This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.3025003, IEEE Transactions on Games

Increasing Engagement with Engineering Escape Rooms

Robert Ross*, Artemisia (Soula) Bennett†
*Department of Engineering, La Trobe University, Bundoora Victoria, 3086. *R.Ross@Latrobe.edu.au*
†Quantum Victoria. *soula.bennett@quantumvictoria.vic.edu.au*

***Abstract*—Although games are intrinsically engaging, standard educational practices are not necessarily. So gamification and game based learning within education is a topic of interest. In this paper, we use the popular escape room concept within an engineering education environment using a physical hardware decoder box. We outline a collection of four sets of puzzles, which we have used to increase engagement, with four different sets of participants within the engineering department: faculty, international students, high school students and undergraduate students. Our results indicate that the escape room learning paradigm is well received by participants. They report high levels of engagement and motivation as a result of the activity.**

***Index Terms*—Student Engagement, Game Based Learning, Gamification, Engineering Education, Escape Rooms**

I. Introduction

In a world full of distractions, student engagement within the classroom is a variable and important factor in student learning [1], [2]. Various attributes impacts their engagement that are largely outside the control of an educator. Such factors include: learning motivation, frame of mind, and language proficiency. However, an educator has considerable control over other variables including the type and pace of the learning activity and the arrangement of the classroom [3]. Consequently, an educator can have an impact on whether students are motivated to be both physically and mentally present—correlating with educational success [4].

Student motivation tends to be higher with higher achieving students, but this motivation is an element which can be learned and managed, to some degree, by the different learning approaches used by educators [5], [6]. In particular, a high level of intrinsic motivation (where students are motivated by the task itself rather than just an extrinsic reward) is positively related to student grade outcomes [7]. Since games are engaging, that is, humans seem "hard-wired" to enjoy games [8], the trend of educational gamification (adding game elements to education) and serious games or game based learning (creating games which embed educational content) is increasing [9], [10].

Majuri et al. recently conducted an extensive empirical review of 128 research papers around gamification. It highlights that 'points' (as distinct from marks), challenges, badges and leaderboards are common elements to show achievement [11]. Approximately 71% of these papers which quantified outcomes were positive in nature. Lopes et al. effectively argues for the use of gamification in improving student motivation, but also student involvement to overcome barriers such as dispersion or inactivity [12]. Many learners already play games, so switching some of this gameplaying to games which have a useful learning outcome should help in student learning.

Escape room games consist of a series of team based activities where players need to 'escape' from a room by solving a series of puzzles within a prescribed time limit (typically 1 hour) [13]. They originated in Japan around 2007 and have spread rapidly around the world in the past decade [14]. Escape room activities broadly appeal to males and females equally and teams consist of work groups, school friends, families, couples, and pre-wedding parties [14]. Escape rooms need not be confined to a room. More recently they have been adapted as board-games and computer based activities. This makes the concept more scalable for use in larger educational environments [13].

Escape room game based learning activities are in their infancy for teaching and learning with very recent examples in computer science, pharmacy and chemistry [15]–[17]. Recently we showed preliminary results of an escape room puzzle design for engineering using decoder boxes which we have released as open source [18], [19].

Frameworks and games designed to be shared around classrooms are also being developed. Studies have reported that learners typically report high levels of engagement within the activities [20], [21].

There were four groups of people with whom we wished to engage around engineering escape rooms: academics, high-school students, new international students, and current undergraduate students. We wanted to engage with university *academics*, for three reasons. Firstly, we wanted to test the concept of engineering escape rooms with engineering academics to gauge their feedback prior to running our first escape room with students. Secondly, a much higher percentage of academics would have been in the high-achieving cohort as students and so we wanted to hear their views on the pedagogical value of educational escape rooms. Finally, we also wanted to identify academics who might be interested in trialing this concept within their own courses.

Our future academic livelihoods depend on successfully engaging with *high school students*. In order to prevent a precipitous drop in first year engineering student numbers, a range of local marketing approaches have been supported

978-1-7281-1884-0/19/$31.00 ©2020 IEEE

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.3025003, IEEE Transactions on Games

over the years by universities: mentoring STEM students in schools, various STEM museums, widespread promotion of engineering shortages, flashy open days, student showcases, industry nights and high school students coming onto campus for various outreach activities [22]. We wanted to create a portable, hands on engagement activity for secondary-school students with the right mix of fun, cool-factor, and engineering. We wanted it to be easily deployable within any or all such marketing ventures, both local and further afield.

With *new international students* (NIS), an escape room game provides an organised ice-breaker activity for them. It is helpful they start collaborating early in preparation for team projects. Given that they are new arrivals and thus the novelty value of being in Australia is at its peak, we designed an escape room which helps them orientate themselves to their new-found environment in terms of language, geography and innovation history.

Last and certainly not least, we wanted to test escape rooms with *current undergraduate students* (CUS). As an engineering educator, our primary purpose was to try to determine whether escape rooms improved knowledge transfer of specific engineering course content. We wanted to focus on material that has historically proven more difficult for students to understand as demonstrated by consistent exam underperformance by CUS across different years. One unexpected result was that, although our educators expected students to have fun in participating, the educators themselves really enjoyed the escape room design exercise (more than writing exams and much more than marking exams). Hence, it is unsurprising to see new emerging research examples where students are tasked with writing escape rooms themselves [23].

In this paper we discuss the escape room games that we developed for these four groups of people. Before discussing these games, in Section II we briefly discuss the learning environment in terms of how the escape rooms activities are run. In Section III we describe the puzzles used within the escape rooms. In Section IV we evaluate the different escape room experiences and how learners and educators responded to them. And finally, we consider the extent to which our engagement with these four groups was successful in Section V.

II. The Escape Room Environment

We begin by discussing how the escape room activities are conducted and administered from an educators point of view. We didn't have a whole series of small rooms available nor the resources to support this. Hence, we have opted for table-top educational escape rooms. Within the escape room we needed some way of validating participant answers so they know if they have solved the puzzle or have to keep on trying. Several options were available which others have used including physical locks or a phone/computer web interface [21], [24]. In contrast to these we chose to use a physical electronic decoder box (Figure 2) which is further described in [19]. This decoder has since been upgraded significantly to provide the following additional features:

- Simple configuration interface for setting up the boxes we built using C# (Figure 1).
- Inbuilt data analytics to record time taken to solve each puzzle.
- Inbuilt data analytics to record incorrect guesses for each puzzle.
- Cloning functionality which allows the settings to be extracted from one decoder and copied to another.

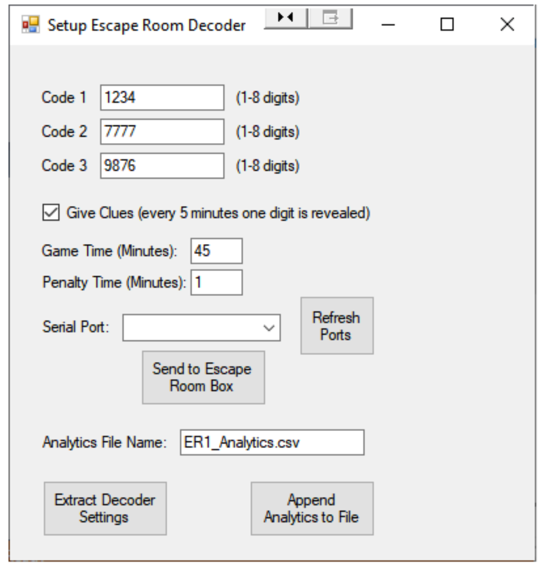

Fig. 1. Escape Room Decoder Configuration User Interface.

The decoder boxes consist of an LCD screen (for displaying clues, a timer and messages) a keypad (for entering codes), a key-switch for enabling power and an Arduino microcontroller to provide the required processing. The key on/off switch is in keeping with the escape room 'locked' theme. Pragmatically, it stops people from either accidentally restarting the decoder because they bump something or deliberately resetting their countdown. The use of the electronic decoder (in contrast to physical locks or an online solution) allows for data analytics, rapid reconfiguration for different puzzles, better security and better reliability. User feedback was positive around this regard that they were happy a electronic decoder box was developed rather than an app being created as it felt more real and less abstract.

The software user interface provides an easy mechanism for less technically inclined educators to configure their own decoder box and extract the data. All data on the decoders is stored in EEPROM (as shown in Table I) which means that it is not lost if it is power cycled or the batteries go flat.

Before we investigate how the escape room runs and the actual puzzles used, it is helpful to identify roles within the escape room environment. Anyone engaging with our escape rooms will be wearing at least one of these hats:

- Escape room participants (ERP) co-solve the puzzles and may directly manipulate the decoder (by entering in their solution).

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.3025003, IEEE Transactions on Games

Fig. 2. Escape Room Decoder Top View.

TABLE I
ESCAPE ROOM DECODER EEPROM MEMORY MAP

Bytes	Description	Example
0–7	Code 1 packed with leading spaces	\1234"
8–15	Code 2 packed with leading spaces	\7777"
16–23	Code 3 packed with leading spaces	\9876"
24	Bottom bit = give clue flag	\1"
25	Upper Byte of count down timer (seconds)	0x07 (Top Byte 30 min)
26	Lower Byte of count down timer (seconds)	0x08 (Bottom Byte 30 min)
27	Wrong answer penalty (minutes)	0x02 (2 minute penalty)
28	Analytics: Time taken for round 1 upper byte (seconds)	0x00 (Top Byte 4 min)
29	Analytics: Time taken for round 1 lower byte (seconds)	0xF0 (Top Byte 4 min)
30	Analytics: Time taken for round 2 upper byte (seconds)	0x02 (Top Byte 12 min)
31	Analytics: Time taken for round 2 lower byte (seconds)	0xD0 (Top Byte 12 min)
32	Analytics: Time taken for round 3 upper byte (seconds)	0x01 (Top Byte 7 min)
33	Analytics: Time taken for round 3 lower byte (seconds)	0xA4 (Top Byte 7 min)
34	Analytics: Number of errors for round 1	0x00 (no errors)
35	Analytics: Number of errors for round 2	0x02 (2 errors made)
36	Analytics: Number of errors for round 3	0x04 (4 errors made)

- Escape room facilitators (ERF) are a special type of participant who do not solve the puzzles but organise the room, ensuring the decoders are functioning, set the scene, and give instructions and help as necessary. ERF's essentially fulfil the role of game master for traditional escape rooms.
- Escape room designers (ERD), need to decide the solutions, the puzzles, and the narrative. The ERD may often also wear the ERF hat but never the ERP (at least not for the activity they are designing).
- Escape room testers (ERT) are a special ERP who play the game with an eye on quality assurance of all aspects (similar to a book editor).
- Escape room researchers (ERR), use data collected from participants during the escape exercises to draw broader conclusions related to their experiments. In the educational space, ERR will typically also wear the ERD hat.

For each escape room activity, a written narrative is provided which sets the scene for why the students need to escape. For our activities we have used variations on classic escape room themes including being trapped in a military bunker with decreasing oxygen levels, a spy theme, a variation on a jail-break and escaping from an Australian souvenir shop. Teams are spread out on separate tables around the room and are provided with ample writing supplies. They may use the internet (on phones or laptops) to assist in solving problems (although lecture notes will probably be the most useful).

The decoder box supports three rounds of puzzles for each activity. Each has a separate numerical answer of between 1 and 8 characters. Each of the puzzles are printed out and stored in a separate sealed envelope. ERPs can open the next envelope when the previous one has been solved. When ERPs enter a *correct* code, the decoder indicates that the code entered is correct and moves onto the next puzzle, or finishes the game. When ERPs enter an *incorrect* code, their total countdown time (set by the ERD) is reduced by a penalty amount (to disincentivise code guessing) which is also configured by the ERD.

The ERF configures whether ERPs will be drip-fed individual digits by the decoder (by revealing one digit at a time) at a rate of one clue every five minutes. In addition the ERF is responsible for monitoring whether ERPs are in danger of hitting the proverbial brick wall and falling way behind other teams. Similar to a real escape room, the ERF can help teams in this situation by giving additional clues. In the worst case, the ERF will have to enter the correct code to move teams along to the next puzzle, and make a note that team B did not solve puzzle X.

III. ESCAPE ROOM PUZZLES

In this chapter we detail the four different escape room games designed for our different participants. Each of these escape rooms have three puzzle rounds. Each of the puzzles typically consists of multiple parts (each one decodes a digit) which can be undertaken by different participants within the team.

A. ER1: Digital Electronics

Our first escape room was targeted towards teaching undergraduate students skills for digital electronics. This activity was first undertaken by academics on a year-end retreat as a reflective practice and team-building activity. Hence this effectively allowed staff to act as ERTs to provide feedback related to gameplay, pedagogy and learning outcomes. A total of 45 minutes was set for this escape room. The puzzles were as follows, and given the domain knowledge required, should make sense to those versed in digital electronics and programming, but possibly very little to those not initiated:

1) C Decoding [Codes]: The solution to the *Codes* puzzle is a four digit code (1843). Solving the first sub-puzzle (shown in Figure 3) results in the first single digit (1). The three other sub-puzzles, whose solutions are three remaining digits (843), are not shown.

2) Waveform Decoding [Waves]: The solution to the *Waves* puzzle is a different four digit code (2362). Solving the first sub-puzzle (shown in Figure 4) results in the first single digit (2) when decoded and combined with a ASCII table.

3) 7 Segment Display [Lights]: The solution to the *Lights* puzzle is also a different four digit code (7346). Solving the first sub-puzzle (shown in Figure 5) results in the first single digit (7) which is the number displayed on the 7-Segment display based on which LEDs are turned on and off.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.3025003, IEEE Transactions on Games

```
unsigned char number_1 = 78;
unsigned char number_2 = 156;
unsigned char number_3 = 240;
unsigned char digit[4];

number_1++;    number_2>>=1;    number_3+=85;

digit[0]=number_1;    digit[1]=number_2;    digit[2]=number_3;
printf("Digit 1 is %c%c%c\n",digit[0],digit[1],digit[2]);
```

Fig. 3. The puzzle for the first digit of A.

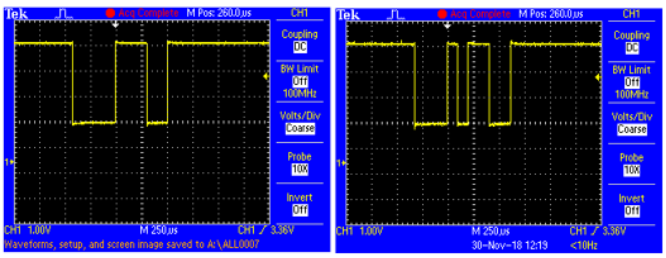

Fig. 4. The puzzle for the first digit of B.

B. ER2: Electronics Hardware

Rather than exclusively using paper based puzzles we wanted to test puzzles based around physical hardware. In this case, electronic test equipment was used. This escape room was designed and tested as a short escape room (25 minutes) to be used for high-school engagement and as a first year laboratory introduction activity using multimeters.

1) Measuring Voltage [PowerUp]: The solution to the *PowerUp* puzzle (see Figure 6) is a five-digit code (13523), and is trivial for ERPs who know how to use a multimeter (not shown). The ERP attaches the earth lead to the *Ground* pin, then touches the probe to pins 1-5 respectively. Clues are provided as to the setting required for the multimeter. Combining the associated voltages measured by the multimeter gives the solution (by rounding to the nearest volt). The reason the pins have a gap is because our puzzle used an Arduino Microcontroller (not shown), which has a gap in its pins that can output analog voltages.

2) Continuity Testing [Irresistible]: The solution to the *Irresistible* puzzle (see Figure 7) is an eight-digit code (13234165) derived based on circuit continuity from input to output. It is slightly more complicated than the previous puzzle, and also requires a multimeter. Wiring inputs directly to corresponding outputs would give (112233445566). However, our ERD has only 8 digits to work with, so we omit two connections to make an 8 digit code, eg. (11224466). If we keep these four input pins, but no longer wire straight across, we can then create all sorts of different codes (e.g. 13224165).

3) LED Lighting [LED]: The solution to the *LED* puzzle (see Figure 8) is a four-digit code (4812). ERPs set a series of DIP switches to match the binary key then read the digit off the LED display. This puzzle helps participants to understand how 7-Segment LED displays are addressed and allows students to

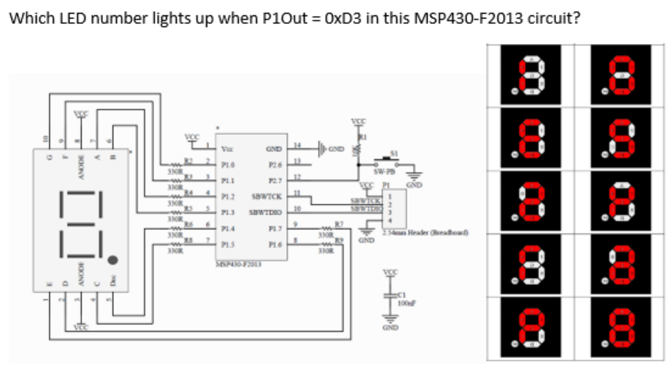

Fig. 5. The puzzle for the first digit of C.

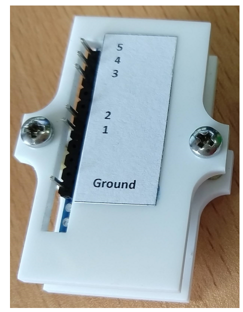

Fig. 6. Hardware for PowerUp Puzzle.

explore various binary combinations. As most letters can also be displayed on a 7-Segment LED display we could extend this activity by spelling out letters similar to the Caesar cipher employed for the Wheel Easy puzzle.

C. ER3: Choose STEM

We wanted to create another short puzzle (25 minute) which could be used for high school engagement around STEM disciplines without the need for other hardware (like multimeters). This puzzle is designed to be general enough so that the majority of students could solve them independently if necessary. We certainly did not want to give the impression that only smart people can study engineering and could not afford to risk frightening the students away entirely.

1) Hydraulics [Fill the Bucket]: The solution to the *Fill the Bucket* puzzle is a three digit code (725), identifying which bucket is filled first. This puzzle is purely visual, an easy mental warm up, and is intended to quickly build confidence in ERPs that they are on top of operating the decoders and that they can successfully compete as players in this game. All sub-puzzles are shown in Figure 9.

2) Rotational Equilibrium [Balance the See-Saw]: The solution to the *Balance the See-Saw* puzzle is a five digit code (14125), all sub-puzzles are shown in Figure 10. Students are also given a formula which shows that mass x distance is equal on the left hand side and right hand sides. This puzzle is more difficult than the first, requiring the application of basic multiplication and equation re-ordering skills.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.3025003, IEEE Transactions on Games

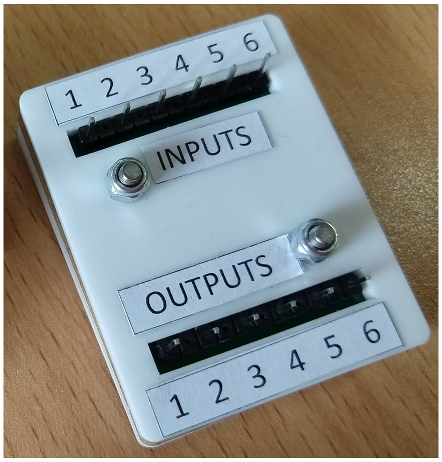

Fig. 7. Hardware for Irresistible Puzzle.

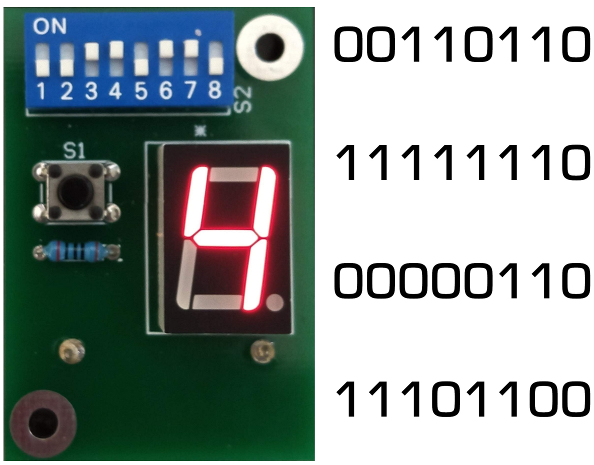

Fig. 8. Binary Keys and Hardware for LED Puzzle.

3) Caesar Cipher [Wheel Easy]: The solution to the *Wheel Easy* puzzle is an eight-digit code (13133281). ERP work out that the inner cipher wheel needs to be matched to the outer wheel at a specific spot which correctly converts one letter of the alphabet to another as a Caesar replacement cipher. We print these wheels on different sheets of paper to be spun relative to each other. Similar to the first puzzle, this puzzle is entirely visual. All sub-puzzles are shown in Figure 11.

This was the most difficult puzzle in the set and often required additional assistance. Successful groups tended to solve this puzzle in one of two ways. Firstly, some groups spotted double letters (like in NBLYY) and quickly identified these should relate to the 'EE' in 'THREE'. Secondly some groups noted that shorter words (like IHY) should relate to a 3 lettered number and would hence test 'ONE', 'TWO', 'SIX' or 'TEN' until they uncovered the correct result.

D. ER4: Welcome to Australia

Our final escape room was designed for international tertiary students as these make up a signification proportion of our student cohort. Hence, this escape room is designed to

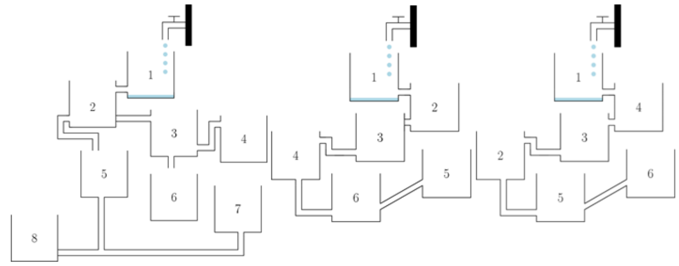

Fig. 9. All sub-puzzles for the three digits of A.

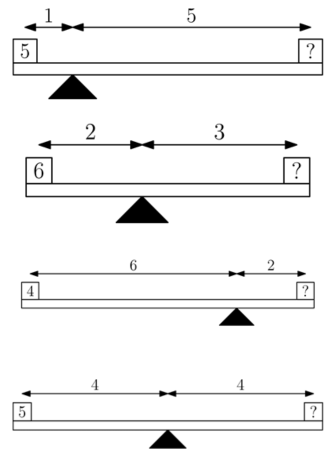

Fig. 10. All sub-puzzles for B. NB. The third gives two digits.

orientate students to Australia whilst allowing them to 'break the ice' with their classmates.

1) Australian Slang [Strine]: The solution to the *Strine* puzzle is an eight-digit code (53287164) derived using a Pigpen cipher. ERPs match the decoded words to their pictures, paired to an associated digit. The ERP then look up words on the internet and match one of the definitions to the pictures. All sub-puzzles are shown in Figure 12.

2) Australian Geography [Crow Flies]: The solution to the *Crow Flies* puzzle is an six-digit code (323113) which is deduced first, by ERPs unscrambling the source and destination place names, then secondly, by measuring the distance between these place names on a map, rounding to the nearest thousand kilometres, and dividing by a thousand. After all, Australia is a reasonably big island. The ERF may be needed with this puzzle to assist with unscrambling. We printed the ruler and map on separate pages and cut out the ruler so that ERPs can apply the ruler to the map. All sub-puzzles are shown in Figure 13.

3) Australian Inventions [Inventor]: The solution to the *Timeline* puzzle is an eight-digit code (38216745) relating to famous Australian inventions. Observant ERP will note that the clue 9434 relates the keys on a mobile phone to the letter WIFI, then looking up when WIFI was invented to work out the order of the associated digit (WIFI was invented in 1992 which is paired with the digit 5). All sub-puzzles are shown in Figure 14.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.3025003, IEEE Transactions on Games

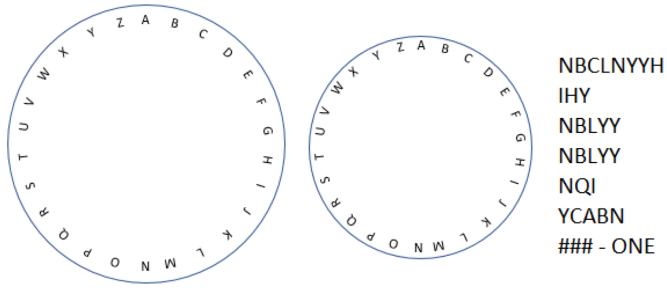

Fig. 11. All sub-puzzles for C. NB. One gives two digits.

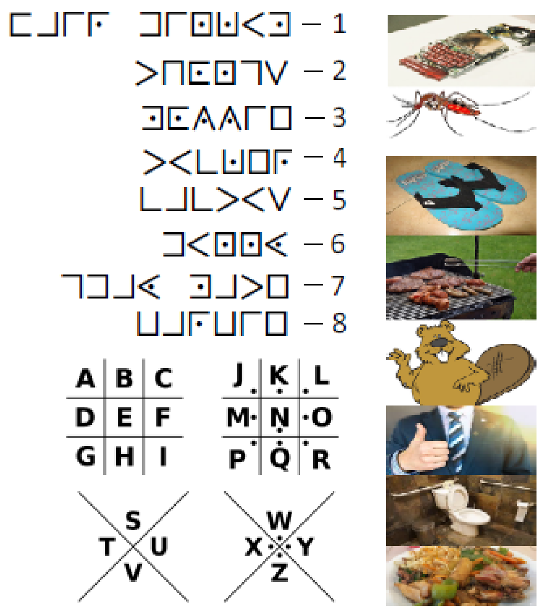

Fig. 12. All sub-puzzles for Strine Puzzle.

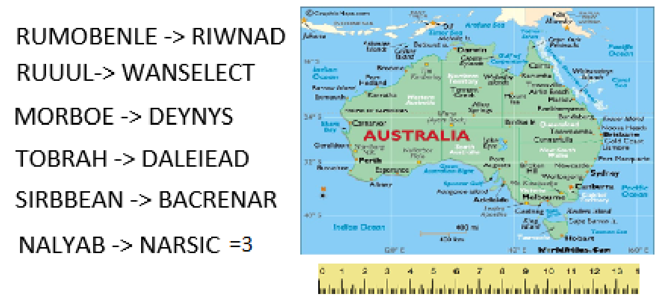

Fig. 13. All sub-puzzles for Crow Flies Puzzle.

Fig. 14. All sub-puzzles for Inventor Puzzle.

IV. Evaluation of Escape Room Activities

A. Faculty Feedback

As a pilot we first ran our ER1 activity with academics from the engineering faculty during a retreat. Our faculty consists of disciplines including electronic, civil, mechanical, and materials engineers. Consequently, while we were hoping to receive specific feedback from the electronic engineers, we were also hoping to receive more general educational feedback from the rest. Around 20 people were expected, and given we had eight staff with an electronic background, we thought four tables with two of these staff each should be adequate (Figure 15).

Feedback from staff was overwhelmingly positive. Constructive feedback was given and incorporated to optimise the escape rooms for the classroom. Following on from the activity, three staff have already conducted escape-rooms and 4 staff are currently designing escape rooms for the following areas: materials engineering, mechanical design, first year skills and oscilloscope training.

B. Undergraduate Feedback

The ER1 activity has been run with 50 undergraduate students, split into 12 groups in a 3rd year microcontrollers course. Student feedback was overwhelmingly positive with requests for more escape rooms. Surprisingly, they asked for marks to be allocated to escape room activities. Staff supervising the activity reported that students were highly focussed and worked together well in teams. Thus students were clearly highly engaged intrinsically as the only reward (besides a box of chocolates) was bragging rights.

Although the teams were physically situated in the same room (separated on different tables), there appeared to be minimal interaction between teams (until the end of the activity) and high levels of interaction within each team throughout. Although it is true that the higher achieving cohorts are more likely to engage in this activity, as they tend to attend more classes, they were not alone and collectively gave detailed feedback (in evaluation surveys). This led to small tweaks in the puzzles resulting in clearer layouts and more cohesive narratives. As a result of the activity, several of the A and B level students have been actively engaged in creating and running escape rooms for high school and 1st year engineering

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.3025003, IEEE Transactions on Games

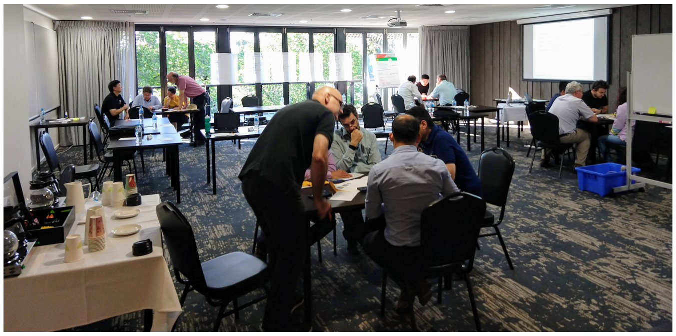

Fig. 15. Our escape room running at our 2019 staff retreat.

TABLE II
STEM ESCAPE ROOM SURVEY RESULTS

Question	Response (Average)
1. I wanted to complete the escape room activity?	4.7
2. I became unaware of my surroundings while doing the escape room activity?	3.9
3. I felt absorbed in the escape room activity?	4.5
4. If I had to vote, I would be in favour of using escape room learning in the classroom?	4.6
5. I found the activity difficult?	3.2

students demonstrating motivation to engage in high-order learning objectives.

C. High School Students Feedback

ER2 and ER3 were conducted during open day and a series of high-school engagement activities for 160 participants. The vast majority (98%) of participants were able to solve the puzzles within the 25 minute time frame and many immediately requested a chance to try the other activity. Participants filled out a Likert survey (Strongly Disagree to Strongly Agree) with the results shown in Figure 16 and summaried in Table II

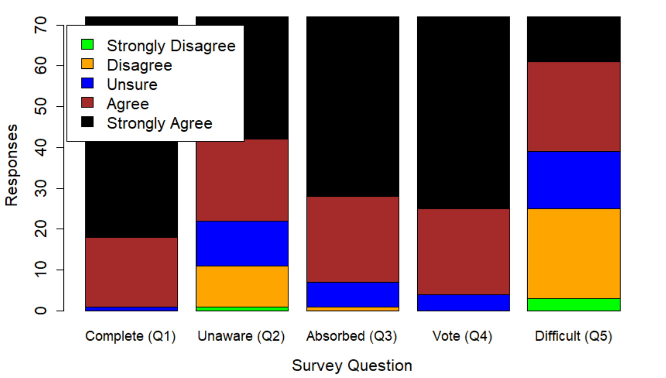

Fig. 16. Breakdown of survey responses for STEM Escape Room.

Based on the survey results, the majority of participants didn't find the activity too difficult (Q5), which was our aim. They also had high intrinsic motivation to complete the activity (Q1) (with no performance based prize offered). Participants were strongly in favour of escape rooms as an educational technique (Q4) and many effectively managed to tune out to the busy hustle and bustle of the open day environment (Q2 and Q3). When quizzed on what aspect of the escape room was the most difficult, puzzle three was named by almost all teams. Although it is at a reasonable difficultly level for upper secondary students, a more simple puzzle or additional clues would be required for lower secondary participants.

We note that of those surveyed, 70% had not done an escape room before. The average number of escape rooms done across all participants was 0.53 and the highest number of escape rooms completed by a single participant was 5.

D. International Student Feedback

Our final cohort of students was a class of 90 masters students who had moved to Australia to study engineering. We made this escape room a little too difficult for the time allocated (45 minutes) with only 4 out of the 28 groups successfully completing it. Next time this activity is used some additional clues and time will be provided.

Despite the relatively low success rate in escaping, demonstrators reported that the students were interested, very engaged and really wanted to succeed. The survey data from student feedback on this activity is very positive as shown in Figure 17 and Table III.

TABLE III
AUSTRALIAN ESCAPE ROOM SURVEY RESULTS

Question	Response (Average)
1. I wanted to complete the escape room activity?	4.6
2. I became unaware of my surroundings while doing the escape room activity?	4.2
3. I felt I achieved something in the escape room activity?	4.3
4. I found the escape room activity satisfying?	4.4
5. I felt I learnt something during the activity?	4.5

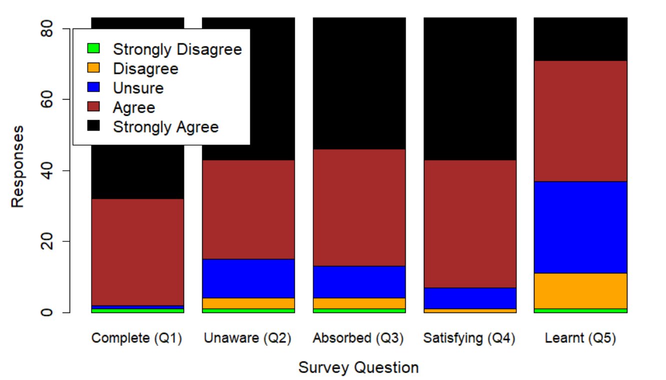

Fig. 17. Breakdown of survey responses for Australian Escape Room.

Once again, participants were highly motivated to complete the escape room (Q1) even though only four groups did 'escape'. Only one student answered question 1 as 'strongly

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.3025003, IEEE Transactions on Games

disagree', although they 'agreed' that they found the activity satisfying and that they learnt something through the activity. Even with the low escape rate the vast majority of respondents rated they they found the activity satisfying and they felt they achieved something (Q4 and Q3). This surprised us as we thought that would be more apparent only for successful escapes. If escape rooms become common, we suggest that the satisfaction would drop if student are consistently unable to escape. Finally, the students agreed that they did learn something. We expected this given the general lack of knowledge for international students of Australian geography (outside of their immediate vicinity), slang and Australian inventions.

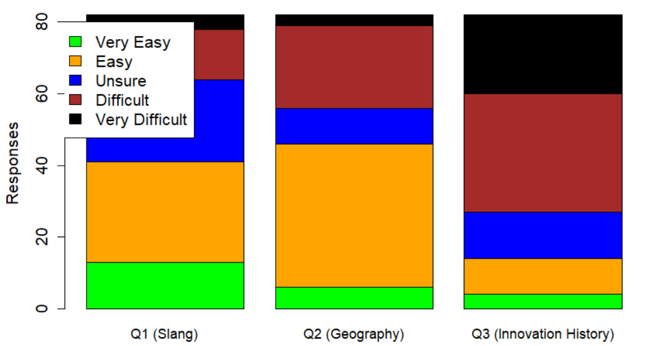

Fig. 18. Survey results from the Australian Escape Room for puzzle difficulty.

Figure 18 shows the survey results where the students reported the level of difficulty they had with each of the puzzles. Puzzle three was rated by students as the most difficult—particularly the step of decoding the innovations using the mobile phone keypad. The much higher perceived difficultly results may be skewed by the fact that participants were running out of time and many teams didn't successfully complete this puzzle (as shown in Figure 20).

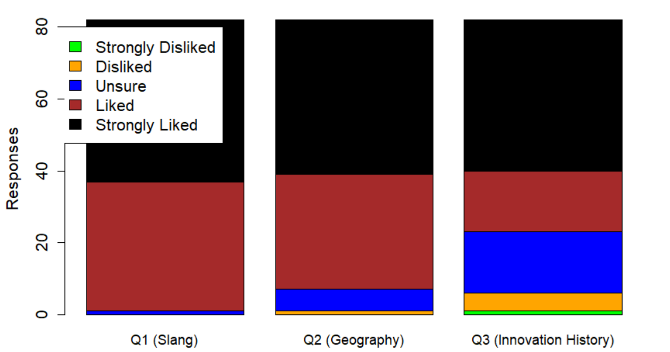

Fig. 19. Survey results from the Australian Escape Room for puzzle enjoyment.

Along with being rated as the most difficult puzzle, puzzle three was also rated as the least enjoyable (although approximately 75% of participants either 'Liked' or 'Strongly Liked' it). We are pleased to see that students have enjoyed these puzzles so much and we expect the enjoyment figures would fair very favourably compared to a traditional tutorial or test which, by and large, are not fun.

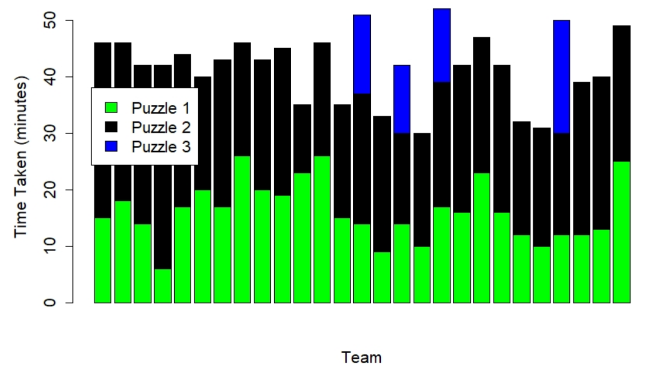

Fig. 20. Time taken for each puzzle (where puzzle 3 is missing team did not escape).

Figure 20 shows the time taken for each of the 27 teams which participated in the escape room. Unfortunately, only 4 groups completed the activity within the allocated time (where a time for puzzle 3 is displayed). Many more groups were close to solving the puzzle, so in future iterations we plan to provide a few more written clues to help students progress through faster. There is significant variability with how long it took to solve each puzzle. Some groups solved one puzzle very quickly, but then got significantly stuck on a different puzzle (e.g. the 4th group).

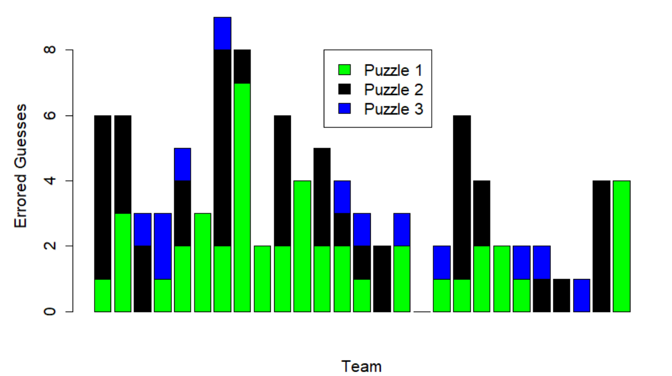

Fig. 21. Number of errors recorded for each puzzle.

Finally, Figure 21 shows the numbers of incorrect guesses entered by each team for each puzzle. In this scenario each error resulted in a 1 minute time penalty. Interestingly the only team to make no errors was one of the teams who successfully escaped (although they took the longest time to escape—possibly as a result of double or triple checking answers before entering them). The teams who did escape made an average of 2 incorrect guesses across the activity which is significantly lower than the 4 guesses made by non-escaping teams (who suffered a time penalty as a result).

V. Conclusion

In this paper we identified four different groups of people with whom we wished to engage around engineering escape rooms for different purposes: academics, high school students, new international students, and current undergraduate students. We upgraded our reconfigurable decoder to support the escape rooms and designed escape room activities which were undertaken by each of these groups. For each of the escape rooms, we designed three puzzles resulting in a total of twelve puzzles.

From trial and error, we established the importance of testing escape rooms (the ERT role) with ERT's who were not involved in the escape room design. This is to ensure a solution is possible without making huge leaps of logic. In terms of class room deployment, we run our educational escape rooms for 45 minutes (which gives time for a pre-briefing and discussion at the end). Conversely our school engagement exercises are significantly shorter (25 minutes) which gives students a taste of the activities, but also leaves sufficient time for a short talk about the discipline of engineering.

Engagement observed by our facilitators and measured by the survey was very high for all groups. As a result of running our academic escape room at our engineering staff retreat and at a subsequent university symposium, we have had interest from a number of academic staff who have gone on to design their own escape rooms for their students. These have included engineering disciplines such as materials and mechanical engineering, and other broader STEM disciplines such as statistics, mathematics and biology. Secondly, we have run our high school escape rooms now with over 300 students during various promotional events: university open day and high school outreach events (both on-site and off-site). Finally, there have been over 4,800 views in the first nine months of our open-source Escape Room Decoder Box hosted on the *instructables* website with 81 people marking the design as a favourite [25].

From an escape room researcher (ERR) point of view, there is far more work to do in exploring the pedagogical value of escape rooms. Although students may not have been able to escape, they were still highly engaged and satisfied by the activity. We believe that refining the designs so that the majority of student can escape (but not with lots of time to spare) would enhance the experience. We were pleasantly surprised that undergraduate students enjoyed the escape room so much that they requested it become an assessable component of the subject (although with a low mark component of 5%). Future work will include running the escape rooms with disparate disciplines, physiologically monitoring students (heart rate and galvanic skin response), quantifying the effect on student learning and analysing student-developed escape rooms.

From our experience, we believe that there is wide scope for game based learning using our escape room decoder particularly in collaborative problem solving. In the engineering educational space, we see great potential for integrating the decoder box with other hardware including laboratory equipment (through both physical and wireless connection) and with augmented reality. We really believe that just the tip of the iceberg has been exposed in terms of the potential applications of escape rooms in the STEM space and beyond. It is an exciting time for gamification research which we hope will lead to more inescapable learning experiences.

Acknowledgment

This research was funded by a grant from the Telematics Trust: DA-2019-9730.

References

[1] E. R. Kahu, "Framing student engagement in higher education," *Studies in higher education*, vol. 38, no. 5, pp. 758–773, 2013.
[2] R. M. Carini, G. D. Kuh, and S. P. Klein, "Student engagement and student learning: Testing the linkages," *Research in higher education*, vol. 47, no. 1, pp. 1–32, 2006.
[3] B. L. Wiggins, S. L. Eddy, L. Wener-Fligner, K. Freisem, D. Z. Grunspan, E. J. Theobald, J. Timbrook, and A. J. Crowe, "Aspect: A survey to assess student perspective of engagement in an active-learning classroom," *CBE—Life Sciences Education*, vol. 16, no. 2, p. ar32, 2017.
[4] C. E. Schaeffer and G. D. Konetes, "Impact of learner engagement on attrition rates and student success in online learning," *International Journal of Instructional Technology & Distance Learning*, vol. 7, no. 5, pp. 3–9, 2010.
[5] R. D. Balavendran Joseph, A. Pal, J. Tunks, and G. Mehta, "Intrinsic vs. extrinsic motivation in an interactive engineering game," *Journal of Advances in Computer Engineering and Technology*, vol. 5, no. 1, pp. 37–48, 2019.
[6] P. Buckley and E. Doyle, "Gamification and student motivation," *Interactive learning environments*, vol. 24, no. 6, pp. 1162–1175, 2016.
[7] Y.-G. Lin, W. J. McKeachie, and Y. C. Kim, "College student intrinsic and/or extrinsic motivation and learning," *Learning and individual differences*, vol. 13, no. 3, pp. 251–258, 2003.
[8] J. Hamari, J. Koivisto, H. Sarsa *et al.*, "Does gamification work?-a literature review of empirical studies on gamification." in *HICSS*, vol. 14, no. 2014, 2014, pp. 3025–3034.
[9] D. Dicheva, C. Dichev, G. Agre, G. Angelova *et al.*, "Gamification in education: A systematic mapping study." *Educational Technology & Society*, vol. 18, no. 3, pp. 75–88, 2015.
[10] J. Nolan and M. McBride, "Beyond gamification: reconceptualizing game-based learning in early childhood environments," *Information, Communication & Society*, vol. 17, no. 5, pp. 594–608, 2014.
[11] J. Majuri, J. Koivisto, and J. Hamari, "Gamification of education and learning: A review of empirical literature," in *Proceedings of the 2nd International GamiFIN Conference, GamiFIN 2018*. CEUR-WS, 2018.
[12] M. Soler-Porta, R. Caña-Palma, M. J. Bentabol-Manzanares, L. Cortes-Fernandez, M. A. Bentabol-Manzanares, M. d. M. Muñoz-Martos, A. I. Esteban-Pagola, M. J. Luna-Jimenez, A. P. Lopes *et al.*, "Gamificacion in education and active methodologies at higher education," 2019.
[13] M. Wiemker, E. Elumir, and A. Clare, "Escape room games," *Game Based Learning*, vol. 55, 2015.
[14] S. Nicholson, "Peeking behind the locked door: A survey of escape room facilities," *White Paper available online at http://scottnicholson.com/pubs/erfacwhite. pdf*, 2015.
[15] C. Borrego, C. Fernández, I. Blanes, and S. Robles, "Room escape at class: Escape games activities to facilitate the motivation and learning in computer science," *JOTSE*, vol. 7, no. 2, pp. 162–171, 2017.
[16] H. N. Eukel, J. E. Frenzel, and D. Cernusca, "Educational gaming for pharmacy students–design and evaluation of a diabetes-themed escape room," *American journal of pharmaceutical education*, vol. 81, no. 7, p. 6265, 2017.

[17] N. Dietrich, "Escape classroom: The leblanc process—an educational "escape game"," *Journal of chemical education*, vol. 95, no. 6, pp. 996–999, 2018.

[18] R. Ross and C. Bell, "Turning the classroom into an escape room with decoder hardware to increase student engagement," in *Conference on Games*. IEEE, 2019, pp. 1–4.

[19] R. Ross, "Design of an open-source decoder for educational escape rooms," *IEEE Access*, vol. 7, pp. 145 777–145 783, 2019.

[20] S. Clarke, D. J. Peel, S. Arnab, L. Morini, H. Keegan, and O. Wood, "Escaped: A framework for creating educational escape rooms and interactive games for higher/further education," *International Journal of Serious Games*, vol. 4, no. 3, pp. 73–86, 2017.

[21] S. Nicholson, "Creating engaging escape rooms for the classroom," *Childhood Education*, vol. 94, no. 1, pp. 44–49, 2018.

[22] R. Ross, J. Whittington, and P. Huynh, "Lasertag for stem engagement and education," *IEEE Access*, vol. 5, pp. 19 305–19 310, 2017.

[23] D. Davis and J. G. Lee, "Building escape rooms to increase student engagement in first-year engineering classes," *American Society for Engineering Education*, 2019.

[24] J. Cain, "Exploratory implementation of a blended format escape room in a large enrollment pharmacy management class," *Currents in Pharmacy Teaching and Learning*, vol. 11, no. 1, pp. 44–50, 2019.

[25] R. Ross, "Escape room decoder box," *Available online at https://www.instructables.com/id/Escape-Room-Decoder-Box/*, 2019.