if specific individuals are not participating?
4. What if specific individuals want to participate but are too shy?
5. What if teams are dysfunctional?
6. What adverse effects could an escape room have on students?
7. How might this escape room fit in with other classes?
8. Any other drawbacks of escape rooms in an educational context?
9. How to ensure that work is distributed among team members?
10. What size team do you think would be too small?
11. What size team do you think would be too large?
12. How many teams might this format work for?
13. What sort of a person do you think this might not work for?
14. What year levels do you think this might be best suited?

Many suggestions touched on a number of these questions: randomly allocating people to teams (2,3,5,9); changing teams per puzzle with some sort of consensus individual score (1,2,3,6,9); and building in an after action review of team performance following each puzzle (2,3,4,5,8). In terms of fit (7), respondents thought this escape room concept could be broadly used in any engineering or discipline – leaving significant room for further investigation.

One suggestion was having an individual version that could be used either for summative assessment (1,9,13) or used by students who could not, for whatever reason, play as part of a team (4,5,13). This suggestion eliminates the collaborative component and converts the game into a test with a narrative.

In terms of size (10,11,12), respondents thought 3-5 people per team was appropriate, and could work concurrently for between 4-10 teams per demonstrator. Most people thought 2nd year students would be a good target audience for this format.

Ideas about possible adverse effects on students (6) included lowering student confidence in their abilities and lowering their self-esteem. However, given that this escape room would be run over a one-hour period, within an intense schedule of studies, we would hope that any long-term effects would be minimal (and may be a gentle wake-up call). One other suggestion was to stream groups to allow them to choose more challenging problems and fewer clues (1,9,13). However, this did not meet our requirement of improving performance on difficult material.

One aspect that has undergone significant change as a result of participant feedback is the decoder box. The first pilot decoder (Figure 5(a)) only had feedback in the form of 4 LED's (which indicate the current puzzle stage - 1, 2, 3 or complete) and some sound effects. Based on participant feedback the decoder was significant improved in functionality to a second generation decoder which included an LCD screen allowing for automated timing and clue delivery (Figure 5(b)). Finally, a third generation decoder was created which includes a waterproof case, rechargeable lithium ion

(a) 1st Generation (b) 2nd Generation (c) 3rd Generation

Figure 5. Escape Room Decoder Hardware starting with simple LED's to indicate which rounds through to an LCD screen with rechargeable batteries.

battery and data analytics (Figure 5(c)). The keypad and key-switch remains which allows entry of numerical codes and prevents participants from resetting their timers. The decoder device contains all the keys for all three rounds of puzzles and so only one decoder per group is required.

We now consider requirements for which further work is required as summarized in Table 4 (with reference to Table 1). With respect to our quality-in-use model, we found that the escape

Table 4. Product Quality Assessment and Plan.

Requirements	Self-Assessment	Further Work
Improve student performance and engagement	Staff found activity engaging and retained some knowledge	Should be tested with larger student cohorts across different disciplines
The educational content does not detract from the escape room	The content did not appear to detract from the experience	We need tools to evaluate whether students experienced flow during the game
Teams can escape within an Hour	The longest path was 1 hour	Need to study effect of team dynamics on performance
Can be run with large cohorts	Capacity similar to standard tutorials	Investigate supervisor to participant ratio for larger groups
Supports other learning materials and can be used in a traditional tutorial	Open-book activity encourages material to be used in tutorial environment	Investigate material content used
Gameplay must be easily understandable	Only one puzzle was failed by one team	Investigate what conceptual ideas are most challenging
No-one gets stuck indefinitely	Supervisor can give clues	Decoder boxes 2 and 3 gives clues (1 digit every 5 minutes)
Design process goes through several iterations	Participant feedback is essential in improving puzzles	Qualifying common de-sign flaws
The escape room must be a safe place for students to fail	Failures were not communicated outside teams	We will closely monitor for any adverse impacts
The escape room must be trivial to redesign for subsequent use	Decoder reprogramming is trivial, puzzle design is non-trivial	Research into the process and challenges for faculty and students in puzzle design
At least one team member must have domain knowledge	Experienced team member would carry and educate their team	Student knowledge and communication within teams should be investigated

room did reinforce key digital electronics concepts even for some subject matter experts – some commented that it brought back some knowledge and skills that they were out of practice on, but really enjoyed revising.

Student Results

Subsequently, after refinement the digital electronics escape room scenarios were used on four cohorts of students (44 students over a total of 14 teams total) studying an intermediate digital electronics and microcontrollers subject. Although the escape room activities are 'open-book' the students were advised the week prior to the escape room on the general nature of what the questions would entail.

Only the second and third generation decoders were used with students and although they liked the improved aesthetics of the third encoder they had no significant suggestions for further improvements. The second and third generation decoders provide clues (every 5 minutes a new number of the code is uncovered) to stop teams getting stuck indefinitely. The activity for students was run as an open book activity where students could use lecture notes or the internet for reference.

Student feedback from post-activity focus groups was overwhelmingly positive with some expected and surprising responses:

1. Some students were strongly in favour of choosing their own teams
2. 95% were in favour of allocating some small marks (5%) for the activity based on time remaining when escaped
3. Tutorial attendance improved by 25% when the escape room was run
4. Several students described the activity as 'hard' or 'intense' but 'in a good way'
5. Several students noted it uncovered things they thought they knew but didn't
6. Some students noted they were pleasantly surprised on their ability to apply knowledge they had only just recently learnt.
7. Some students wanted the puzzles to be less obfuscated and straightforward whereas some students wanted them to be more so.

Each of the rounds of puzzles had several puzzles that needed to be solved using similar reasoning – resulting in a numerical key for each puzzle. One thing that initially tripped up over half the teams was the order that the numbers needed to be entered. For each of these puzzles we printed a numerical order on the back side of the paper.

Some students were seeking further puzzling and interaction with the environment like hiding clues in the room (under the table). We plan to experiment with this further (possibly having a cipher at some point which when decoded instructs participants to look underneath the table). Though this won't directly impact the educational content we expect it may have some small effect on the game flow and enjoyment.

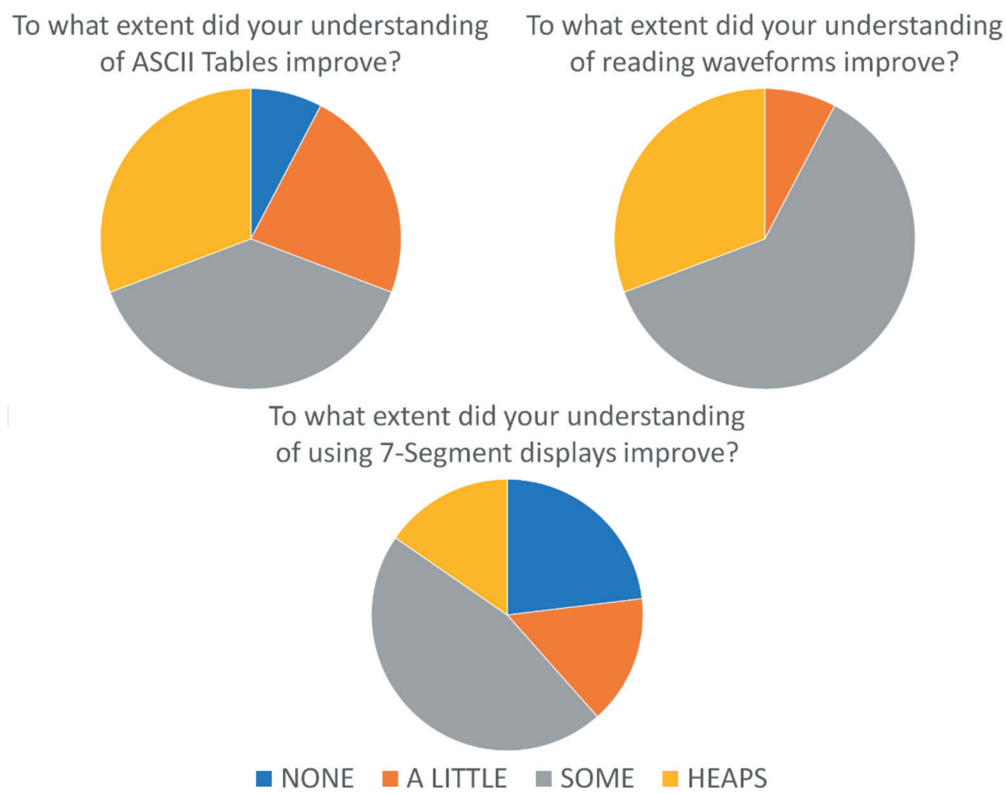

Figure 6. Results from evaluation how student ranked the escape room improved their understanding.

All of the students seemed to engage well with the escape room activities. Some of the self-selected teams were comprised of students who were academically lower performing and, although these teams enjoyed the activity, they gave some valuable feedback on how much it challenged what they thought they knew (but didn't). These teams did take longer to complete the escape rooms, required additional assistance in the form of clues and struggled more in general.

The students were surveyed in relation on how much they felt their knowledge improved as a result of each of the escape room activities (Figure 6) and how difficult they perceived each escape room activity was (Figure 7). Clearly students found the second (waveform) puzzle the most difficult and the area they improved the most. Students commented that in particular paying attention to the endianness of the data and ensuring they correctly identified start and stop bits was reinforced for them.

Students were surveyed in how much they "wanted to complete the escape room puzzle" (Figure 8). Even with some quite difficult puzzles and several groups failing to 'escape' the student

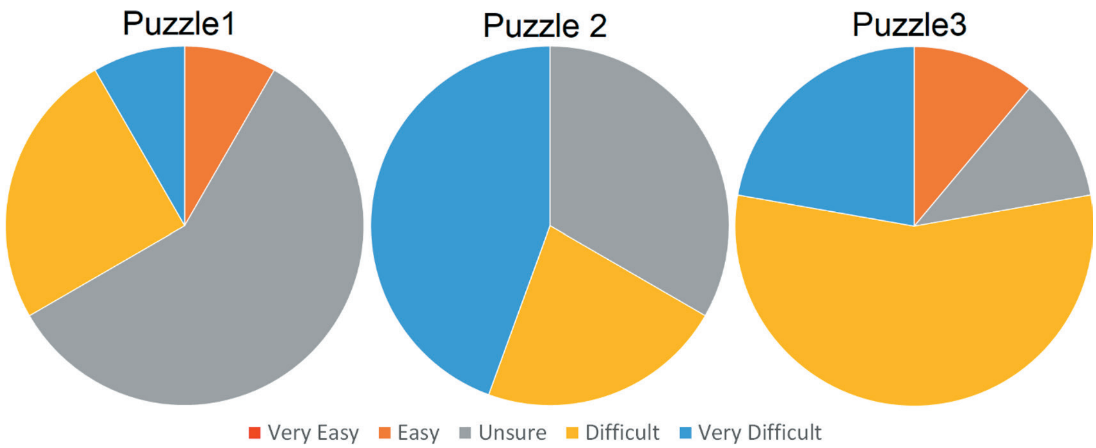

Figure 7. Results from evaluation for each puzzle based on perceived difficulty.

motivation for completing the activity was very high (significantly higher than we would expect from a traditional tutorial).

Theoretically if different groups of students were completing the activity at different times (e.g. different campuses or over different years) they could share the solution keys with other groups. We

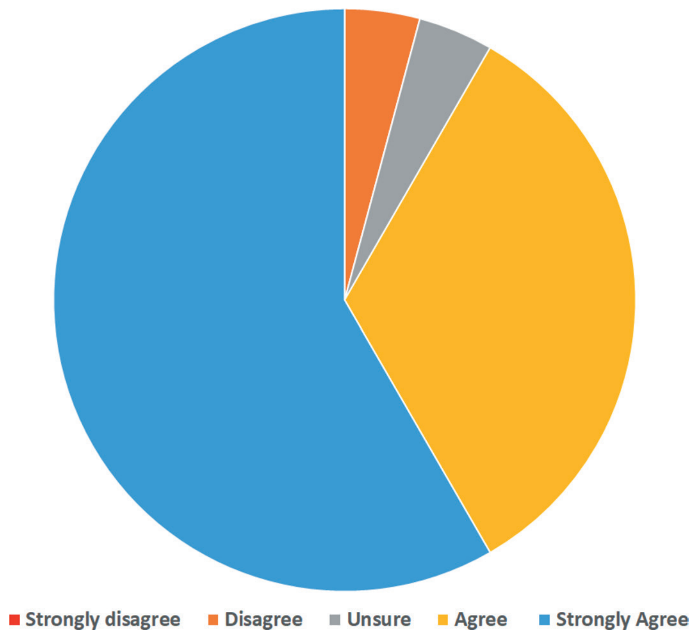

Figure 8. Student survey: I wanted to complete the escape room activity.

have not detected this yet as the competitive nature of the activity tends to deter it and no marks were allocated to it. If this became a problem the solution order of the keys could be easily swapped to ensure that each group of students needs to solve the puzzles. Given the positive feedback from both faculty and students we have piloted escape room activities throughout other areas within engineering (e.g. circuit design and programming) and outside of engineering in mathematics, biochemistry (Ross and Bell, 2019), (Ross and Bennett, 2020). The main considerations in terms of designing puzzles are to ensure that they are cryptic (but not too cryptic), only have one correct answer and can be somehow represented as a numerical value. We are currently designing a series of puzzles related to safety, Hofstede's cultural dimensions, gearing ratios, hamming codes, python, hydraulics and Phase Shift Keying (PSK).

Our puzzle design process has been refined as follows. Firstly, we select some topics we wish to educate students in. We then conduct a brainstorming exercise about how these topics could be incorporated as discrete puzzles, an overarching narrative which might connect them and how they could be numerically encoded. We then create our puzzles and play-test these puzzles with willing participants. After incorporating participant feedback, we then try them out in the classroom. Based on our experience the brainstorming, design and implementation phase takes approximately 1 full day per set of puzzles, although this time is often broken up over several days to allow the creative ideas to permeate.

Although we did not collect student or faculty data related to gender, we believe our participants to be approximately representative of gender demographics of students and faculty. We saw no evidence that would suggested differences in experiences based on gender for either students or faculty. We see significant scope for further research in analysing the performance of educational escape rooms of different demographics (e.g. gender, GPA, first year vs final year).

CONCLUSION

The idea of applying gamification to undergraduate electronics education has been discussed and an example of modifying the design of an existing game concept of an escape room presented. To provide further insights into our game concept, we plan to test our escape room in second year electronic engineering. We are interested in determining whether either student performance or student engagement improves through playing the escape room. We recognize that escape rooms may not be a magic bullet for students and they may work better for some students than others. We are interested in determining the characteristics of students for which escape rooms might provide the most value.

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