Educational Research Review 31 (2020) 100364

Contents lists available at ScienceDirect

Educational Research Review

journal homepage: www.elsevier.com/locate/edurev

Escape education: A systematic review on escape rooms in education

Alice Veldkamp[a,*], Liesbeth van de Grint[b], Marie-Christine P.J. Knippels[a], Wouter R. van Joolingen[a]

[a] *Freudenthal Institute, Utrecht University, Princetonplein 5, 3584 CC, Utrecht, the Netherlands*
[b] *Faculty of Social and Behavioural Sciences, Utrecht University, Heidelberglaan 1, 3508 TC, Utrecht, the Netherlands*

A B S T R A C T

The global increase in recreational escape rooms has inspired teachers around the world to implement escape rooms in educational settings. As escape rooms are increasingly popular in education, there is a need to evaluate their use, and a need for guidelines to develop and implement escape rooms in the classroom. This systematic review synthesizes current practices and experiences, focussing on important educational and game design aspects. Subsequently, relations between the game design aspects and the educational aspects are studied. Finally, student outcomes are related to the intended goals. Educators in different disciplines appear to have different motives for using the game's time constraints and teamwork. These educators make different choices for related game aspects such as the structuring of the puzzles. Unlike recreational escape rooms, in educational escape rooms players need to reach the game goal by achieving the educational goals. More alignment in game mechanics and pedagogical approaches is recommended. There is a discrepancy in perceived and actual learning of content knowledge in recreational escape rooms. Recommendations in the article for developing and implementing escape rooms in education will help educators in creating these new learning environments, and eventually help students to foster knowledge and skills more effectively.

1. Introduction

Worldwide, recreational escape rooms have inspired teachers to adapt the popular entertainment activity for education (Sanchez & Plumettaz-Sieber, 2019). Escape rooms (ERs) are live-action team-based games in which players encounter challenges in order to complete a mission in a limited amount of time. Originally, the nature of the mission was an "escape" from a room. Nowadays, the missions vary; players may solve a murder mystery or break into a vault (Nicholson, 2015). However, the "escape room" moniker is the term most used for this type of games (Wiemker, Elumir, & Clare, 2015).

Parallel to the immense popularity in the entertainment industry, ERs are gaining popularity as learning environments in primary, secondary, higher education, and professional development programs (Sanchez & Plumettaz-Sieber, 2019). The implementation of educational ERs started bottom-up with enthusiastic teachers. They share materials on platforms such as Breakout EDU which has about 40,000 members (Breakout EDU, 2018; Sanchez & Plumettaz-Sieber, 2019). These developments rely on early adopting teachers adapting the recreational ER concept. Teachers develop the rooms based on ER video games, and/or their experiences in recreational ERs (e.g., Franco & DeLuca, 2019). This bottom-up phenomenon of ERs in education is unique and increasing. There is a need to evaluate their use, and a need for guidelines to develop and implement educational ERs (Jenkin & Fairfurst, 2019). A systematic review of current practices and experiences will help educators in creating these new learning environments, and eventually help students to foster knowledge and skills more effectively.

* Corresponding author.,
E-mail address: a.veldkamp@uu.nl (A. Veldkamp).

https://doi.org/10.1016/j.edurev.2020.100364
Received 24 January 2020; Received in revised form 10 September 2020; Accepted 16 October 2020
Available online 22 October 2020

1.1. Escape rooms for education

Escape rooms have been used for various educational purposes: to recruit students (Connelly, Burbach, Kennedy, & Walters, 2018; Gilbert, Meister, & Durham, 2019), for students to get to know institutional services (Guo & Goh, 2016; Wise, Lowe, Hill, Barnett, & Barton, 2018), or to increase students' earthquake preparedness (Novak, Lozos, & Spear, 2018). A different purpose is the ER as a research environment, for example to observe students' information search behaviour (Choi, An, Shah, & Singh, 2017), learning processes in student teams (Järveläinen & Paavilainen-Mäntymäki, 2019), or the use of teamwork and leadership skills among students (Warmelink et al., 2017). Other case studies describe students developing ERs to foster design skills (Li, Chou, Chen, & Chiu, 2018, pp. 250–253; Ma, Chuang, & Lin, 2018). Escape rooms have been designed to foster domain specific skills and knowledge, such as nursing (Adams, Burger, Crawford, & Setter, 2018; Brown, Darby, & Coronel, 2019), medicine (Cotner, Smith, Simpson, Burgess, & Cain, 2018), pharmacy (Cain, 2019; Eukel, Frenzel, & Cernusca, 2017), physiotherapy (Carrión et al., 2018), chemistry (Dietrich, 2018), physics (Vörös & Sárközi, 2017), computer science (Ho, 2018), mathematics (Arnal et al., 2019), history (Rouse, 2017), and English (López, 2019) or to support the development of generic skills (Craig, Ngondo, Devlin, & Scharlach, 2019).

Like recreational ERs, these ERs combine hands-on and minds-on activities to be achieved with a team in a limited time. In a classroom setting, teachers try to create authentic environments with meaningful activities and room for failure. For education, each of the ER characteristics is not unique on its own. However, their combination seems unique and appealing to teachers.

ERs have emerged spontaneously in education through platforms such as Breakout EDU (Breakout EDU, 2018). These platforms are mainly driven by educational practitioners who copied and adapted recreational ERs. As a consequence, little work has been reported on their theoretical foundation in educational science. However, as developed ERs share features with educational games, we can resort to theories of Game Based Learning (GBL) to provide the start of a theoretical approach to educational ERs. Systematic reviews on GBL found, in most studies, improved knowledge acquisition, content mastery and motivation as an effect of educational games (Conolly, Boyle, MacArthur, Hainey & Boyle, 2012; Subhash & Cudney, 2018). These reviews stress the importance of both educational and game design aspects to be considered and require an understanding of the relations between educational and game design aspects for engagement (Connolly, Boyle, MacAuthor, Hainey, & Boyle, 2012; Jabbar & Felicia, 2015) and learning (Ke, 2016; Van der Linden, van Joolingen, & Meulenbroeks, 2019). Important game design aspects are a narrative which contextualises knowledge and skills needed, with a role for students contributing to ownership and autonomy in their learning (Annetta, 2010; Jabbar & Felicia, 2015; Subhash & Cudney, 2018). Furthermore, unambiguous feedback, rewards and increased complexity (levels or progressive challenges) scaffold the learning process. The feature interactivity is related to collaborative learning. Both concepts refer to arrangements that involve two or more students working together on a shared learning goal. Van Leeuwen & Janssen's review study (2019) on the teacher role during collaborative learning showed a crucial, yet challenging role of teachers to remain a central figure in supporting collaborative learning, without taking control of the moments in which opportunities to learn arise for students. In addition, educational ERs align with situated learning theory (Lave & Wenger, 1991) which states that situated or scenario-based learning should take place in the environment in which it would normally be applied.

1.2. The escape room concept and design characteristics

A wide range of scenario's for ERs is possible, as Nicholson's inventory of 175 recreational ERs has shown (2015). Players need to transfer from their real-life context into the game context, such as a crime scene or a submarine in the past. Therefore, the immersion of players during gameplay is very important. Immersion is the process where a player is lured into a story or particular problem (Douglas & Hargadon, 2001). In educational games, it is used to get a learner engaged, solving challenges and finishing the task (Annetta, 2010). Consistency in the game context (time period and place), the characters of the players, the activities, the tools, and the props is recommended to prevent cognitive dissonance (Nicholson, 2016). Within ER literature, all activities are called puzzles and they use a simple game loop: a challenge, a solution and a reward (e.g., a code for a lock, or information needed in the next puzzle). Puzzles can be

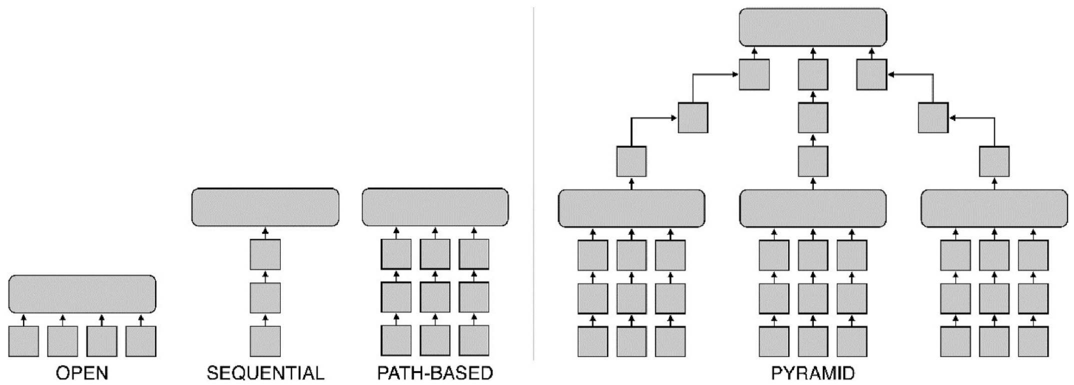

Fig. 1. *Puzzle structures in escape rooms: a) basic structures: open, sequential and path-based; b) a complex, hybrid structure, such as a pyramid. Squares are puzzles and rectangles are meta-puzzles (adapted from Nicholson, 2015).*

categorized as: a) cognitive puzzles that make use of the players' thinking skills and logic, b) physical puzzles that require the manipulation of artefacts to overcome a challenge, such as crawling through a laser maze and c) meta-puzzles, the last puzzle in the game in which the final code or solution is derived from the results from the previous puzzles (Wiemker et al., 2015). Cognitive puzzles seem to be predominant in ERs (Nicholson, 2015).

Nicholson (2015) identified four ways of organizing the puzzles, see Fig. 1. In an open structure, the players can solve different puzzles at the same time. All other puzzles need to be solved before the last one. The sequential structure presents the puzzles one after another; solving a puzzle unlocks the next, until the meta-puzzle can be solved. The path-based structure consists of several paths of puzzles. Combining some of the basic structures produces a complex, hybrid structure, which may take, for example, the form of a pyramid. To solve the puzzles, players require skills such as searching, observation, correlation, memorization, reasoning, math, reading, and pattern recognition (Wiemker et al., 2015). After the gameplay, the gamemaster debriefs the players on the process and what they have achieved (Nicholson, 2015; Wiemker et al., 2015). The skills required and reflection about what was accomplished hint at the idea that ERs can be used in education.

1.3. Recreational versus educational settings of escape rooms

In contrast to recreational ERs, which intend to attract a broad audience, educational ERs are developed for a specific target group with well-defined learning goals. Educational developers aim for a high success rate; success gives students positive learning experiences, and solving all puzzles will help to achieve all learning goals. Consequently, designing ER puzzles is challenging. Firstly, the puzzles need to align with the curriculum. Secondly, puzzles need to prevent boredom and frustration, that both of which may lead to dropping out of the game (Hermanns et al., 2018). Thirdly, the puzzles' outcomes need to be numerical or alphabetical codes due to the locks involved, which limits how questions are posed. In the entertainment industry, an escape usually takes place in one or more connected permanent rooms, whereas in an educational setting such a space is usually not available. Instead, classrooms are used and teachers have limited time to set up, reset and clear away materials. Another important difference is the number of participants playing at the same time. An ER is usually designed for one team with a limited number of players (on average 3–7) (Nicholson, 2015). In education, teachers need to organize an ER activity for a whole class or course, up to hundreds of students (Cain, 2019; Hermanns et al., 2018).

Due to the differences between recreational and educational settings in classrooms, educators need to adapt the ERs concept and

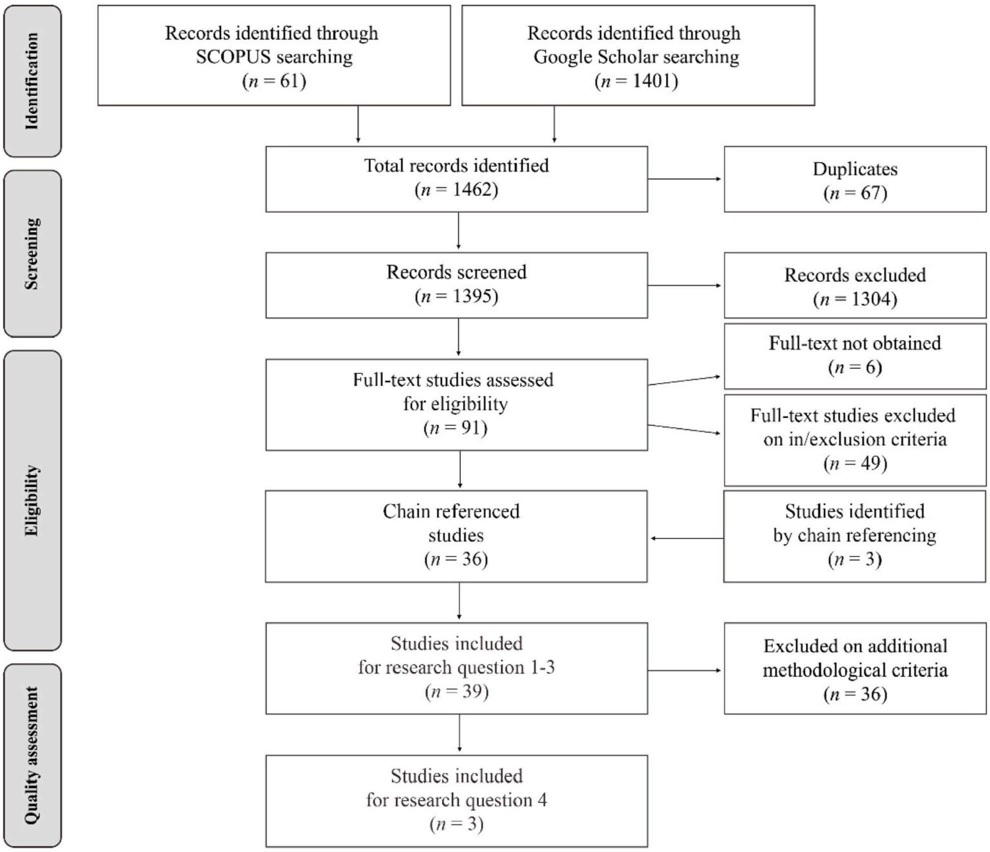

Fig. 2. Flow diagram illustrating the review selection process.

make choices on various educational and game design aspects. This review aims to synthesize the practices and their theoretical considerations on these aspects. The following research questions (RQs) are explored in this systematic review.

1. In educational ERs, what are common practices and theoretical considerations regarding their educational aspects?
2. In educational ERs, what are common practices and theoretical considerations regarding their game design aspects?
3. How are educational and game design aspects related to educational ERs?
4. To what extent have the intended goals of the educational ERs been achieved?

Regarding the educational aspects (RQ1), we studied the target groups, learning goals, the game's positioning in the course curriculum and the teacher's role. Studied game design aspects (RQ2) are: puzzles and their structuring, the game organisation, team size, playtime and the use of technology.

2. Method

This systematic review consists of the following steps based on Hannes and Lockwood (2012), p. 1) search strategy, 2) selection, 3) quality assessment, 4) data extraction and 5) data synthesis.

We conducted a search on the June 1, 2019. Databases SCOPUS and Google Scholar were searched, with the search string ("escape room" OR "escape game") AND ("education*"), identifying respectively 61 (SCOPUS) and 1401 (Google Scholar) records, see Fig. 2. All SCOPUS records also showed up in the Google Scholar search. These duplicates were excluded, as well as internal duplicates; in total 67 records. In the second step, two researchers independently screened the remaining 1395 publications' title, abstract, and keywords on defined inclusion/exclusion criteria.

As we intended to synthesize practices on ERs with physical elements for teams in classroom settings, exclusion criteria were 1) ERs for one participant and 2) completely virtual or digital ERs. These games differ in gameplay, puzzles and therefore puzzle design, game design and settings. Inclusion criteria are 1) the accessibility of the publications written in English, German or Dutch, 2) an experimental study on the development *and* evaluation of an educational ER, with 4) a design for classroom settings, with restricted setup and reset times. This excludes permanent environments such as library settings, as it has consequences for the design criteria regarding setup and reset times and game organisation.

Full text versions of the 91 studies identified at initial screening were obtained, and a checklist of all inclusion/exclusion criteria was used to establish whether to include studies in the review. This final selection process resulted in 36 publications (see Fig. 2). Three additional studies were found by chain-referencing from the studies selected for inclusion, based on the same inclusion/exclusion criteria. The final data set consisted of 39 documents, including research articles, conference proceedings, conference papers and short reports in medical journals.

In the third step, the quality of the data set (39 documents) was assessed in light of the research questions. For research questions one to three, on specific game design and educational aspects, all studies meeting the inclusion criteria were included; 39 documents. For research question four concerning student outcomes, only peer reviewed studies with assessed learning outcomes (e.g., pre- and post-tests) were included, resulting in 3 articles (see Fig. 2).

In the data extraction step, the four educational aspects (target groups, learning goals, the game's positioning in the course curriculum and the teacher's role), the five game design aspects (puzzles and their structuring, the game organisation, team size, playtime and the use of technology), were used as sensitizing concepts, following Boeije (2010). Sensitizing concepts are guiding concepts; they function as the researcher's lens through which to view the study and extract data in relation to these concepts. In addition to these aspects common in educational and (educational) game theories, the studies' field of discipline, the authors' intentions for implementing educational ERs, methodology, conclusions, and recommendations were extracted. Nicholson's (2015) categorisation of puzzle structures was used to classify the puzzle organisations in the studies, see Fig. 1.

A team of three researchers conducted this review so that at least two researchers assessed each study and extracted data with 96% agreement.

3. Results

3.1. Dataset characteristics

The 39 included studies were published between 2017 and 2019: 2017 ($n = 8$), 2018 ($n = 13$), and 2019 ($n = 18$; till June 2019). The studies, nearly all single case studies, are described in various types of documents: peer reviewed articles ($n = 24$), conference papers ($n = 2$), conference proceedings ($n = 6$), short notices or communications ($n = 5$), a poster ($n = 1$) and a book chapter ($n = 1$). Nineteen studies were carried out in the USA, most of the rest in European countries. The developed ERs were tested by various numbers of players ($n = 10$–213).

3.2. Common practices in educational aspects

3.2.1. Target groups

In the studies, target groups are participants from secondary education ($n = 3$), higher education ($n = 31$), professional development programs ($n = 3$), both higher education & professional development ($n = 1$), and one ER was open for everyone, see

Appendix A. Three of the 39 ERs were developed for informal education, all in the field of Science, Technology, Engineering and Mathematics (STEM). The rest of the ERs were developed for formal education in various disciplines. The majority, 21 ERs were developed for various medical disciplines. Fifteen ERs were developed for STEM education, two ERs covered the field of communication strategies, leadership and teamwork skills, and one ER introduced learning theories.

3.2.2. Learning goals

The studies describe learning goals in different levels of detail. To distinguish different *types* of goals, the goals are summarized at an abstract level in Appendix A. The learning goals describe (1) specific content knowledge and content related skills, (2) general skills, and (3) affective goals.

For 33 ERs, the learning goals are a *combination of content knowledge goals and related skills*, such as clinical skills. The ERs are used to *foster* ($n = 18$) and to *demonstrate* or *assess* students' knowledge and skills ($n = 14$). Less often, ERs are used to *introduce* ($n = 7$), to *extend* or to *integrate* ($n = 3$) content knowledge and skills.

Looking at the learning goals on *general skills*, most of them involve *practising* or *developing* teamwork and communication skills ($n = 20$), problem solving ($n = 11$), critical thinking and/or analytic thinking/reasoning skills ($n = 7$). In comparison to STEM ERs, medical ERs describe more general skills and affective goals, all relating to (future) career situations, such as performing under pressure, insight in one's professional functioning, formulating professional developmental goals. Examples of formulated *affective* goals are: to increase situational awareness, or on the bias of framing patients. Four out of twenty-one medical ERs describe learning goals solely on job relevant general skills and affective goals (Franco & DeLuca, 2019; Friedrich, Teaford, Taubenheim, Boland, & Sick, 2019; Seto, 2018; Wu, Wagenschutz, & Hein, 2018). The authors' rationale for these stand-alone ERs is that in debriefings on learning, the reflections on these skills easily get lost in reflections on subject specific goals. For STEM ERs, the rationale for goals on teamwork and communication is their role in active, team-based and collaborative learning and it has been shown to promote deeper understanding of content and transferability of a skill beyond the classroom (Ho, 2018).

3.2.3. The positioning of the game

An overview of the positioning of the educational ERs in the course curriculum is given in Appendix A. The positioning appears to be related to the educational setting, informal or formal, and the educational goals. For informal education, all three ERs are developed as stand-alone activities; a playful way to introduce people to STEM subjects such as robotics (Giang et al., 2018), or entomology (Healy, 2019).

In formal education, six out of 36 ERs are stand-alone activities. The rest of the ERs is embedded in a course curriculum; taking place at the introduction of a course ($n = 2$), during a course in addition to lectures ($n = 11$), or as assessment ($n = 11$). In six studies, these data are lacking. Students were assessed midterm ($n = 3$), or just before the final exams ($n = 7$). One study lacks these data. In six ERs, students were graded, using different systems. Some educators had socio-dynamic motives, as points were given to the first three teams to finish in time to prevent teams conferring (Gómez-Urquiza et al., 2019), or for attending the activity and additional points for all teams finishing in time (López, 2019). Other grading systems are closely related to the learning goals. Students were individually graded on performances during the gameplay or based on their reflection reports regarding their performances in relation to the learning goals (Franco & DeLuca, 2019; Järveläinen & Paavilainen-Mäntymäki, 2019). Clauson et al. (2019) assessed team performances during game play and individual performance using a post-test. In two ERs without assessment goals, students were graded to ensure that students take the ER activity seriously and to prevent passing on the solutions of the puzzles to other teams (Cain, 2019; Ho, 2018).

3.2.4. The teacher's role

Teachers are crucial in the learning process, also in collaborative learning (Hattie, 2009). *When* to interrupt in students' collaboration and *what* to address is challenging for teachers (Van Leeuwen & Janssen, 2019). In the studies included in this review, teachers have a role at the introduction of the game, during and after gameplay. In the introduction, players are introduced to game rules, such as the use of mobile phones, the role of collaboration and less often, the learning goals. Movies, emails, audio tapes or information sheets were also used instead of oral instruction (e.g., Cain, 2019; Franco & DeLuca, 2019).

During the gameplay, different aspects of the role of teachers and staff can be distinguished: 1) monitoring, 2) guiding, 3) providing hints, and 4) debriefing. In the studies, the assigned role varies from one aspect to all aspects, see Appendix A. In six studies, it is mentioned that players are solely *monitored*, see Appendix A. Staff members monitor the team's progression for safety reasons and to check whether players follow the rules. In contrast to recreational ERs (Nicholson, 2015), the monitoring usually takes place within the same room. In three studies, staff members adopt a role in the narrative, such as witnesses (Ferreiro-González et al., 2019), to keep the players immersed in the game narrative, as is an important precursor in game theories for engagement of players, see Section 1.2. In four studies, staff members monitor players from adjacent rooms, as seen in Appendix A. The rationale is, assumingly as in recreational ERs, the continuing immersion and feeling of ownership in players during the gameplay. However, in none of the studies we found that students felt less immersed when staff was physically in the same room. Students did feel frustration and less ownership when staff gave guidance too early (e.g., Giang et al., 2018; Järveläinen & Paavilainen-Mäntymäki, 2019), or gave no guidance when needed (Hermanns et al., 2018).

Studies refer to the *guiding role* of teachers as game masters described by Nicholson (2015), (Carrión et al., 2018; Giang et al., 2018; Mills & King, 2019). This is remarkable, as Nicholson compares the role of gamemasters to the role of good teachers; only intervene in the process when needed. In our review, some studies describe the nature of the guiding; affirming and encouraging students to work as a team (Carrión et al., 2018), giving instructions (Järveläinen & Paavilainen-Mäntymäki, 2019; Morrell & Ball, 2019), verifying answers and reasoning (Guigon, Humeau, & Vermeulen, 2018; Monaghan & Nicholson, 2017), or checking whether techniques or skills are correctly performed (Adams et al., 2018; Eukel et al., 2017; Franco & DeLuca, 2019; Gómez-Urquiza et al., 2019). In four ERs, staff guided so that teams made roughly the same progress, preventing teams from diverging too much with one team ahead of the others finishing the game and the learning process for all teams, see Appendix A.

Nineteen studies mentioned that *hints* were provided during gameplay. Twelve studies described hint rules and systems. The use of specific hint rules and systems prevails more in ERs with assessment goals (7/11) than without assessment goals (5/28). Used hint rules are 1) teams get a restricted number of hints (Brown et al., 2019; Eukel et al., 2017; Franco & DeLuca, 2019; Gómez-Urquiza et al., 2019), 2) the first hints are free, but if more hints are needed, a time penalty is given (Adams et al., 2018; Cain, 2019; Clauson et al., 2019; Vergne, Simmons, & Bowen, 2019), and 3) players had to earn a hint by making a small knowledge test which takes time (Lopez-Pernas, Gordillo, Barra, & Quemada, 2019). Hints can be delivered to players personally or by pre-set hint cards. For pre-set hint cards, developers need to know precisely what players need at which moment (Eukel et al., 2017; Ho, 2018). Motives for the use of hint cards are not described. We assume that the cards are used to prevent disruption to the players' immersion and feeling of ownership, elements of various educational theories (see Section 1.1).

In addition to feedback by staff, locks provide immediate and unambiguous feedback to learners, which is important in the learning process (see Section 1.1). Monaghan and Nicholson (2017) regard this as one of the powerful aspects of an ER. However, other educators reflect on the loss of direct feedback by teachers on learning opportunities. This is due to the time constraint, as you cannot stop time and discuss the situation (Franco & DeLuca, 2019; Mills & King, 2019).

The role of the teacher after the gameplay is to debrief. A debriefing is a common element in recreational ERs (Nicholson, 2015). In this review, more than half of the studies (25/39) mention a form of debriefing, usually in facilitated small group discussions. The duration ranges from 5 min to 2 h, which reflects the importance given to the debrief by the educators. We have listed and summarized components of the debriefs mentioned. In general, a debrief start with 1 and 2, followed by 3–7 in no particular order.

1. Time to decompress after the intense gameplay, with room for primary reactions. This phase is also known in recreational ER as a cooling down period (Nicholson, 2015).
2. Exchange of experiences on the gameplay, as developers want to get feedback on the activity.
3. Questions and concerns of participants. Participants can ask questions and verify their reasoning.
4. Discussion of the puzzles, content course knowledge and skills needed to solve them. The relation to the learning goals is seen as crucial, to solidify the learners' knowledge as they recall and elaborate on the course content.
5. Extent of content knowledge. For example, to connect the knowledge and skills to other contexts, or discuss new topics encountered during gameplay.
6. Feedback on students' performances. The feedback is given in relation to learning goals and is important in ERs with an assessment goal.
7. Reflection on the individual learning process and formulating goals for future developmental goals or job skills.

Students acknowledge the role of debriefing in the learning process, for example, on the postulation "debriefing helped to understand the course content," 84.5% of 142 students agreed (Friedrich et al., 2019, p. 2).

3.3. *Common practices in game aspects*

3.3.1. *Puzzles and puzzle structure*

In all 21 medical ERs, a sequential puzzle path is used, as seen in Appendix A. Cain's (2017, p. 2) choice for this structure is intentional; "a consequence of the sequential nature of the learned process by the students. Besides, the linearity reduced the variability in 'paths', and eased the guidance of the teachers while the 24 teams were playing at the same time." This argument applies when a large number of teams is at work, and course content has a sequential nature. The use of sequential puzzle structures in other medical ERs seems self-evident. A possible explanation is that it resembles the common practice of case based or simulation-based education (Jenkin & Fairfurst, 2019).

The fifteen STEM ERs show a greater diversity in puzzle paths; sequential, path-based and hybrid puzzle paths, as summarized in Appendix A. The use of a sequential puzzle path is explained four out of five times; students need to work according to a learned sequential analytic or other method (Healy, 2019; Järveläinen & Paavilainen-Mäntymäki, 2019; Vergne et al., 2019), or follow the historical footsteps of a scientist during his discovery and its consequences in time (Dietrich, 2018). The choice of path-based or hybrid structures is motivated by the stimulation of active or collaborative learning by means of positive social interdependency. By forcing teams to split, students need to discuss the relation of the puzzles and build on each other's knowledge. The hybrid structures found in STEM rooms have a strong linearity. Puzzles done in parallel lead together to the unfolding of a next layer of puzzles (Ferreiro-González et al., 2019; Guigon et al., 2018). The rationale is that more linear pathways are easier for students to understand, therefore less guidance is needed, and progression is easier to monitor (e.g., Guigon et al., 2018; Lopez-Pernas et al., 2019). Among the 39 ERs, the open structure appears to have been used once, in an ER on communication and teamwork skills (Clarke et al., 2017).

The description of the puzzles showed that some puzzles were based on puzzles common in recreational ERs, such as sudokus, rebuses, crosswords, jigsaw puzzles, cryptograms and riddles. Other puzzles resembled course tasks with a puzzle twist added. Some studies mentioned the use of intentional deceivers, *red herrings*, a common feature in recreational ERs.

3.3.2. Game organisation

Even within the relative short time period spanning this review, an evolution in educational ER organisation can be seen. Most of the first ERs were copied from recreational ERs, usually with only one team at a time playing (Nicholson, 2015). If more or all teams play at the same time, it will considerably reduce both the time investment for the educators and the occupancy rate of the rooms. However, it requires more materials and trained staff. Carrion et al. (2017) and Clauson et al. (2019) describe settings where two teams at the same time play in different rooms. In Guigon et al. (2018), two teams play independently in the same room. In one third of the studies, educators scale the game up to whole classes. Here teams play in competition with each other, though they are sometimes forced to cooperate at some point (Ho, 2018; Morrell & Ball, 2019).

We see two developments in the designs where all teams play at the same time. First, instead of one room where the gameplay takes place, the game spreads over the whole building or area (e.g., Boysen-Osborn, Paradise, & Suchard, 2018; Franco & DeLuca, 2019). The second development is the use of boxes. The use of “a box with a lock” is common practice, thanks to Breakout EDU (see Introduction). In other studies, big boxes are used that include all puzzles in locked files or smaller locked boxes. One box centres the activities of one team and, all teams work alongside each other in the same room (Healy, 2019; Monaghan & Nicholson, 2017). Digital technology used to facilitate upscaling ERs for whole classes is discussed in Section 3.3.5.

3.3.3. Team size

Appendix A shows the group sizes in the studies. A group size of two was used once, to require students to work on all the puzzles, and thereby on all concepts and skills (Lopez-Pernas et al., 2019). In 24 of the 32 studies which mention the team size the range is 3–6 players, as educators want to prevent “free-riding”, and create more participation and immersion of students during gameplay (Adams et al., 2018; Cain, 2019). Four additional studies advised a group size in this range after their gameplay with larger numbers, see Appendix A. These studies, all medical, explained that not everyone in the pilots was or could be active, as is conditional for active or collaborative learning.

Two studies specifically researched the team size in their educational ER. The outcome of one study is that, with a group size of four, everyone can be active and involved in the group process (Watermeier & Salzameda, 2019). Another study researched the team size in relation to the required playtime. Teams with more than six participants required more playtime than teams with six participants. And none of the teams with group sizes higher than six were able to escape in time due to the observed loss of communication and organisation in teams with higher numbers (Eukel et al., 2017). A team size up to four or five players is advised in ERs with individual grading. (Ho, 2018; Järveläinen & Paavilainen-Mäntymäki, 2019).

3.3.4. Play time

The playtime in ERs is constrained, giving urgency to the players’ actions. Table 1 shows the number of ERs with a specific amount of playtime. This is the time players actually spend on the puzzles, without the instruction before the gameplay and the debriefing afterwards. The range of the playtime is 20–120 min, with most games lasting 60 min. The choice for a specific playtime is seldom underpinned by specific pedagogical reasons. If explicated, one refers to the common practice of recreational ERs. Other studies refer to classroom time slots (e.g., Franco & DeLuca, 2019). The playtime is not related to formal or informal education, or a specific discipline, see Appendix A. In informal, formal, STEM or medical education, the median is alike, 60 min.

The allowed playtime (maximum duration of the gameplay) and their number in the studies (n = 39). The range is 20–120 min, the median is 60. For five escape rooms, this data is lacking in the studies.

In medical studies, the time constraint is considered not only as a game design aspect, but also an educational aspect, as collaborating under time constraints is a life-saving skill in medical professions. In other disciplines or settings, the restricted time is a way to create social interdependence; everyone is needed to finish all the puzzles in time.

For education, it is important that as many students as possible reach all goals in time, and frustration, dropping out, or trial-and-error behaviour are prevented. In two studies where none of the teams succeeded, students mentioned being frustrated, showed trial-and-error behaviour, and were most critical about achieving the educational goals (Hermanns, 2018; Mills & King, 2019). These studies conclude that playtests to define a realistic playtime are crucial in an ER design.

Table 1
The number of escape rooms with a specific amount of playtime.

Allowed playtime (min.)	Number of escape rooms with a specific playtime
20	1
30	4
45	3
60	20
75	1
80	1
90	3
120	1
Total number of escape rooms	**34**

3.4. The use of digital technology

As seen in Appendix A, twenty ERs implemented digital technology. In four studies, technology is used to monitor the safety and progression of learners from an adjacent room (see Appendix A, 'Role teacher and staff'). In nine out of the 21 medical ERs, technology is mainly used to structure the gameplay and so ease the work of the teacher, which is especially important for large groups. Examples are the unlocking of puzzles by scanning a QR code or the combination of technologically mediated validation of answers, linked to the unlocking of a code or a cardio photo (e.g., Cain, 2019; Franco & DeLuca, 2019; Gómez-Urquiza et al., 2019; Hermanns et al., 2018). Students also need IT tools to search and interpret medical information (e.g., Brown et al., 2019; Eukel et al., 2017; Monaghan & Nicholson, 2017).

In nine out of fifteen STEM ERs, IT tools are used mostly as part of the learning goals (e.g., Borrego, Fernández, Blanes, & Robles, 2017; Giang et al., 2018; Lopez-Pernas et al., 2019). In addition, the technology is used to structure the game, especially for large groups (Guigon et al., 2018; Järveläinen & Paavilainen-Mäntymäki, 2019). Technology is also used to support the narrative and to enhance immersion, for example with a security video footage of a crime scene.

3.5. How are educational and game aspects related to educational escape rooms?

Implementing GBL requires an understanding of the relations between educational and game design aspects, see Introduction. In the previous Sections, common practices in educational ERs in relation to specific educational and game design aspects are synthesized. Subsequently, the following relations become evident.

3.5.1. Goals & related aspects

The function of an ER in the learning trajectory and the specific learning goals are decisive for its design. Sequential puzzle pathways were implemented when learning goals comprised a sequential process which students had to follow, or when students were assessed individually. Path-based and specific hybrid structures were implemented ensuring that all participants are active and interdependent, to scaffold active and collaborative learning.

ERs with learning goals solely on *introducing* a subject, general skills or affective goals, are all stand-alone activities. ERs that are intended to foster content knowledge and related skills are embedded in a course curriculum, usually positioned in addition to lectures. ERs with formative assessment goals are positioned either mid-term or just before the final exams. Whether or not students are assessed during game play has consequences for the role and amount of staff, the group size of students, and the (fair) delivery of hints. The use of hint rules or systems prevailed more in ERs with an assessment goal.

In STEM ERs, the implementation of technology is often related to the learning goals. Technology is also used to scale up for large enrolment, resulting in the need of less staff in other roles.

3.5.2. Group size and playtime

The aspects of group size and playtime in the educational ERs are independent of the setting, target group, discipline or any other studied aspect. This is remarkable for the aspect of playtime, as STEM and medical educators appoint different roles for the restricted time in the learning process during escape games. The playtime seems more determined by available time slots and the assumed common practice in recreational ERs.

3.6. To what extent have the intended goals of educational escape rooms been achieved?

In 36 out of the 39 studies, the educators' intentions to implement an ER is 1) to *explore* an active learning environment which is said 2) to increase students' motivation and/or engagement, 3) to foster learning, while 4) practising or developing teamwork and communication skills. To what extent these goals have been achieved will be discussed in this Section.

3.6.1. To explore an active learning environment

The most important intention for implementing educational ERs for educators is to explore an active learning environment. The studies usually refer to a specific pedagogy such as active, collaborative, team-based and/or game-based learning, see Appendix A. The studies concluded that the development of an active learning environment was successful. However, in their considerations educators refer not only to pedagogies such as active, collaborative or team-based learning, but also to practices in recreational ERs, or seem based on classroom practice (as seen in Section 3.2 and 3.3). This makes sense as the current educational ERs are not designed from theory by designed based research but adapted from a recreational activity. In Section 4.4 a framework is introduced, which recognises the current practice of a complexity in the educators' decisions with a variety of considerations and guides alignment of the various decisions on specific crucial parts of educational ER design.

3.6.2. To increase students' motivation and/or engagement

The studies based their conclusions on 'informal observations', meaning observations without pre-set points of attention. In addition, participants gave feedback after the gameplay in group discussions and/or in post activity surveys. As the studies used different questions, postulations and answer scales, it is not possible to aggregate the answers. However, in all studies a vast majority of students enjoyed the activity and educators concluded that students were highly engaged and active during the activity.

Sometimes, it is stated that students become intrinsically motivated for learning by playing ERs (e.g., Giang et al., 2018; Peleg, Yayon, Katchevich, Moria-Shipony, & Blonder, 2019; Watermeier & Salzameda, 2019). However, we found no basis for these conclusions. Moreover, extrinsic factors such as competition, time constraints and grading, were involved. We assume that the researchers interpreted the motivation for winning as intrinsic motivation for learning, more discussion on this topic in Section 4.1.4. One study with 84 participants tested for gender bias (Lopez-Pernas et al., 2019). The male participants showed a high inclination towards gaming, whereas the females showed a statistically significant lower interest. However, no gender bias was detected in any of the questions in the surveys that addressed the ER activity.

3.6.3. To improve learning

In the studies, participants were asked about their learning in feedback sessions and/or post activity surveys. The participants ranging from a majority to all, perceived that the ER environment helped them achieve the learning goals, and/or agreed on implementation in their curriculum.

Only three studies measured the achievements on the learning goals by means of a pre- and post-knowledge test. In addition, one of the studies compared the learning outcomes of the ER with the regular case activity on infectious diseases (Cotner et al., 2018). Both activities were perceived positively. The ER was preferred by eighteen of the nineteen students, but only eleven of the nineteen students indicated they learned better from the activity. The scores dropped in the post-test for the regular case activity, from 90.5 to 82.1. After the ER, neither a knowledge drop or gain was shown. A debriefing session after the ER was not mentioned. A limitation is that only nineteen students participated in the study. In Clauson et al. (2019), the overwhelming majority of students (96%, $n = 51$) experienced that the debrief on the pharmacy knowledge improved clinical skills and facilitated learning. However, the pre-test/post-testshowed no significant results. In the third and last study, a cross-sectional pre-test/post-test research design was used to assess the students' performances ($n = 74$) (Eukel et al., 2017). Students' mean score for the post-test, 81%, was statistically higher than the mean score for the pre-test 56%, $p < 0.001$. A week passed between the pre-knowledge test and the escape game. As the prospect of an ER with a competitive character might have stimulated students to study the content knowledge in the meantime, the knowledge increase cannot be solely attributed to the game. So, out of the three studies, one showed a disputable improvement in content knowledge after an educational ER, while most students experienced learning.

Interestingly, Lopez-Pernas et al. (2019) showed that their students' engagement ($N = 124$) and their perceived learning in ERs are related. Moreover, the students who were already comfortable with the course topic were the ones who made the most of the ER. In this regard, it is interesting that studies evaluating ERs with goals to acquire new knowledge contained the most critical remarks on the effectiveness of learning (Giang et al., 2018; Mills & King, 2019; Vörös & Sárközi, 2017). The last study, concluded that students only retained information that had helped them solve the puzzles, and for deeper understanding of new topics additional classes are needed. Giang et al. (2018) and Mills and King (2019) have similar conclusions.

3.6.4. To practise and develop teamwork and communication skills

Twenty-one studies mentioned practising or developing teamwork and communication skills as intentions for implementing an educational ER. Nineteen studies evaluate these goals based on educators' informal observations and/or students' self-perception. Four ERs have goals solely on general skills, such as teamwork and communication skills (see Appendix A). Educators and students agreed that the activity promoted teamwork and communication. For example, in Friedrich et al. (2019), p. 79.5% of the 142 students did so, and 76.1% regarded it a valuable addition to the curriculum. Seto (2018) concluded that their ER addressed every competency in the team skill domain, and strengths and challenges could be indicated and discussed with students afterwards. Likewise, studies combining content knowledge and skills with general skills, concluded that teamwork and communication are practised and/or developed in ERs. The study on learning in teams during an ER, concluded that team dynamics were more diverse with time limited (Ho, 2018). Based on the studies, we conclude that, with an adequate design, teamwork is conditional to finish an ER in time and it is possible to assess and discuss the teamwork and communication skills afterwards.

4. Conclusions and discussion

The main purpose of this article is to review common practices and their theoretical considerations in educational ERs, regarding specific educational aspects (RQ1) and game design aspects (RQ2), how these aspects are related (RQ3), and to what extent the goals of these ERs have been achieved (RQ4). In nearly all studies, educators developed an ER to explore an active learning environment aiming to increase students' motivation and engagement and fostering learning, while developing teamwork, communication and other general skills.

4.1. Common practices and their theoretical considerations on educational aspects (RQ1)

In this review, target groups of the ERs are participants from secondary education, higher education, professional development programs, and "everyone". The described ERs are mostly implemented in formal education; the majority in medical education (22/39), and STEM education (15/39). The learning goals describe specific content knowledge and content related skills, general skills, and affective goals. In medical ERs, the content related goals are combined with goals on general skills and affective goals related to profession. The general goals that are mentioned most often are teamwork and communication skills. In STEM ERs, the rationale for stimulating students' teamwork and communications skills is the relation with active and collaborative learning. In informal education, all ERs are stand-alone activities. In formal education, depending on the educational goals, most ERs are imbedded in the course curriculum and take place either at the start of a course, in addition to lectures or just before the final exams. One third of the ERs was developed to assess students. Grading systems differed in *who* was graded (team or individual) and *what* was graded (solely the gameplay or with the preparation and reflection on learning afterwards). The diversity was due to the different learning goals of the ERs. Moreover, some educators used socio-dynamic motives for their grading Van Leeuwen and Janssen (2019) showed that the teacher's role in collaborative learning is crucial, and w*hen* to interrupt in students' collaboration and *what* to address is challenging for teachers. This seems even more challenging in educational ERs. We see this firstly, reflected in the different aspects of the role teachers adopted during the gameplay: monitoring, guiding, providing hints, and debriefing. Secondly, in the studies, the assigned role variates enormously, from one aspect to all aspects. The students' reactions show that the intervening of teachers is more delicate and challenging as the students' immersion and highly valued feeling of autonomy appear at stake. These elements are important in GBL theory (see Section 1.2) and appear guiding in decisions whether or not staff is in the same room during gameplay, staff has a role in the narrative, or pre-set hints are used. Only half of the studies mention a debrief after the play game. The debriefs vary in components and duration (5–120 min), due to the assigned educational value of debriefing. All components together cover the elements of Lederman's model on debriefing as a systematic evaluation of theory and practice (Lederman, 1992).

The studies do not describe considerations for all choices made in relation to the studied educational aspects. The considerations 1) refer to theories on collaborative learning, game-based learning or game theories, 2) refer to common practices in recreational ERs and/or 3) seem based on classroom practice.

4.2. Common practices and their theoretical considerations on game design aspects (RQ2)

In educational ERs, various forms of puzzle structures are used, seemingly less complex than in recreational ERs. When the nature of the learned process is sequential or students are graded on their performances during the gameplay, educators choose a sequential pathway. Another rationale for the overall use of sequential puzzle paths in medical ERs is that it resembles the common practice of case and station-based education. In STEM ERs, besides sequential puzzle paths, path-based and hybrid puzzle paths are also used to create positive social interdependency and stimulate collaborative and active learning. A trend is visible in upscaling the game for more or all teams at the same time. This means that either the "room" aspect of the ER concept is abandoned, or the "escape" aspect, as the use of an all-inclusive puzzle box per team requires a "break in". A group size of 4–6 players seems most suitable for immersion, participation and group communication during game play. It seems independent of the discipline or educational setting (informal or formal). The playtime has a range between 20 and 120 min, with a median of 60 min, independent of the educational setting or discipline. This is remarkable as STEM and medical educators ascribe different roles to the restricted time in the learning process during escape games. The playtime seems more determined by available time slots and the assumed common practice in recreational ERs. Technology is implemented in educational ERs for various reasons; 1) to monitor the safety and progression of students from adjacent rooms, 2) to foster students' subject related IT skills, 3) to support the narrative and enhance immersion, and mostly 4) to structure the gameplay by verifying answers and unfolding new puzzles, codes or additional content knowledge. Educators intend to research the possibilities for the last two reasons more thoroughly, to upscale the activity for the whole class with limited staff, and to create autonomy and ownership for students. Related research in the field of educational ERs describes the development of open-source tools ('decoders') to validate players solutions (Ross, 2019), the implementation of digitally pre-set hints and the role of technology in creating immersive authentic learning environments which confront learners with outside world problems (Veldkamp et al., 2020).

The studies do not describe considerations for all choices made in relation to the studied game aspects. The considerations 1) refer to theories on collaborative learning, game-based learning or game theories, 2) refer to common practices in recreational ERs and/or 3) seem based on classroom practice of case based and simulation-based medical education.

4.3. Relations between educational and game design aspects (RQ3)

Educators start their design process with defining educational goals, which guide choices on the puzzle path, the role of technology and the teacher's role during the gameplay. Moreover, these aspects are interrelated too. Two models on designing educational ERs are those of Clarke et al. (2017) and Guigon et al. (2018). The model of Clarke et al. (2017) corresponds to a step-by-step plan to design a recreational ER (Clare, 2015), adding educational aspects as learning goals and their evaluation. It was tested on staff (N = 13). Guigon et al. (2018) developed a model based on a model for roleplaying games in education, which was tested on twenty participants. In this model, an ER consists of rounds of puzzles**.** The gameplay is followed by a debriefing.

Both models provide a rather linear view of the design of ERs and their use in classrooms. The current review, however, shows that more complex patterns of goals, puzzle paths, teacher support and grading occur in the design of educational ERs.

4.4. Achievement of intended goals (RQ4)

In all studies, a vast majority of students enjoyed the activity and was highly engaged during the activity, more than in comparison to regular classes. Educators used ERs mostly in addition to lectures to foster or assess knowledge and skills, and they were satisfied with the goals reached. ERs also seem suitable to experience new phenomena, but less to acquire new knowledge. Only three out of the 39 studies assessed learning by means of a pre-test/post-test, and only one study showed a disputable improvement in content knowledge. This is in contrast with the self-perceived learning of participants and their teachers. With an adequate design, teamwork and communication skills are conditional to finish in time. Moreover, it is feasible to assess and discuss the teamwork and communication skills of students afterwards.

The findings on the discrepancy between perceived and actual learning of content knowledge are in line with other findings on educational games (Minner, Levy, & Century, 2010) and on practical work (Abrahams & Millar, 2008; Minner et al., 2010). Based on their research, these studies advise active linking of knowledge during and after the interventions. In educational ERs, the restricted time gives the players' actions urgency and a strong motive for teamwork. Reflective breaks do not align with a time constrained gameplay; players lose time and immersion, which are both important in ERs. However, a debrief with active linking of knowledge can take place afterwards and, according to Sanchez and Plumettaz-Sieber (2019), fosters learning. More research is needed on the systematic evaluation of sustained learning of content knowledge and content related skills, including a debrief.

For educational ERs educators define educational goals and a game goal. The educators' intention is that by reaching the game goal, students achieve the educational goals set. Matching game goals and learning goals is relevant to the design of educational games in general. For instance, Van Leeuwen and Janssen (2019) present an "intrinsic integration" theory that states the importance of game goals and learning goals and analyses the implication of this for the relation between game mechanics and pedagogical approaches (see Fig. 3).

Applying this to ERs, one can see that specific pedagogical approaches can be related to specific game mechanics, or in this case, ER characteristics, such as the puzzle structure. In our review, we have seen that in medical ERs, approaches such as team-based or collaborative learning do not align with game mechanics like sequential puzzle structures or a team size higher than six participants. Whereas in STEM ERs, collaborative learning was better aligned with the puzzle structure and team size.

The use of intentional deceivers, red herrings, copying recreational ERs was not positively evaluated (e.g., Mills & King, 2019). Although this common game aspect, as part of the game mechanics might add to the atmosphere, the red herrings in those ERs did not align with the pedagogical approach and achieving the learning goals in a restricted time. One can argue that messiness might contribute to simulating authentic situations. In Monaghan & Nicholson's ER (2017), messiness was created by presenting ambiguous medical information students had to analyse as part of the learning goals. Here, alignment in game and learning goals, pedagogy and game mechanics resulted in satisfaction of students and educators.

To conclude, ERs found their niche in educational settings, bringing time constrained authentic work settings or outer world situations into the classroom. The problem-based and meaningful activities in educational ERs provide environments that activate students and requires them to collaborate. This also means that teamwork and communication skills are conditional for finishing the ER in time. Consequently, ERs also have potential to help improve these skills. However, this requires embedding them in the teaching and learning situation at large, for instance by providing preparation and debriefing activities. The outcomes of this review study and the introduced framework shows that educators' decisions on educational ERs are a complex of set of interrelations, which need to be aligned in order to implement an educational game which achieves the desired students' behaviour and outcomes. This framework can not only help educators align their choices in the described educational and game aspects, grounded in theory and related pedagogy. Furthermore, the framework can guide educational researchers in research focus on the interrelations and alignment.

In Appendix B we have summarized a number of recommendations, based on our outcomes and in line with the intrinsic integration theory. We expect that these will help educators in the design and implementation of ERs. In combination with more systematic evaluation of students' outcomes, these recommendations might help the development of highly engaging learning environments where students foster knowledge and skills.

Declaration of interest statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Alice Veldkamp: All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication. **Liesbeth van de Grint:** All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication. **Marie-Christine P.J. Knippels:** All authors listed have made a substantial, direct and intellectual

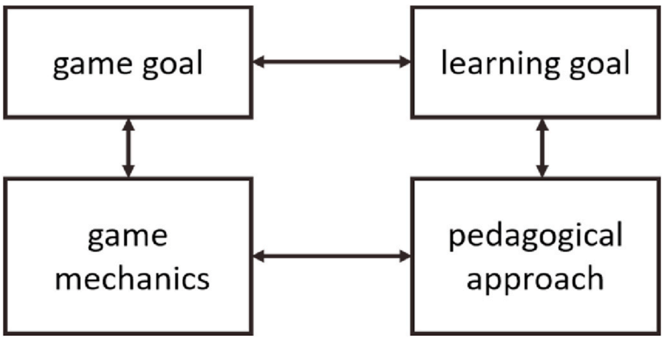

Fig. 3. *The design framework on alignment between the game goal, learning goal, pedagogical approach and game mechanics* (Van der Linden, van Joolingen, & Meulenbroeks, 2019.

contribution to the work, and approved it for publication. **Wouter R. van Joolingen:** All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

Acknowledgements

The authors gratefully acknowledge Talitha Tijsterman, graduate Science Education and Communication, Utrecht University for her assisting role during the research.

Appendix A. Summary table on educational and game design aspects in studies on educational escape rooms

Authors	Educators' intentions with ER	Target-group	Disci-pline	Learning objectives	Positioning in course curriculum	Role teacher and staff	Puzzle pathway	Game organisation	Team size	Play-time (min.)	IT tools
Adams et al. (2018)	To explore an active learning environment using GBL and adult learning theory, to motivate and engage students in order to develop TWS, communication skills and critical thinking.	PD&HE	MED	To demonstrate content knowledge and related skills, to develop TWS, com. Skills and critical thinking.	Formative assessment.	Monitoring & guiding in room: assess performed skills. Hint system: 3 free, more hints -> time penalty. Debriefing: 2, 4.	U	One team	*6–14*	60	N
Arnal et al. (2019)	To demonstrate a teaching environment using collaborative learning for future career, to motivate and engage students towards maths.	HE	STEM	To foster content knowledge and related skills (e.g., mathematical reasoning), to use TWS, awareness of possibilities ER as educational environment.	U	Monitoring & guiding in room: hints.	U	All teams	U	U	Y
Borrego et al. (2017)	To explore an environment to motivate students, to foster learning.	HE	STEM	To demonstrate and foster content knowledge and related skills.	In addition to lectures.	Monitoring from adjacent room.	H	One team	U	60	Y
Boysen-Osborn et al., 2018	To explore an environment to increase students' engagement and foster medical knowledge and teambuilding.	HE	MED	To demonstrate and foster content knowledge and related skill (e.g., recognize poisonings related to course content).	Formative assessment; midterm exam.	Monitoring in room, no hints. Debriefing: 3, 4.	S	All teams	5	60	N
Brown et al. (2019)	To explore an active learning environment for urosepsis simulation.	HE	MED	To foster content knowledge and related skills (e.g., administration proper medicines, interpreting lab results).	In addition to lectures.	Monitoring & guiding in room: hints. Hint system: one hint card. Debriefing: 2, 4, 7.	S	One team	6–8	60	Y
Cain (2019)	To explore an active learning environment, to increase students' engagement and prevent free riding in group work.	HE	MED	To foster content knowledge and related skills.	In addition to lectures.	Monitoring & guiding in room: Hint system: 1 free hint, more needed: time penalty. Hint also given to groups lagging behind. Debriefing: 1, 4.	S	All teams.	5–6	45	Y
Carrión et al. (2018)	To explore GBL, enhancing active learning, increase students' engagement and foster medical knowledge.	HE	MED	To assess content knowledge and related skills, to integrate content knowledge of two different subjects, to practice English.	Formative assessment; prior to exam.	Monitoring & guiding in room: role GM, encouraging to work as a team.	S	Two teams parallel in same room.	*14–16*	60	N
Clarke et al. (2017)	to evaluate a design framework for	HE	OTH	To foster communication	Stand alone.	Monitoring from adjacent room.	U	One team.	*3–6*	20	Y

(*continued on next page*)

(*continued*)

Authors	Educators' intentions with ER	Target-group	Disci-pline	Learning objectives	Positioning in course curriculum	Role teacher and staff	Puzzle pathway	Game organisation	Team size	Play-time (min.)	IT tools
	educational ERs, the feasibility of the ER and acceptance of staff.			strategies and skills, leadership, TWS.							
Clauson et al. (2019)	To explore an environment to assess student readiness for advanced pharmacy practice experiences, while developing TWS, problem solving, critical thinking.	HE	MED	To assess content knowledge and related skills and TWS, critical thinking, problem solving, to develop reasoning skills.	Formative assessment; prior to exam.	Monitoring, observing & guiding in room. Hint system 1 free hint, more needed - > time penalty. Debriefing: 2, 3, 4, 6.	S	Two teams in different rooms.	5–6	60	N
Cotner et al. (2018)	To explore an active learning environment.	HE	MED	To foster content knowledge and related skills.	In addition to classes.	U	U	U	U	U	U
Craig et al. (2019)	To explore an environment to foster course subject, and to increase TWS and students' ability to work in time.	HE	OTH	To foster content knowledge: (communication strategies), and related course skills (communication, TWS) and ability to work in time.	Stand alone.	Monitoring in room. Debriefing: 4, 6, 7.	P	One team.	4–6	30	N
Dietrich (2018)	To explore active learning strategy using GBL to motivate and engage students in order to develop TWS, comm skills.	HE	STEM	To demonstrate and extent content knowledge and skills, develop communication skills and TWS.	In addition to lectures.	Monitoring in room. Debriefing: 4, 5.	S	All teams.	5–7	60	N
Eukel et al. (2017)	To explore a form of GBL, to foster knowledge.	HE	MED	To foster content knowledge and related skills, using TWS.	In addition to lectures.	Monitoring & assess on performed skills from adjacent room. Hint system: 4 pre-set hint cards.	S	One team.	5	75	J
Ferreiro-González et al. (2019)	To explore GBL, to foster active learning, and to motivate and engage students.	HE	STEM	To foster content knowledge and related skills (e.g., analytic thinking).	In addition to lectures & practicals.	Monitoring & guiding in room, by use of characters answering questions.	H	One team.	*6–10*	60	Y
Franco and DeLuca (2019)	To explore an activity with active learning approach to simulate interdisciplinary teamwork environment, to foster critical thinking and problem solving.	HE	MED	To assess and develop teamwork, critical thinking, problem solving, leadership.	Formative assessment; midterm exam.	Monitoring, observing for feedback & assessing in room. Hint system: 2 free hints. Debriefing: 1, 2, 6, 7.	S	All teams.	6	90*	Y
Friedrich et al. (2019)	To explore GBL to engage students, to foster learning and communication skills	HE	MED	Awareness of importance of interprofessional communication and to develop interprofessional communication, and TWS.	Stand alone.	Monitoring in room. Debriefing: 4, 5, 7.	S	One team.	*8*	45	N
Giang et al. (2018)	To explore an environment to motivate and engage students.	ALL	STEM	To get introduced to new subject and related skills, to develop problem solving skills.	Stand alone.	Monitoring, observing & guiding in room: role GM, providing hints. Debriefing: 3, 4, 6.	P	One team.	3–5	30	Y
		HE	STEM		U	Debriefing: 2.	U	One team.	4–5	60	Y

(*continued on next page*)

(*continued*)

Authors	Educators' intentions with ER	Target-group	Disci-pline	Learning objectives	Positioning in course curriculum	Role teacher and staff	Puzzle pathway	Game organisation	Team size	Play-time (min.)	IT tools
Glavaš and Staščik (2017)	To demonstrate a teaching environment to motivate and engage students towards maths.			Awareness of possibilities ER as educational environment.							
Gómez-Urquiza et al. (2019)	To explore an environment to assess theoretical and practical knowledge.	HE	MED	To assess content knowledge and related skills, to develop TWS and performing under pressure.	Formative assessment.	Monitoring, assessing performed skills & guiding: hints in room. Hint system: 2 free hints.	U	One team.	5	30	Y
Gordon, 2017	To explore an active learning strategy, to foster collaborative learning, to motivate and engage students.	HE	MED	To acquire new content knowledge and skills, to develop TWS.	Introduction to new subject.	Debriefing: 2, 4.	S	One team.	U	U	N
Guigon et al. (2018)	To evaluate a design framework for educational ERs, to motivate students by active learning.	HE	STEM	To foster content knowledge and skills.	In addition to lectures.	Monitoring & guiding in room, in a way that teams make same progression, verifying reasoning. Debriefing: 3, 4, 7.	H	Two teams in different rooms.	5	90	Y
Healy (2019)	To explore an active learning strategy to inform students on the study entomology in engaging way.	SE	STEM	To get introduced to new subject and related skills, to develop TWS, communication skills and problem solving.	Stand alone.	Hint system: 4 free hints. Debriefing: 3, 4, 5.	S	All teams.	5	60	N
Hermanns et al. (2018)	To explore an active learning strategy to engage students.	HE	MED	To foster content knowledge and related skill, to develop TWS, com. Skills, problem solving and critical thinking.	U	Monitoring in room. Debriefing: to increase understanding, 2.	S	All teams.	4–5	60	Y
Ho (2018)	To explore a learning environment to motivate and engage students, foster content knowledge and skills.	HE	STEM	To foster content knowledge and skill, to develop critical thinking.	In addition to class.	Monitoring in room. Hint system: pre-set hints. Debriefing	H	All teams.	4–5	60	Y
Järveläinen & Paavilainen-Mäntymäki, 2019	To research learning strategies in groups, to motivate students by active learning.	HE	STEM	To assess content knowledge and related skills.	Assessment: prior to final exam.	Monitoring & guiding in room: affirm, hints and direct instructions.	S	One team.	4–6	45	Y
Kinio, Dufresne, Brandys, and Jetty (2019)	To explore with a learning environment to activate and motivate and engage students in job related roles.	HE	MED	To foster content knowledge and related skills.	In addition to lectures.	U	U	U	3–4	60	N
López (2019)	To explore an active learning activity to motivate an engage students.	HE	STEM	To assess content knowledge and related skills, to develop TWS.	Formative assessment; prior to exam.	Monitoring & guiding in room: hints. Hint system: hints unlimited, received after small test which takes time.	H	All teams.	2	120	Y
Mills and King (2019)	To explore with active and exploratory learning.	HE	OTH	To acquire new content knowledge and related skills.	Start of higher education.	Monitoring and guiding from adjacent room, as GM: feedback and hints. Debriefing: 1, 7.	U	One team.	4	60	Y
		HE	MED				S	All teams.	<5	60	Y

(*continued on next page*)

(*continued*)

Authors	Educators' intentions with ER	Target-group	Disci-pline	Learning objectives	Positioning in course curriculum	Role teacher and staff	Puzzle pathway	Game organisation	Team size	Play-time (min.)	IT tools
Monaghan and Nicholson (2017)	To explore an active learning environment, to foster collaborative learning.			To foster and extent content knowledge and related skills; use TWS, problem solving skills, awareness of frequency and risks of sepsis, awareness of framing patients.	In addition to lectures.	Monitoring & guiding in room, by use of characters: check solutions, provide key to new puzzle. Debriefing: 4, 7.					
Morrell and Ball (2019)	To explore an active learning environment based on adult learning principles, to increase student engagement.	HE	MED	To formative assess content knowledge and skills, use TWS.	Formative assessment.	Monitoring, assess & guiding: check solutions, indicate how to continue. Hint system: 3 free hint. Debriefing: 3, 6, 7.	S	All teams; need to cooperate to unfold next layer of puzzles.	U	60	Y
Mosley, Rogers, & Smith, 2018	To explore an active learning environment for simulations.	PD	MED	To acquire new content knowledge and related skills, situational awareness, awareness of confirmation bias.	Stand alone.	Debriefing: 4.	U	One team.	U	60	N
Nelson, Calandrella, Schmalbach, and Palmieri (2017)	To explore a problem-based active learning environment.	HE	MED	To foster content knowledge and related skills, use problem solving skills.	Stand alone.	Guiding: hints provided.	S	One team.	6–8	80	Y
Peleg et al. (2019)	To explore an active learning environment using collaborative learning, to motivate and engage student, to bridge gap classroom and real world while developing TWS.	SE	STEM	To foster content knowledge and related skills, to develop observation skills.	U	Monitoring & guiding: hints for teams lagging behind. Debriefing: 2, 3, 4.	H	All teams; need to cooperate for last puzzle.	4–6	60	N
Seto (2018)	To explore an active learning environment for simulation training of TWS.	HE	MED	To develop TWS, to reflect on one's functioning, and to set developmental goals.	U	Debriefing: 7.	U	One team.	5	30	N
Styling, Welton, Milijasevic, Peterson, & Sia, 2018	To explore an environment to engage participants, to raise awareness around patient safety and required practices using collaborative learning.	PD	MED	Awareness of patient safety and required practices, to acquire new content knowledge and related skills, using TWS.	Stand alone.	U	S	One team.	U	U	N
Vergne et al. (2019)	To explore an active learning environment using collaborative learning, to motivate and engage student, to foster lab skills, critical thinking, problem solving, and TWS.	HE	STEM	To assess content knowledge and related skills, to develop critical thinking, problem solving, and TWS.	Formative assessment; end of semester.	Hint system: two free, 3 - > time penalty. Debriefing: 4	S	One team.	4–6	60	N
Vörös and Sárközi (2017)	To explore an active learning environment using GBL to motivate and engage students in order to develop knowledge, TWS,	SE	STEM	To get introduced to new content knowledge and related skills, to develop TWS, comm. Skills and problem solving.	Stand alone.	Monitoring & guiding in room, by use of characters. Debriefing: 2, 4.	S	All teams.	4–6	90	N

(*continued on next page*)

(*continued*)

Authors	Educators' intentions with ER	Target-group	Disci-pline	Learning objectives	Positioning in course curriculum	Role teacher and staff	Puzzle pathway	Game organisation	Team size	Play-time (min.)	IT tools
	com. Skills and problem solving.										
Watermeier and Salzameda (2019)	To explore an active learning environment to review knowledge, to engage students with different learning styles using problem solving skills.	HE	STEM	To assess content knowledge and related skills, to develop problem solving and TWS.	Formative assessment: prior to exam.	Monitoring & guiding: hints per station after time span to prevent lagging behind, or on request.	H	One team.	4	60	N
Wu, C., Wagenschutz, H., Hein, J.	To explore learning environment using experiential and collaborative learning.	HE	MED	To foster leadership competencies: leading self, communication skills, problem-solving, TWS, systems thinking, to positively impact the team's connection, in high-pressure situation.	U	Debriefing: 4, 7.	U	U	7–10	U	N

Note: U = data unknown; GBL = game-based learning; TWS = teamwork skills; PD = professional development; HE = higher education; MED = medical studies; STEM = science, technology, engineering and mathematics; ER = escape room; H = hybrid pathway; P = path-based pathway; S = sequential pathway; N = no; Y = yes; the column 'team size' indicated in italics which team size numbers were reduced after evaluation of the game.

Appendix B. Recommendations for practitioners on implementing educational escape rooms

Based on this systematic review, the following recommendations will help educators to design more aligned ERs for the classroom. The rationale behind a lot of design choices are the students' immersion and their highly valued feeling of autonomy.

Alignment. We recommend looking at alignment of learning goals, game goal, pedagogics and game mechanics in the design of educational ERs. When choosing pedagogical approaches in support of the learning goals, alignment with game aspects, such as puzzle structure, type of puzzles and team size, are very important to achieve the educational goals. When choosing approaches such as team-based or collaborative learning, an aligned puzzle structure can be path-based or hybrid, creating interdependence between the players. When using a hybrid structure, a degree of linearity is advised, as it will help guide the players and it is easier to monitor for staff (see 4.1.4).

Dare to 'leave' the room. When adapting ERs for whole classes at the same time, the option of abandoning the 'room' aspect of escape rooms is worth considering. Options are to create station-based tasks in more rooms, or to use one box that includes all puzzles and equipment for each team (see 4.1.2). The implementation of freely available technology can structure puzzle paths, validate answers linked to unlocking new information, present pre-set hints for teams lagging behind, and enhance immersion in an out of school context (see 3.3.5; Ross, 2019; Veldkamp et al., 2020).

The role of the teacher. Teachers and staff have a better view on the players' behaviour guiding in the same room than with digital monitoring from an adjacent room. The players' immersion seems not to suffer from the presence or intervention of staff balancing the need of students and their feelings of immersion and autonomy. Consequently, the organisation of monitoring devices is not needed and the game organisation less complicated. The role of the teacher and staff during the gameplay is delicate and challenging as students' immersion and feeling of autonomy can be disrupted. Giving the teachers and staff a role in the narrative in which they can be questioned by the students, might prevent this (see 3.2.4).

Debriefing. The implementation of a debrief, with the elements described in 3.2.4, seems crucial. This would actively link knowledge and decontextualize that knowledge for use in future situations (Sanchez & Plumettaz-Sieber, 2019). In order to finish an ER in time, teamwork and communication skills are conditional. When fostering of teamwork and communication skills is a goal of the ER, a specific debrief or an ER solely on these social skills is advised, as reflection on these goals is usually lost in a reflection on other educational goals (see 3.5.3).

Grading. When players are assessed on performances during gameplay, smaller team sizes (4–5 players) and a sequential puzzle path are recommended (see 3.3.3 and 3.4.1). Let the learning goals decide *who* is graded (team or individual) and *what* is graded (solely the gameplay or the preparation and reflection of the student included) (see 3.2.3). The precautionary measure to grade students in order to activate them, seems unnecessary as participants of all ages are highly engaged by the ER as learning activity. The need for grading to prevent teams exchanging codes or answers might be related to the age of the target group (see 3.2.3).

References

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education, 30*(14), 1945–1969.

Adams, V., Burger, S., Crawford, K., & Setter, R. (2018). Can you escape? Creating an escape room to facilitate active learning. *Journal for Nurses in Professional Development, 34*(2), E1–E5. https://doi.org/10.1097/NND.0000000000000433

Annetta, L. A. (2010). The "I's" have it: A framework for serious educational game design. *Review of General Psychology, 14*(2), 105–113.

Arnal, M., Antonio Macías García, J., Duarte Tosso, I., Mónica, A., Juan Antonio, M., & Isabel Duarte, T. (2019). Escape rooms as a way to teach magnitudes and measure in degrees in education. In E. Bacenetti (Ed.), *New perspectives in science education* (pp. 1–4). Retrieved from https://www.researchgate.net/publication/331976643.

Boeije, H. (2010). *Analysis in qualitative research*. London, England: Sage Publishing.

Borrego, C., Fernández, C., Blanes, I., & Robles, S. (2017). Room escape at class: Escape games activities to facilitate the motivation and learning in computer science. *Journal of Technology and Science Education, 7*(2), 162–171. https://doi.org/10.3926/jotse.247

Boysen-Osborn, M., Paradise, S., & Suchard, J. R. (2018). The toxiscape hunt: An escape room-scavenger hunt for toxicology education. *Journal of Education & Teaching in Emergency Medicine, 3*(1), 1–11. https://doi.org/10.21980/J8NW58

Breakout EDU. (2018). Retrieved June 22, 2019, from http://www.breakoutedu.com/.

Brown, N., Darby, W., & Coronel, H. (2019). An escape room as a simulation teaching strategy. *Clinical Simulation in Nursing, 30*, 1–6. https://doi.org/10.1016/j.ecns.2019.02.002

Cain, J. (2019). Exploratory implementation of a blended format escape room in a large enrollment pharmacy management class. *Currents in Pharmacy Teaching and Learning, 11*(1), 44–50. https://doi.org/10.1016/j.cptl.2018.09.010

Carrión, S. C., Ureta, R. L., Sánchez, C. J., Bruton, L., Palomares, S. P., Pilar, M., et al. (2018). Room escape: A transversal gamification strategy for physiotherapy students. July. In *Proceedings of EDULEARN18 conference 2nd-4th july 2018, Palma, Mallorca, Spain* (pp. 4149–4154). Retrieved from https://www.researchgate.net/profile/Lopez_Royo_Mp/publication/326461466.

Choi, D., An, J., Shah, C., & Singh, V. (2017). Examining information search behaviors in small physical space: An escape room study. *Proceedings of the Association for Information Science and Technology, 54*(1), 640–641.

Clare, A. (2015). *Escape the game: How to make puzzles and escape rooms*. Toronto, Canada: Wero Creative Press.

Clarke, S. J., Peel, D. J., Arnab, S., Morini, L., Keegan, H., & Wood, O. (2017). EscapED: A framework for creating educational escape rooms and interactive games to for higher/further education. *International Journal of Serious Games, 4*(3), 73–86. https://doi.org/10.17083/ijsg.v4i3.180

Clauson, A., Hahn, L., Frame, T., Hagan, A., Bynum, L. A., Thompson, M. E., et al. (2019). An innovative escape room activity to assess student readiness for advanced pharmacy practice experiences (APPEs). *Currents in Pharmacy Teaching and Learning, 11*, 723–728. https://doi.org/10.1016/j.cptl.2019.03.011

Connelly, L., Burbach, B. E., Kennedy, C., & Walters, L. (2018). Escape room recruitment event: Description and lessons learned. *Journal of Nursing Education, 57*(3), 184–187.

Connolly, M. T., Boyle, A. Z., MacAuthor, E., Hainey, T., & Boyle, M. J. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59*, 661–686. https://doi.org/10.1016/j.compedu.2012.03.004

Cotner, S., Smith, K. M., Simpson, L., Burgess, D. S., & Cain, J. (2018). *Incorporating an "escape room" game design in infectious diseases instruction* (Vol. 5). Open Forum Infectious Diseases. SI), S401. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6252427/.

Craig, C., Ngondo, P. S., Devlin, M., & Scharlach, J. (2019). Escaping the routine: Unlocking group intervention. *Communication Teacher*, 1–5. https://doi.org/10.1080/17404622.2019.1593475, 0(0).

Dietrich, N. (2018). Escape classroom: The leblanc process - an educational "escape game". *Journal of Chemical Education, 95*(6), 996–999. https://doi.org/10.1021/acs.jchemed.7b00690

Douglas, J. Y., & Hargadon, A. (2001). The pleasures of immersion and engagement: Schemas, scripts and the fifth business. *Digital Creativity, 12*(3), 153–166.

Eukel, H. N., Frenzel, J. E., & Cernusca, D. (2017). Educational gaming for pharmacy students - design and evaluation of a diabetes-themed escape room. *American Journal of Pharmaceutical Education, 81*(7), 1–5. https://doi.org/10.5688/ajpe8176265

Ferreiro-González, M., Amores-Arrocha, A., Espada-Bellido, E., Aliano-Gonzalez, M. J., Vázquez-Espinosa, M., González-De-Peredo, A. V., et al. (2019). Escape classroom: Can you solve a crime using the analytical process? *Journal of Chemical Education, 96*(2), 267–273. https://doi.org/10.1021/acs.jchemed.8b00601

Franco, P. F., & DeLuca, D. A. (2019). Learning through action: Creating and implementing a strategy game to foster innovative thinking in higher education. *Simulation & Gaming, 50*(1), 23–43. https://doi.org/10.1177/1046878118820892

Friedrich, C., Teaford, H., Taubenheim, A., Boland, P., & Sick, B. (2019). Escaping the professional silo: An escape room implemented in an interprofessional education curriculum. *Journal of Interprofessional Care, 33*(5), 573–575. https://doi.org/10.1080/13561820.2018.1538941

Giang, C., Chevalier, M., Negrini, L., Peleg, R., Bonnet, E., Piatti, A., et al. (2018). Exploring escape games as a teaching tool in educational robotics. *Proceedings of Educational Robotics 2018 (EDUROBOTICS)*, 1–12.

Gilbert, B. W., Meister, A., & Durham, C. (2019). Escaping the traditional interview approach: A pilot study of an alternative interview process. *Hospital Pharmacy, 54*(1), NP2–4.

Glavaš, A., & Staščik, A. (2017). Enhancing positive attitude towards mathematics through introducing escape room games. In Z. Kolar-Begović, R. Kolar-Šuper, & L. Jukić-Matić (Eds.), *Mathematics education as a science and a profession MATH TEACH 2017*. Retrieved from https://files.eric.ed.gov/fulltext/ED577935.pdf#page=290.

Gómez-Urquiza, J. L., Gómez-Salgado, J., Albendín-García, L., Correa-Rodríguez, M., González-Jiménez, E., & Cañadas-De la Fuente, G. A. (2019). The impact on nursing students' opinions and motivation of using a "nursing escape room" as a teaching game: A descriptive study. *Nurse Education Today, 72*, 73–76. https://doi.org/10.1016/j.nedt.2018.10.018

Guigon, G., Humeau, J., & Vermeulen, M. (2018). *A model to design learning escape games: SEGAM. 10th international Conference on computer supported education, mar 2018*. Funchal, Madeira, Portugal. https://doi.org/10.5220/0006665501910197, 191–197.

Guo, Y. R., & Goh, D. H. L. (2016). Library escape: User-centered design of an information literacy game. *The Library Quarterly, 86*(3), 330–355.

Hannes, K., & Lockwood, C. (2012). *Synthesizing qualitative research: Choosing the right approach*. West Sussex, UK: John Wiley & Sons.

Hattie, J. A. C. (2009). *Visible learning: A synthesis of 800 meta-analyses relating to achievement*. Oxon, England: Routledge.

Healy, K. (2019). Using an escape-room-themed curriculum to engage and educate generation Z students about entomology. *American Entomologist, 65*(1), 24–28. https://doi.org/10.1093/ae/tmz009

Hermanns, M., Deal, B., Campbell, A. M., Hillhouse, S., Opella, J. B., Faigle, C., et al. (2018). Using an "escape room" toolbox approach to enhance pharmacology education. *Journal of Nursing Education and Practice, 8*(4), 89–95. https://doi.org/10.5430/jnep.v8n4p89

Ho, A. M. (2018). Unlocking ideas: Using escape room puzzles in a cryptography classroom. *Primus, 28*(9), 835–847. https://doi.org/10.1080/10511970.2018.1453568

Jabbar, A. I., & Felicia, P. (2015). Gameplay engagement and learning in game-based learning: A systematic review. *Review of Educational Research, 85*(4), 740–779.

Järveläinen, J., & Paavilainen-Mäntymäki, E. (2019). Escape room as game-based learning process: Causation - effectuation perspective. *Proceedings of the 52nd Hawaii International Conference on System Sciences, 6*, 1466–1475. https://doi.org/10.24251/hicss.2019.178

Jenkin, I., & Fairfurst, N. (2019). Escape room to operating room: A potential training modality? *Medical Teacher, 1*. https://doi.org/10.1080/0142159X.2019.1657821

Ke, F. (2016). Designing and integrating purposeful learning in game play: A systematic review. *Educational Technology Research & Development, 64*(2), 219–244.

Kinio, A. E., Dufresne, L., Brandys, T., & Jetty, P. (2019). Break out of the classroom: The use of escape rooms as an alternative teaching strategy in surgical education. *Journal of Surgical Education, 76*(1), 134–139. https://doi.org/10.1016/j.jsurg.2018.06.030

Lederman, L. C. (1992). Debriefing: Toward a systematic assessment of theory and practice. *Simulation & Gaming, 23*(2), 145–160.

Li, P. Y., Chou, Y. K., Chen, Y. J., & Chiu, R. S. (2018). *Problem-based learning (PBL) in interactive design: A case study of escape the room puzzle design*. IEEE International Conference on Knowledge Innovation and Invention (ICKII). https://doi.org/10.1109/ICKII.2018.8569131. *2018*.

López, Á. G. (2019). The use of escape rooms to teach and learn English at university. In S. P. Aldeguer, & D. O. Akombo (Eds.), *Research, Technology and best practices in education* (pp. 94–101). Eindhoven, the Netherlands: Adaya Press.

Lopez-Pernas, S., Gordillo, A., Barra, E., & Quemada, J. (2019). Examining the use of an educational escape room for teaching programming in a higher education setting. *IEEE Access, 7*, 31723–31737. https://doi.org/10.1109/ACCESS.2019.2902976

Ma, J. P., Chuang, M. H., & Lin, R. (2018). An innovated design of escape room game box through integrating STEAM education and PBL Principle. *International Conference on Cross-Cultural Design*, 70–79. https://doi.org/10.1007/978-3-319-92252-2

Mills, J., & King, E. (2019). Exploration: ESCAPE! Puzzling out learning theories through play. In A. James, & C. Nerantzi (Eds.), *The power of play in higher education* (pp. 33–41). https://doi.org/10.1007/978-3-319-95780-7

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction - what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474–496.

Monaghan, S. R., & Nicholson, S. (2017). Bringing escape room concepts to pathophysiology case studies. *HAPS Educator Journal of the Human Anatomy and Physiology Society, 21*(2), 49–65. https://doi.org/10.21692/haps.2017.015

Morrell, B., & Ball, H. (2019). Can you escape nursing school? Educational escape room in nursing education. *Nursing Education Perspectives, 1*(1), 1–2. https://doi.org/10.1097/01.NEP.0000000000000441

Nelson, M., Calandrella, C., Schmalbach, P., & Palmieri, T. (2017). 159 Escape the conference room. *Annals of Emergency Medicine, 70*(4), S64. https://doi.org/10.1016/j.annemergmed.2017.07.186

Nicholson, S. (2015). Peeking behind the locked door: A survey of escape room facilities. White Paper Available at: Http://Scottnicholson.Com/Pubs/Erfacwhite.Pdf http://scottnicholson.com/pubs/erfacwhite.pdf. Retrieved from. 1-35.

Nicholson, S. (2016). *Ask why: Creating a better player experience through environmental storytelling and consistency in escape room design* (Vols. 1–17). Meaningful Play 2016. Retrieved from http://scottnicholson.com/pubs/askwhy.pdf.

Novak, J., Lozos, J. C., & Spear, S. E. (2018). Development of an interactive escape room intervention to educate college students about earthquake preparedness. *Natural Hazards Review, 20*(1), Article 06018001.

Peleg, R., Yayon, M., Katchevich, D., Moria-Shipony, M., & Blonder, R. (2019). A lab-based chemical escape room: Educational, mobile, and fun! *Journal of Chemical Education, 96*(5), 955–960. https://doi.org/10.1021/acs.jchemed.8b00406

Ross, R. (2019). Design of an open-source decoder for educational escape rooms. *IEEE Access, 7*, 145777–145783.

Rouse, W. (2017). Lessons learned while escaping from a zombie: Designing a breakout edu game. *The History Teacher, 50*(4), 553–564.

Sanchez, E., & Plumettaz-Sieber, M. (2019). Teaching and learning with escape games from debriefing to institutionalization of knowledge. *International Conference on Games and Learning Alliance, 11385*, 242–253. https://doi.org/10.1007/978-3-030-11548-7

Seto, A. V. (2018). P134 Escape game as a theatre-based simulation for teamwork skills training in undergraduate medical education. *Canadian Journal of Emergency Medicine, 20*(1), 104–105.

Subhash, S., & Cudney, E. A. (2018). Gamified learning in higher education: A systematic review of the literature. *Computers in Human Behavior, 87*, 192–206.

Van der Linden, A., van Joolingen, W. R. van, & Meulenbroeks, R. F. G. (2019). Designing an intrinsically integrated educational game on Newtonian mechanics. *International Conference on Games and Learning Alliance, 11385*, 123–133. https://doi.org/10.1007/978-3-030-11548-7

Van Leeuwen, A., & Janssen, J. (2019). A systematic review of teacher guidance during collaborative learning in primary and secondary education. *Educational Research Review, 27*, 71–89.

Veldkamp, A., Daemen, J. W. M. J., Teekens, S., Koelewijn, S., Knippels, M. C. P. J., & van Joolingen, W. R. (2020). Escape boxes: Bringing escape room experience into the classroom. *British Journal of Educational Technology, 51*(4), 1220–1239. https://doi.org/10.1111/bjet.12935

Vergne, M. J., Simmons, J. D., & Bowen, R. S. (2019). Escape the lab: An interactive escape-room game as a laboratory experiment. *Journal of Chemical Education, 96*(5), 985–991. https://doi.org/10.1021/acs.jchemed.8b01023

Vörös, A. I. V., & Sárközi, Z. (2017). Physics escape room as an educational tool. *AIP Conference Proceedings, 1916*. https://doi.org/10.1063/1.5017455. December 2017.

Warmelink, H., Haggis, M., Mayer, I., Peters, E., Weber, J., Louwerse, M., et al. (2017). AMELIO: Evaluating the team-building potential of a mixed reality escape room game. CHI PLAY '17 extended abstracts publication of the annual symposium on computer-human interaction in play, (November). https://doi.org/10.1145/3130859.3131436, 111-123.

Watermeier, D., & Salzameda, B. (2019). Escaping boredom in first semester general chemistry. *Journal of Chemical Education, 96*(5), 961–964. https://doi.org/10.1021/acs.jchemed.8b00831

Wiemker, M., Elumir, E., & Clare, A. (2015). Escape room games: "can you transform an unpleasant situation into a pleasant one? In J. Haag, J. Weißenböck, M. W. Gruber, M. Christian, & F. Freisleben-Teutscher (Eds.), *Game based learning* (pp. 55–68). St. Pölten, Austria: Fachhochschule st Pölten GmbH.

Wise, H., Lowe, J., Hill, A., Barnett, L., & Barton, C. (2018). Escape the welcome cliché: Designing educational escape rooms to enhance students' learning experience. *Journal of Information Literacy, 12*(1), 86–96.

Wu, C., Wagenschutz, H., & Hein, J. (2018). Promoting leadership and teamwork development through escape rooms. *Medical Education, 52*(5), 561–562. https://doi.org/10.1111/medu.13557