Turning the classroom into an escape room with decoder hardware to increase student engagement

Robert Ross
Department of Engineering
La Trobe University
Bundoora, Australia
R.Ross@latrobe.edu.au

Carolyn Bell
Department of Physiology Anatomy and Microbiology
La Trobe University
Bundoora, Australia
C.Bell@latrobe.edu.au

***Abstract*—Intuitively we know that un-engaged learners learn less. In this paper we describe the use of escape room activities using a hardware decoder box to create a highly engaging learning environment which fosters teamwork and problem solving skills. We evaluate the escape room based learning methodology using learner and instructor focus groups across several different science and engineering disciplines. Results demonstrate high levels of engagement and attentiveness suggesting this approach has wide scope across many learning disciplines.**

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

I. Introduction

Within education learner engagement is a key factor of success. If a learner isn't physically there (to physically engage with learning) or mentally there (mind on other things) the likelihood of learning is vastly diminished [1].

Learner engagement is a multifaceted problem with many variables contributing to learners being engage. The instructor has some control over a number of these factors (e.g. type of learning activity, pace of activity, charisma of presenter, the group composition). Conversely the instructor has little control over other factors (e.g. learning motivation, frame of mind, language proficiency) [2].

Professional game designers tend to create better games than novice game designers when designed from scratch. A better strategy for novice designers is to adapt existing successful game concepts in creating a new game. We use a similar approach in this paper as we embed learning within the escape room game concept.

Gamification, the realisation of embedding game elements into products and services, has been touted as a next-generation method for engagement, given humans are "hard-wired" to enjoy games [3]. Gamification implementations are not all created equal with a projected 80% of gamification implementations in 2014 failing to meet business objectives due to poor design [4].

Gamification for active learning has recently been an area of considerable innovation across many domains. Implementations have included Khan Academy for mathematics, Codecademy for programming and more broadly the Quest to Learn program which gamifies curriculum across a whole 6-12 school program [5].

Escape rooms are 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) [6]. Escape rooms are a relatively new concept having originated in Japan around 2007 and have grown rapidly around the world over the last 10 years [7]. Escape room activities appeal to males and females equally and participants include corporate groups, families and couple dates [7].

Escape rooms need not be confined to a room. More recently they have been adapted as board-games and computer based activities, thus making the concept more scalable for use in larger educational environments [6].

Escape room themed activities are in their infancy for teaching and learning with very recent examples in computer science, pharmacy and chemistry [8], [9], [10]. Frameworks and games designed to be shared around classrooms are also being developed. Learners typically report high levels of engagement within the activities [11], [12].

In this paper we demonstrate the escape room learning approach in the context of tertiary studies in science/engineering disciplines. This paper is organised as follows: in Section II we describe the hardware framework to facilitate the escape room along with some sample escape room problems. We then summarise feedback from instructors in Section III and learners in Section IV with concluding remarks in Section V.

II. Learner Environment

In this section we discuss the format of our escape rooms in terms of decoder hardware and sample questions used to engage students. The concepts behind each of these questions were not brand-new to students but are being presented in a different context, mirroring a typical exam – similar but different.

To validate learner results we used a decoder box, which we have described elsewhere [13]. This decoder box is reprogrammable (for different escape room codes) and includes a keypad for entering numerical data and an LCD screen for providing feedback to the user. The LCD screen includes a countdown timer, information about the current code (e.g.

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'****' for a 4 digit code) and appropriate messages for correct or incorrect guesses.

The encoder box also allows for time penalties to be imposed for incorrect guesses (we used 1 minute penalties) to encourage problem solving rather than guessing. To avoid learners becoming stuck for long periods of time the system also includes automated clue delivery (every 5 minutes learners are stuck in a problem one digit of the code is revealed).

The escape room scenarios were conducted with groups all in the same room, each gathered together around a table (figure 1). After a few brief instructions the decoder boxes were activated (key switch turned on and removed) and the participants were invited to open the first envelope containing the first puzzles.

Fig. 1. Photo from escape room activity with academic staff.

In addition to the puzzles we include a back-story scenario to help set the context for the problems and why users need to escape. This provides a slightly more immersive experience and helps learners bond together as a team as they read through the scenario they are placed in. Currently we have back-stories around an earthquake induced cave-in, a sealed cold-war bunker and a futuristic droid-themed adventure. These scenarios slightly extend the escape room time (reading half a page of text), but provide a good engagement activity and can be an added place to hide clues.

The following problems are a subset of those used in the classroom to evaluate learners engagement with the materials and problem solving. The escape room exercises have been open-book activities and each stage of the activity (typically there are 3) contains a collection of similar problems which need to be decoded.

The first example puzzle is from molecular biology and was framed around calculating water volumes for a PCR (Polymerase chain reaction) given a series of reagents with specified concentrations (Table I). This problem requires students to calculate all reagent volumes and determine the extra volume of water required.

The second puzzle shown related to arithmetic across numbers with different number bases (decimal, binary and hexadecimal) (Figure 3). These sorts of problems are common with discrete maths and digital electronics disciplines and

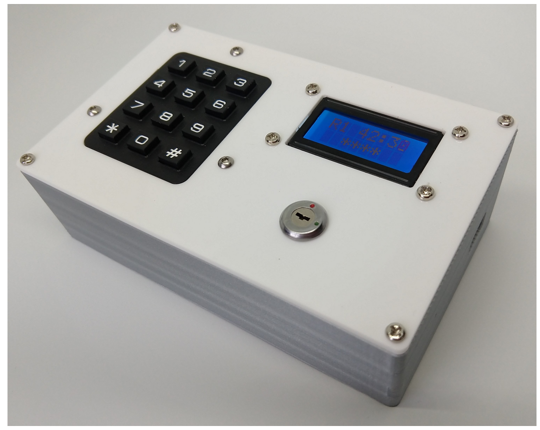

Fig. 2. Decoder box used to validate answers.

Reagents	Stock Solution	Required Concentration	Volume
$MgCl_2$	50mM	1.5mM	? uL
Forward Primer	30uM	0.5mM	? uL
Template DNA	50ng	1ng	? uL
$MgCl_2$	50mM	1.5mM	? uL
		Total Volume	100uL

TABLE I
PARTIAL LIST OF REAGENTS FOR BIOCHEMISTRY REACTION PUZZLE

requires students to convert numbers to a common number base before performing arithmetic operations.

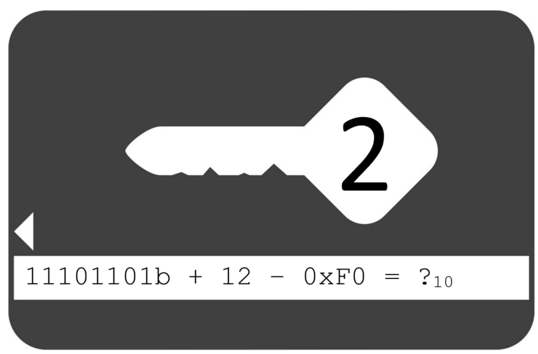

Fig. 3. Puzzle for arithmetic between different number bases (solution = 9).

The third puzzle (Figure 4) involved decoding data transmitted as a serial string and captured on an oscilloscope. As students solve this puzzle they demonstrate their understanding of serial communications, ASCII tables and data transmission.

The fourth puzzle (below) involves stepping through C code and computing the final value based on a series of arithmetic and logical operations. This example question involves bit-shifting, bitwise ORing and addition (solution 52).

```
unsigned char C = 87;
C >>= 1;
C |= 4;
C += 5;
```

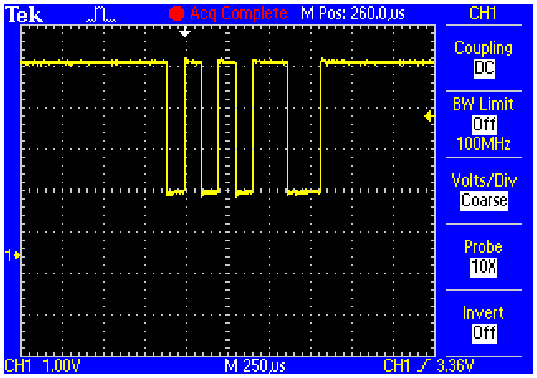

Fig. 4. Puzzle involving waveform decoding (Solution = 5).

The final type of puzzle question we present (Figure 5) involved working out how digital logic gates should be used to construct a circuit to implement a logic look-up table (not shown). This requires students to fill in gaps in the look-up table and propagate logic to develop a solution one gate at a time.

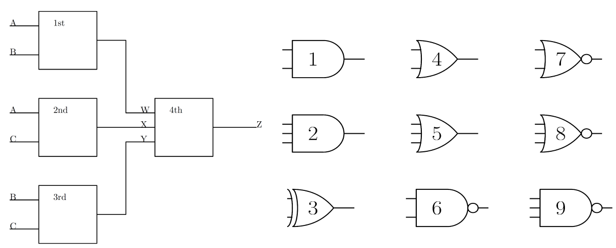

Fig. 5. Puzzle involving propagating digital logic through a circuit given a based on a look-up table (not provided).

As the decoder box only accepts numerical answers, the results of each of the puzzles needs to have a numerical solution. This solution may be generated from some sort of a look-up table (e.g. puzzle 5), a computation or other clues which are visually embedded (like decoding the waveforms).

We suggest that the solutions to these puzzles shouldn't be immediately obvious but likewise shouldn't be too cryptic requiring large leaps in logic. Having a second person complete each escape room (who is not involved in writing questions) has been very instructive, with some questions judged too easy and some completely perplexing or with minor errors.

III. Instructor Evaluation

To date, we have had five teams of academics (4-5 per team) complete one of the escape room activities and provided feedback through a survey and focus group which are discussed elsewhere [14]. We have also had three academic staff run escape room activities to observe progress, engagement and learning of students.

The academics experience was overwhelmingly positive with all but one academic actively engaging in the exercise even though half of the academics didn't have a background in the engineering problem domain that the escape room was conducted in. Encouragingly, in all the groups the academics with a stronger background tended to help the other academics understand the problem and work together to effectively decode key aspects of the puzzles which contributed to the team performance. A focus group conducted over a week later indicated that academics lacking the background still had significant recall of key details in the problem solving steps for each of the problems.

Teaching staff involved in supervising escape room activities have reported four things: all students present seem actively engaged and focussed on the activity, many students worked together happily who had never collaborated before, attendance was typically higher than for traditional tutorials and students clearly enjoyed the activity (often asking for more similar types of learning activities).

IV. Learner Evaluation

Feedback sessions were held for learners directly after two of the engineering escape room activities to gauge the learner acceptance of this learning mode. Students were asked to comment on three questions and were also provided with an opportunity to provide other unstructured feedback. The questions put to students were as follows:

1) How engaging did you find the activity and why?
2) How did you find the activity in terms of a teamwork activity?
3) Would you like to see marks allocated to an escape room activity?

The engagement question attracted positive responses with the following comments recorded: 'very fun', 'really enjoyed the activity', 'was great to get practical confirmation of knowledge'. Some students commented that the hints (currently provided every 5 minutes into each round) came a little bit too early and they wanted to have the chance to be stuck for a little longer. Students also reported they liked interacting with a real piece of hardware (the decoder box) rather than just paper and pen or an app on their phone.

In relation to teamwork students reported it was a great teamwork activity and they felt it was much better than a 'long drawn out project where group members go missing or don't contribute for long periods of time'.

To date, the escape room activities were conducted in tutorial sessions and no marks have been allocated (currently winning teams are rewarded with chocolates and bragging rights). Students unanimously requested that marks be allocated for this activity on the provision they get a demonstration of the escape room hardware beforehand, citing it as a great problem solving and teamwork activity. We will experiment with marking schemes into the future. Students agreed that approximately 5% of a subjects marks per escape room activity seemed a reasonable mark allocation.

Finally in other student feedback some students requested a longer activity (with more questions), more confusion and cryptic questions they need to wrestle with and other possible types of inputs for answers (e.g. control knobs or RFID). Some students raised the idea that escape rooms could be used to validate hands-on learning in laboratories (e.g. with oscilloscopes) but were also wary of potential hardware faults.

V. Conclusion

In this paper we have described a series of escape-room based learning activities centred around a physical decoder box to facilitate an engaging learning experience within science and engineering based disciplines. Both instructors and learners reported high levels of engagement and focused teamwork taking place throughout the activity.

We see significant scope for future work related to using AR/VR technologies to provide an even more immersive experience. Thought has been given to tracking and correlating biometric data from learners as they progress through different puzzles. We are also interested in investigating the use of escape rooms for hands-on laboratory work and would like to test the use of a live leaderboard within the classroom so students can see the progress of their peers.

We see wide scope for the use of escape room learning exercises across a wide variety of subject domains and for mixed purposes including focusses on: teamwork, introducing new material, exam revision and integrating knowledge.

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