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Escape Education: a systematic review on escape rooms in education

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Abstract. The global increase of 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 in order 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. In different disciplines, educators appear to have different motives to use aspects such as time constraints or teamwork. These educators make different choices for related game aspects such as the structuring of the puzzles. Other educators base their choices on common practices in recreational escape rooms. However, in educational escape rooms players need to reach the game goal by achieving the educational goals. More alignment in game mechanics and pedagogical approaches are recommended. These and more results lead to recommendations for developing and implementing escape rooms in education, and will help educators creating these new learning environments, and eventually help students' foster knowledge and skills more effectively.

Keywords: escape room, escape game, game design, team work, collaborative learning, student engagement

1 Introduction

Worldwide, recreational escape rooms have inspired teachers to adapt the popular entertainment activity for education (Breakout EDU, 2018; Sanchez & Plumettaz-Sieber, 2019). Escape rooms or escape games are live-action team-based games in which players encounter challenges in order to complete a quest in a limited amount of time. Originally, the nature of the quest was an "escape" from a room. Nowadays, the quests 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, escape rooms are gaining popularity as teaching and learning environments in primary, secondary, higher education, and professional development programs (Sanchez & Plumettaz-Sieber, 2019). The implementation of educational escape rooms started bottom-up with enthusiastic teachers. They share materials on platforms, for example, 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 escape room concept. As escape rooms are increasingly popular in education, there is a need to evaluate their use, and a need for guidelines in order to develop and implement educational escape rooms (Jenkin & Fairfurst, 2019). A systematic review on the current practices and experiences will help educators creating these new learning environments, and eventually help students' foster knowledge and skills more effectively.

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1.1 The escape room concept and design characteristics

The escape room concept comprises a common goal and the need for collaboration in order to achieve that goal in time. Escape rooms can have very different narratives and settings in time and place, as Nicholson's inventory of 175 recreational escape rooms 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. Consistency in the game context (time and place), the characters of the players, the activities, the tools, and the props is advised to prevent cognitive dissonance (Nicholson, 2016). Within an escape room, all activities are called puzzles and they use a simple game loop: a challenge to overcome, a solution and a reward (e.g. a code for a lock, or information needed in the next puzzle). Puzzles can be 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 predominate in escape rooms (Nicholson, 2015).

Nicholson (2015) identified four basic ways of organizing the puzzles, see Figure 1. In an open structure, the players can solve different puzzles at the same time. All 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 escape rooms can be used in education.

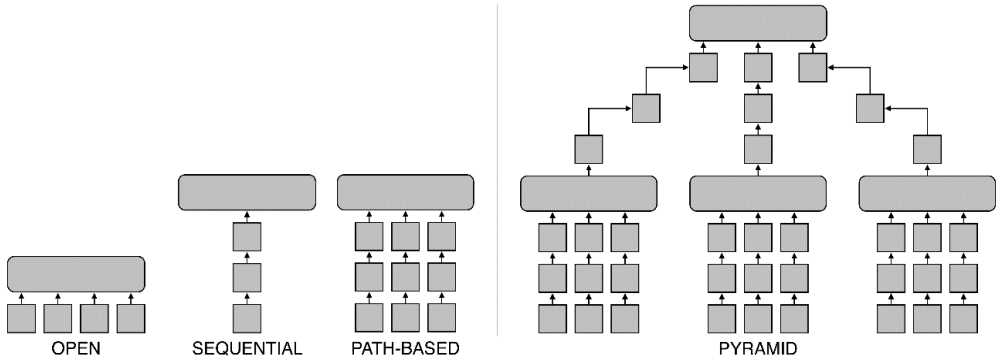

Figure 1. Puzzle structures in escape rooms: a) basic structures: open, sequential and path-based; b) a complex, hybrid structure, such as a pyramid. Squares are puzzles and the rectangles are meta-puzzles (adapted from Nicholson, 2015)

1.2 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 escape room 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 escape rooms in order to foster design skills (Li, Chou, Chen, & Chiu, 2018; Ma, Chuang, & Lin, 2018). Escape rooms have been designed to

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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). Teachers appreciated the diversity of content-related activities, the need for collaboration and the engagement shown by students. Students perceived to be more active, to think more thoroughly than in a regular lesson and enjoyed the feeling of autonomy during gameplay (Veldkamp, Knippels, & van Joolingen, 2019).

1.3 Recreational versus educational settings of escape rooms

In contrast to recreational escape rooms, which intend to attract a broad audience, educational escape rooms are developed for a specific target group with well-defined learning goals. In the entertainment industry, designers have different views on whether or not to aim at a high success rate in participants finishing the room in time (Nicholson, 2015). Educational developers aim at a high success rate; success gives students positive learning experiences and solving all puzzles will help to achieve all learning goals. Consequently, designing educational puzzles is challenging. Firstly, easy puzzles can create boredom and too difficult ones can lead to learners' frustration and drop out of the game (Hermanns et al., 2018). Secondly, the puzzles need to align with the curriculum. Thirdly, the puzzles' outcomes need to be numerical or alphabetical codes due to the locks involved, which limits the way of questioning. In the entertainment industry, an escape usually takes place in one or more connected and permanent rooms, whereas in an educational setting such space is usually not available. Instead, classrooms are used and as a result, teachers have limited time to set-up, reset and clear away activities. Another important difference is the number of participants playing at the same time. An escape room 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 escape room activity for a whole class or course, up to hundreds of students (Cain, 2019; Hermanns et al., 2018).

Due to the differences in recreational and educational settings, educators need to adapt the escape rooms concept and make choices on various educational and game design aspects. This review aims to synthesize the practices and their rationale on these aspects. The following research questions (RQs) are explored in this systematic review.

1. What are common practices and their rationale in educational escape rooms, regarding educational aspects?

2. What are common practices and their rationale in educational escape rooms, regarding game design aspects?

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

4. To what extent have the intended goals of the educational escape rooms 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.

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2 Method

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

We conducted a search on the 1th of June 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 Figure 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.

Exclusion criteria were 1) escape rooms for one participant and 2) completely virtual or digital escape rooms, as these games differ in game environment and game design. 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 escape room, with 4) a pop-up design for classroom settings. This excludes permanent environments such as library settings, as it has consequences for the design process 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 Figure 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 till 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 Figure 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) and 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. Furthermore, the studies' methodology, conclusions, and recommendations were extracted. The categorisation of puzzle structures by Nicholson (2015) was used to assort the puzzle organisations in the studies, see Figure 1.

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

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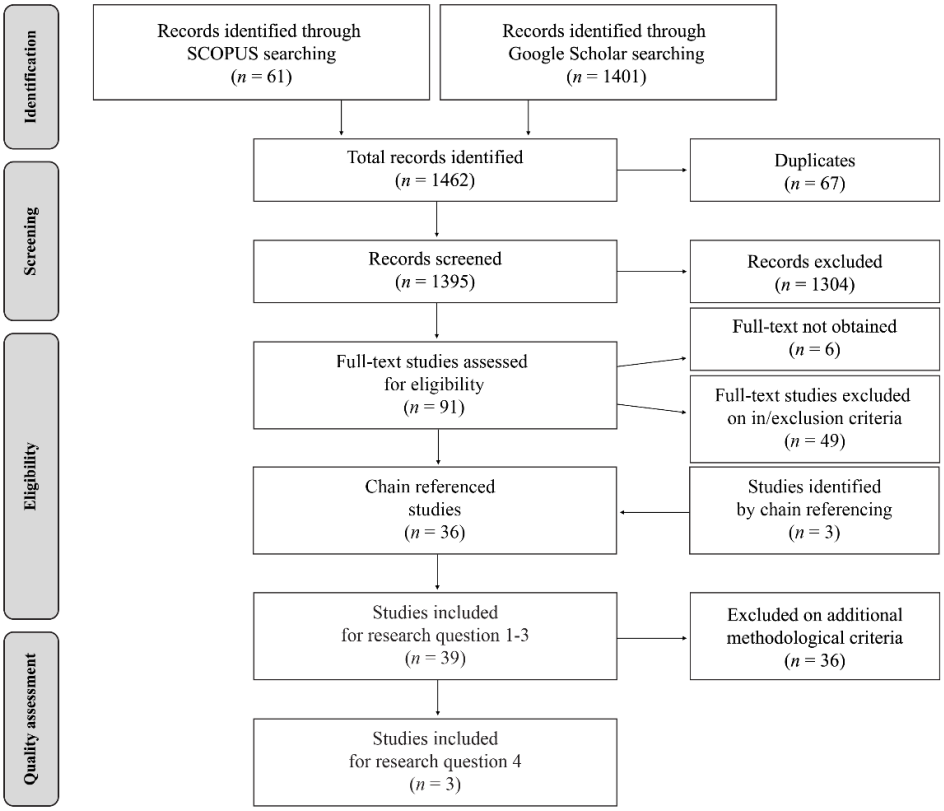

Figure 2. Flow diagram illustrating the review selection process

3 Results

3.1 Dataset characteristics

The 39 included studies were published between 2017-2019: 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, the rest in mainly European countries. The developed escape rooms (ERs) were tested by various numbers of players (n = 10-213). In 36 studies, the educators' motivation to implement an ER is to explore an active learning environment which is said 1) to increase students' motivation and/or engagement, 2) to foster learning, while 3) practising or developing teamwork and communication skills.

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 I. Three of the 39 ERs, are 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

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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. In order to distinguish different *types* of goals in educational escape rooms, the goals are summarised on an abstract level in Appendix I. 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) or to *extent* or to *integrate* (n = 3) content knowledge and skills.

Looking at the learning goals on *general skills*, most goals aim at *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, awareness on patient safety, on the bias of framing patients, or on confirmation bias. 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 escape rooms 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 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 I. 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), entomology (Healy, 2019) or extracurricular physics (Vörös & Sárközi, 2017).

In formal education, six out of 36 ERs are stand-alone activities. The rest of the ERs is embedded in a course curriculum; they take place either at the introduction of a course (n = 2), during a course in addition to lectures (n = 11), as assessment (n = 11). In six studies, the precise position is not mentioned. Students were assessed midterm (n=3), or just before the final exams (n = 7). One study does not mention the moment of assessment. In six ERs students were graded, using different systems: points were given for attending the activity and additional points for all teams finishing in time (López, 2019), for team performances (Clauson et al., 2019), or to the first three teams to finish (Gómez-Urquiza et al., 2019). Sometimes, students were individually graded on performances during the ER or based on their reflection reports (Franco & DeLuca, 2019; Järveläinen & Paavilainen - Mäntymäki, 2019). In some studies, it remains unclear how students were graded. 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

In the studies, teachers have a role in 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, or the students' role in the narrative. Instead of a

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teachers' oral instruction also movies, emails, audio tapes or information sheets were used to instruct the players before gameplay (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 variates enormously, from one aspect to all aspects, see Appendix I. In six studies, it is mentioned that players are solely *monitored*, see Appendix 1. Staff monitors the team's progression for safety reasons and whether players follow the rules. In contrast to recreational escape rooms (Nicholson, 2015), the monitoring usually takes place within the same room. In three studies, staff adopts a role in the narrative, such as witnesses (Ferreiro-González et al., 2019), or Emergency Room physicians (Monaghan & Nicholson, 2017), to keep the players immersed in the game narrative. In four studies, staff monitors the players from adjacent rooms. In these situations, players and staff communicate by Skype (Mills & King, 2019), walkie-talkie, and/or with image and sound of players on monitor (Borrego, Fernández, Blanes, & Robles, 2017; Clarke et al., 2017; Eukel et al., 2017). The rationale is, assumingly as in recreational ERs, the continuing immersion and feeling of ownership of 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 less ownership and frustrated, when staff gave guidance too early (e.g. Giang et al., 2018; Järveläinen & Paavilainen - Mäntymäki, 2019), or 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 in a way that teams roughly make the same progression, preventing teams to diverge too much, with one team ahead of the others finishing the game and learning process for all teams (Cain, 2019; Guigon et al., 2018; Peleg, Yayon, Katchevich, Moria-Shipony, & Blonder, 2019; Wu et al., 2018).

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 (one to four) (Brown et al., 2019; Eukel et al., 2017; Franco & DeLuca, 2019; Gómez-Urquiza et al., 2019), 2) the first hints (one-three) are free, but if more hints are needed, a time penalty is given (Adams et al., 2018; Cain, 2019; Clauson et al., 2019; Vergne et al., 2019), and 3) players had to earn a hint by making a small knowledge test which takes time (Lopez-Pernas et al., 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 on 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 in order to prevent disruption the players' immersion and feeling of ownership.

In addition to feedback by staff, locks provide immediate feedback to learners. Monaghan & Nicholson (2017) regard this as one of the powerful aspects of an escape room. 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 minutes to 2 hours, which reflects the importance given to the debrief by the educators. We have listed and summarized components of the debriefs mentioned. After components 1 and 2, the list is not

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prescriptive in chronology. In general, a debrief start with 1 and 2, followed by 3-7 not in a particular order.

1. Time to decompress after the intense gameplay; this phase is also known in recreational ERs as a cooling down period with room for primary reactions after a high-stress environment (Nicholson, 2015).
2. Exchange of experiences on the gameplay, as the developers want to get feedback on the activity.
3. Questions and concerns of participants. Participants can ask questions and verify if their reasoning was correct.
4. Discussion of the puzzles, content course knowledge and skills needed to solve them. The discussion of the puzzles in relation to the learning goals, is seen as crucial. The rationale is 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 such as framing of patients and confirmation bias.
6. Feedback on students' performances. The feedback is given in relation to learning goals and important in ERs with an assessment goal.
7. Reflection on the individual learning process and formulate 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, p2).

3.3 Common practices in game aspects

3.3.1 Puzzles and puzzle structure

In all 21 medical escape rooms, a sequential puzzle path is used, see Appendix I. 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 working 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, see Appendix I The use of a sequential puzzle path is four out of five times explained; 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 for path-based or hybrid structures (Borrego et al., 2017; Ferreiro-González et al., 2019; Guigon et al., 2018; Ho, 2018; Lopez-Pernas et al., 2019; Peleg et al., 2019; Watermeier & Salzameda, 2019) is motivated by the stimulation of active or collaborative learning by means of positive social interdependency. Students need to discuss the relation of the puzzles and build on each other's knowledge by forcing teams alternatively to split and cooperate during the gameplay (Borrego et al., 2017; Craig et al., 2019; Ferreiro-González et al., 2019; Giang et al., 2018; Guigon et al., 2018). The hybrid structures found in STEM rooms have a strong linearity. Puzzles done 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, and therefore less guidance is needed and the progression is easier to monitor (e.g. Guigon et al., 2018; Lopez-Pernas et al., 2019). Among the 39 ERs, the open structure seems used once, in an ER on communication and teamwork skills (Clarke et al., 2017).

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Based on the description of the puzzles, we recognised that some puzzles were based on puzzles common in recreational escape rooms, such as sudokus, rebuses, crosswords, jigsaw puzzles, cryptograms and riddles. Other puzzles resembled tasks from courses with a puzzle twist added. Some educators made use of intentional deceivers, *red herrings;* a common feature in recreational escape rooms.

3.3.2 Game organisation

Even within the relative short time period spanning this review, an evolution in educational escape room organisation can be seen. Most of the first ERs were copycats from recreational escape rooms, usually only one team plays at a time (Nicholson, 2015). However, if more or all teams play at the same time, it will considerably reduce the time investment for the educators and the occupancy rate of the rooms. Consequently, it requires more materials and trained staff. Carrion et al. (2017) and Clauson et al. (2019) describe settings were two teams play at the same time 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. Hereby, usually teams play in competition with each other, sometimes they are forced to cooperate at same point (Ho, 2018; Morrell & Ball, 2019). We see two developments in the designs when 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 et al., 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 including 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).

3.3.3 Team size

Appendix I shows the group sizes in the studies. A group size of two was used once, to demand 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. These studies, all medical, explained that not everyone in the pilots was or could be active, see Appendix I.

Two studies specifically researched the team size in their educational ER. The outcome of one study is that with a group size of 4 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 organization in teams with higher numbers (Eukel et al., 2017). In ERs with individually grading, a team size up to four or five players is advised (Ho, 2018; Järveläinen & Paavilainen - Mäntymäki, 2019).

3.3.4 Play time

The playtime in escape rooms is constrained, giving urgency to the players actions. Table 1 shows the number of ER with a specific amount of playtime. The range of the duration is 20-120 minutes, with most rooms lasting about 60 minutes. The choice for a specific playtime is seldomly underpinned. If explicated, one refers to the common practice of recreational ERs. Other studies refer to the time slots of classrooms (e.g. Franco & DeLuca, 2019). The playtime is not related to formal or informal education, or a specific discipline, see Appendix I. In informal, formal, STEM or medical education, the median is alike, 60 minutes.

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Table 1.

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

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

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 adequate working (together) under time constraints is a life-saving skill in their profession. 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 the goals in time, and frustration, dropping out or trial-and-error behaviour is prevented. In two studies were none of the teams succeeded, students were most critical on succeeding the educational goals (Hermanns, 2019; Mills & King, 2019). The studies conclude that playtests to define a realistic playtime are crucial in an escape room design.

3.3.5 The use of digital technology

As seen in Appendix I, twenty escape rooms implemented digital technology, such as augmented reality or iPads. In four studies, technology is used to monitor the safety and progression of learners from an adjacent room (see Appendix I, 'Role teacher and staff'). In nine out of the 21 medical ERs, technology is mainly used to structure the gameplay. Examples are the unfolding of new puzzles by a QR code or a digitally locked cardio photo (e.g. Cain, 2019; Franco & DeLuca, 2019; Gómez-Urquiza et al., 2019). 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 et al., 2017; Giang et al., 2018; Lopez-Pernas et al., 2019). In addition, the technology is used to structure the game and thereby ease the work of the teacher which is especially important 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 tape of the crime scene.

3.4 How are educational and game aspects related to educational escape rooms?

In the previous sections, we looked at common practices in educational escape rooms in relation to four educational and five game design aspects. The previous sections showed the following relations between these aspects. The previous sections showed the following relations between these aspects.

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Goals & related aspects

Sequential puzzle pathways were chosen when the leaning goals comprised a sequential process, which students had to follow, or when students were assessed individually. When active and collaborative learning were incentives to implement ERs, the use of path-based and specific hybrid structures intends to ensure that all participants in a team are active and interdependent.

ERs with learning goals solely on general skills, awareness, or introducing a new subject, are all stand-alone activities. ERs which intend to enhance content knowledge and related skills are found embedded in a course curriculum. Most ERs fostering learning are 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 on their performances, has consequences for the role and amount of teachers and 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 enrollment, consequently, it has an effect on the amount of staff and their roles.

3.4.1 Unrelated design aspects

The aspect 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 play time, 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.

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

In most studies, the educators designed and evaluated an escape room to explore an active learning environment which is said to 1) increase students' motivation and/or engagement, 2) fosters learning, while 3) practising or developing teamwork and communication skills. To what extent these goals have been achieved, will be discussed in this section.

3.5.1 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 escape rooms (e.g. Giang et al., 2018; Peleg et al., 2019; Watermeier & Salzameda, 2019). However, we found no ground 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. 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.

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3.5.3 To enhance learning

In the studies, participants were asked about their learning in feedback sessions and/or post activity surveys. The participants ranging from a vast majority to all, perceived that the escape room environment helped them achieve the learning goals, and/or agreed on implementation in their curriculum. There is one exception found, (Kinio et al., 2019). Although, in their study, ten of the thirteen students mentioned they had enjoyed the escape room as a practical exercise, only seven stated that they would like to see the format in their curriculum. Unfortunately, no clarifications were made.

Only three studies in the medical domain actually 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 their regular case activity on infectious diseases (Cotner et al., 2018). Three surveys were sent to each student. The first survey was completed prior to the two activities and functioned as a standard to assess mastery of the content based on pre-assigned reading and previous coursework. After each activity, a survey was completed to assess knowledge and perceptions gained. A debriefing session after the escape room was not mentioned. Both activities were positive perceived. The escape room was preferred by 18 of the 19 students, but only 11 of the 19 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 escape room, neither a knowledge drop or gain was shown. A limitation is that only 19 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- and post-tests showed no significant results. In the third and last study, a cross-sectional pretest-posttest 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 escape room, while most students experienced learning. None of the studies researched the fostering of content knowledge related skills, such as clinical skills.

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). In the last study, the educators observed that students only retained information that had helped them solve the puzzles, and also concluded that ERs are "suitable for phenomenological study of a new phenomenon, but to provide a deeper understanding, extra classes are required" (p. 050002-6). Giang et al., (2018) and Mills & King (2019) have similar conclusions.

3.5.4 To practise and develop teamwork and communication skills

In their motivation to implement an educational escape room, twenty-one studies mentioned practising or developing teamwork and communication skills. Nineteen studies, evaluate these goals based on educators' informally observations and/or students' self-perception. Four escape rooms have goals solely on general skills, such as teamwork and communication skills (see Appendix I). Educators and students agreed that the activity promoted teamwork and communication, for example in Friedrich et al. (2019), 79,5% of the 142 students, 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, strengths and challenges could be indicated, and discussed with students afterwards. Likewise, studies combining content knowledge and skills with general skills, concluded that in ERs teamwork and

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communication are practised and/or developed. 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 rationale in educational escape rooms, 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 escape room to explore an active learning environment aiming at increasing students' motivation and engagement and fostering learning, while developing teamwork, communication and other general skills.

4.1 Conclusions

4.1.1 Common practices and their rationale on educational aspects (RQ1)

In this review, targets 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; mostly 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. Mostly mentioned general goals 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 takes 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). Grading took also place in ERs without assessment goals, stimulating students to take the activity seriously. During the gameplay, different aspects of the role of teachers could be distinguished: monitoring, guiding, providing hints, and debriefing. In the studies, the assigned role variates enormously, from one aspect to all aspects. The players' immersion in the gameplay and feeling of autonomy are funding 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. 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.

4.1.2 Common practices and their rationale 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, 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, also path-based and hybrid puzzle paths are used in order 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. Hereby, either the "room" aspect of the escape room concept tends to be left, 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). When players are graded, somewhat smaller team sizes are used (4-5 players). The playtime has a range between 20-120 minutes, with a median of 60 minutes, independent

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of the educational setting or discipline. This is remarkable 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. 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.

4.1.3 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. This review shows a more complex pattern of interrelated aspects than in current frameworks on designing educational ERs (Clarke et al., 2017; Guigon et al., 2018).

4.1.4 Achievement of intended goals (RQ4)

In all studies, a vast majority of students enjoyed the activity and were highly engaged during the activity, more than in comparison to their 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 seem also 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-posttest knowledge 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 advice 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 does 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 & Plumettaz-Sieber (2019) fosters learning. More research is needed on the systematic evaluation of sustained learning with recreational ERs which include debriefing.

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For educational escape rooms 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 der Linden, Meulenbroeks and van Joolingen (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 Figure 3).

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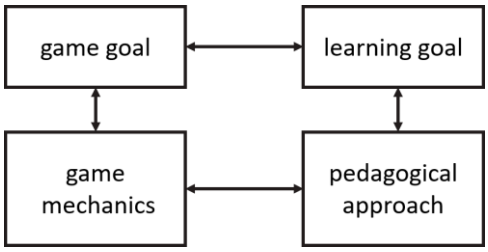

Figure 3. The design framework on alignment between the game goal, learning goal, pedagogical approach and game mechanics (van der Linden et al., 2019).

Applying this to escape rooms, one can see that specific pedagogical approaches, can be related to specific game mechanics, or in this case, escape room characteristics, such as the puzzle structure. In our review we have seen that in medical ERs, pedagogical 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, was not positively evaluated (e.g. Mills & King, 2019). Although this common game aspect, as part of the game mechanics in recreational escape rooms might add to the atmosphere of an ER, it did not align with the pedagogical approach and achieving the learning goals in a restricted time.

4.2 Recommendations on designing educational escape rooms

Instead of copying aspects from recreational ERs, we recommend to look 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 in order to achieve the educational goals. When choosing a pedagogical approach 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.

Teachers and staff have a better view on the players' behaviour guiding in the same room, than with digital monitoring from an adjacent room. Consequently, the organisation of monitoring devices is not needed and the game organisation less complicated. The players' immersion seems not disturbed by the availability of staff.

In order to finish an ER in time, teamwork and communication skills are conditional. When the 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.

The recommendations, based on outcomes and in line with the intrinsic integration theory, will help educators to design more aligned escape rooms for the classroom. In combination with more systematic evaluation of students outcomes, it will help the development of highly engaging and appreciated learning environments where students' foster knowledge and skills.

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