Educational escape rooms in pharmacy education: A narrative review

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Abstract

Background: The pharmacy profession has evolved tremendously, assuming important roles in patient care and often working in multidisciplinary healthcare teams. Educational escape rooms are team-based games delivered in active learning environments that address educational objectives by developing necessary competencies and skills for future pharmacists. **Methods:** This narrative review synthesises current practices and outcomes of educational escape rooms in pharmacy education with the primary aim of helping educators in developing and implementing escape room games. A database search of Web of Knowledge, Scopus, ScienceDirect and Google Scholar identified 1,057 studies. **Results:** After article screening, twenty studies were included. The majority of the studies (85%) reported the development of escape room games for pharmacy practice and professional development. **Conclusion:** Educational escape rooms were positively perceived by students, enhancing knowledge and serving as a platform to foster teamwork, communication, and problem-solving skills while applying clinical skills deemed essential in producing competent pharmacists in the 21st century.

Introduction

Serious games are games designed to teach or train while simultaneously making learning enjoyable, engaging and effective (Susi *et al*., 2007; Cain & Piascik, 2015; Veldkamp *et al.,* 2020; Silva *et al.,* 2021). A type of serious game is educational escape rooms (ER). Originally a recreational activity, an escape room is a live, team-based game in which players use clues, solve puzzles, and complete tasks to escape one or more rooms within a fixed amount of time (Nicholson, 2015; Eukel *et al.,* 2020). Due to its immense popularity with digital native students, recreational escape rooms have been adapted to academic settings. In recent years, ERs appear to gain attention in higher education (Tercanli *et al*., 2019; Veldkamp *et al.,* 2020; Makri *et al*., 2021) and have been implemented in various professional programmes, including engineering (López-Pernas *et al*., 2021), nursing (Sarage *et al.,* 2021), medicine (Guckian *et al.,* 2020) and pharmacy (Eukel *et al.,* 2020). To produce future-ready and competent pharmacists, pharmacy

graduates require not only knowledge recall but also good communication, teamwork, critical thinking and problem-solving skills in teams–pharmacists with such skills are highly sought-after in the era of the Fourth Industrial Revolution (4IR) (Soffel, 2016). In the digital age, capturing and sustaining students' attention and interests in the classroom can prove challenging, especially in some pharmacy courses, e.g., organic chemistry, pharmacy law and management courses. These courses may be perceived as difficult and dry, with no immediate benefits or relevance to pharmacy students' future careers (Cain, 2019; Vergne *et al.,* 2019).

To this end, it is imperative to design instructional strategies and use teaching tools that promote students' engagement and foster higher-order thinking and skills in the pharmacy curriculum. Recently, a systematic review by Aref and authors (2021) reported positive outcomes in various pedagogies for curricular integration in pharmacy education. The review included pedagogies such as case-based learning, problem-based learning, and

simulations but excluded educational games in the analysis (Aref *et al.*, 2021). While educational games as teaching tools in pharmacy schools have been previously reviewed (Akl *et al.,* 2013; Aburahma & Mohamed, 2015; Cain & Piascik, 2015; Sera & Wheeler, 2017), to date, there is no review on educational ERs that focuses specifically on pharmacy education. Existing systematic reviews of educational ERs only provide an overview of the field of education in general (Veldkamp *et al.,* 2020; Makri *et al.,* 2021).

Therefore, this narrative review was conducted by dissecting the body of literature on educational ERs across pharmacy disciplines. In this review, the ER interventions in pharmacy education, their rationale, and motivations for implementation were described. The common practices in the design, development and implementation of ERs were outlined by discussing the roles of faculty members, logistics involved and elements in game design. The review would benefit pharmacy educators who wish to develop and implement educational ERs that engage pharmacy students and pharmacists in learning and professional development, which can help foster skills in the pharmaceutical care workforce.

Methods

This narrative review closely followed the methods of Aburahma & Mohamed (2015) and Veldkamp and colleagues (2020). The literature search was based on the Web of Knowledge, Scopus, ScienceDirect and Google Scholar. The terms used were 'escape room', 'educational games' and 'pharmacy'. Articles were screened by titles and abstracts. The database search identified 1,057 records, of which 1,037 records were removed from the study because they were: (1) not in English; (2) unrelated to pharmacy education, pharmacy students and pharmacists; (3) articles from conferences, books, and book chapters and not peer-reviewed; (4) duplicates and (5) did not assess the learning outcomes. Two studies were excluded: 1) a descriptive article on transferability and implementation of an ER to three campuses (Eukel *et al.,* 2020) and 2) a feasibility analysis on an oncology ER (Wilby & Kremer, 2020), respectively. Of these, 20 studies met the criteria for review: 2017 (n=1) followed by 2019 (n=4), 2020 (n=8) and 2021 (n=7) (Table I). To facilitate analysis of ER practices in pharmacy education, the following data were extracted and summarised in Table I: 1) Authors, Year and Country, 2) Disciplines, 3) Topics, learning objectives and escape room interventions, 4) Number and target participants, 5) Sample size and evaluation methods.

Results

The introduction of ERs and their use in pharmacy education

Eukel and colleagues published the first ER publication in pharmacy education; it appeared two years after the reviews on educational and serious games in pharmacy education in 2015 (Aburahma & Mohamed, 2015; Cain & Piascik, 2015). This ER has been replicated on its campuses (Frenzel *et al.*, 2020) and recently adapted by pharmacy educators at the Medical College of Wisconsin School of Pharmacy (Eukel *et al.*, 2020; Kavanaugh *et al.*, 2020) and serves as a model for implementing escape rooms in pharmacy courses and continuing education sessions (Eukel *et al.,* 2020).

Table I shows that most ER studies were conducted by pharmacy educators in the United States (19) and Switzerland (1). To date, ERs have been employed across most disciplines in pharmacy education. Of all disciplines, pharmacy practice recorded the highest number with a wide range of topics employing ERs followed by leadership, professional development, and pharmaceutical technology. Notably, no educational ERs were reported for topics in pharmaceutical chemistry and pharmacology. Recent studies have reported the use of ERs in related courses such as stereochemistry (Elford *et al.*, 2021) and pharmacology (Smith & Davis, 2021); these can potentially be adapted for those disciplines.

ER Interventions: Why and When

It is well-known that developing and implementing an ER requires significant investment in resources, time, and effort (Nicholson, 2015; Tercanli *et al.,* 2021). In this review, we identified the main motivations for educational ER interventions in pharmacy education, the learning objectives and the timing of the interventions.

As shown in Table I, the primary reasons for an ER intervention are to enhance student knowledge, apply hands-on skills, and foster teamwork and critical thinking skills in a course by engaging them with games (Eukel *et al.,* 2020; Veldkamp *et al.,* 2020). More than half of the educational ERs were embedded in a course curriculum. Out of the 20 studies, 12 developed ER as a post-lecture activity to help students review and reinforce didactic instructions, of which two were employed as formative assessments. Six are standalone ERs, whereas two ERs served as on-boarding and team-building activities during orientation weeks.

Table I: Summary of studies in this review

Authors, year and country	Discipline	Topics, learning objectives (LO) and interventions (I)	Number and target size	Sample size and evaluation
Cerenzio & Ocheretyaner, 2021 (United States)	PP	Antimicrobial Stewardship in Infectious Diseases (ID) **LO:** To assess knowledge on the ID using a patient case study. The ER included interpretation of a Gram stain and antimicrobial susceptibilities and selection with calculations of antimicrobial stewardship-specific metrics. **I: Post-lecture.** To reinforce didactic lecture material on antimicrobial stewardship.	194; 3rd-year pharmacy students.	n=137; A post-activity survey and a multiple-choice exam.
Richter & Frenzel, 2021 (United States)	PD	Preceptors' development **LO:** To use the preceptor handbook and understand the School of Pharmacy Mission and Vision statements. Preceptors learn to apply Pharmacists' Patient Care Process (PPCP) in problem-solving a patient case, e.g., allergy, skin and soft tissue infections, antibiotics and inhaled therapy. **I: Standalone.** To offer a unique alternative for preceptors' development instead of traditional approaches.	18; Pharmacy preceptors.	n=15; Pre- and post-surveys using Qualtrics.
Cole & Ruble, 2021 (United States)	PD	ACPE Continuing Education (CE) on Medication Error **LO:** To apply the information and problem-solve using a root cause analysis (RCA) approach. Fishbone diagrams were utilised as tools for reviewing medication errors. **I: Post-lecture.** To promote engagement and critical thinking on the topic, instead of the traditional lecture format or think-pair-share activity in previous sessions.	136, two teams; Pharmacists and technicians.	n=45; A post-activity survey using Qualtrics.
Dittman et al., 2021 (United States)	IP	Two Interprofessional (IP) course cohorts. C1: IP Quality Improvement and Patient Safety course C2: Foundations of IP Collaborative Practice course **LO:** C1, To discuss a hospital's response to a serious adverse event, and reinforce the positive impact of effective inter-professional communication and collaboration on the delivery of quality patient care and reduction of medical error. C2, To reinforce and apply knowledge about professional roles and responsibilities in interprofessional care, compare and contrast the scopes of various health professions and practice reflections after a team-based activity. **I:** C1, After completion of an open-access module and pre-reading. C2, After completion of pre-reading and formative assessment. To test the feasibility and impact of a virtual escape room on large cohorts of inter-professional learners in synchronous and asynchronous sessions.	C1: 510 students divided into 88 teams. C2: 523 students into 107 teams.	1. C1, n=392; C2, n=517. Retrospective pre-and post-tests. 2. C1, n=463; C2, n=523. Post-activity surveys.
Korenoski et al., 2021 (United States)	PP	Acute care pharmacy elective in toxicology **LO:** To apply concepts of acetaminophen toxicity, lithium toxicity, and serotonin syndrome to clinical practice in a logical, stepwise manner. **I: Standalone.** To teach and apply medical toxicology principles.	22; 3rd-year Doctor of pharmacy.	n=22; Pre- and post-assessments followed by a post-activity survey.
Oestreich et al., 2021 (United States)	PD	Introduction to Pharmaceutical Sciences course: Grant submission training **LO:** To simulate the grant submission process and familiarise participants with internal processes and resources, and cultivate desired skills.	19; First-year trainees in a graduate programme of pharmacists and a physician.	n=8; Post-activity interviews.

Authors, year and country	Discipline	Topics, learning objectives (LO) and interventions (I)	Number and target size	Sample size and evaluation
		I: Standalone. To offer an engaging educational training on the university's grant submission process, which previously involved content discussions and lectures.		
Blue & Zaheer, 2021 (United States)	PP	Toxicology **LO:** To analyse and problem-solve toxicology puzzles and perform dose calculations related to acetaminophen overdose cases, and develop an appropriate treatment regimen. **I: Post-lecture.** To replace the traditional lecture format with a team-based learning activity that engaged students in knowledge retention and applying clinical skills.	161; 3rd-year pharmacy students	n=161; A post-activity survey.
Frenzel et al., 2020 (United States)	PP	Diabetes management topic in Pharmacy Practice Laboratory Note: The ER was based on the design of Eukel and authors (2017).	C1, 83; C2, 84; 3rd-year pharmacy students.	Mixed-method: 1. C1, n=74; C2, n=84. Pre- and post-knowledge assessments. 2. C1, n=79; C2, n= 67. Perception exit survey. 3. n=30. Interviews of student teams on the activity.
Baker et al., 2020 (United States)	PD	Pharmacy practice. Nurturing strengths-based leadership and teamwork **LO:** To apply individual and team strengths concepts in a team-based activity. **I: The penultimate activity in skills lab.** The Clifton StrengthsFinder was used to nurture strengths-based leadership and teamwork.	146; 1st-year pharmacy students	n=146; Post- then pre-questionnaires
Plakogiannis et al., 2020 (United States)	PP	Heart failure topics taught in an integrated course consisting medicinal chemistry, pharmacology, and therapeutics. **LO:** For knowledge reinforcement and retention in heart failure based on five learning objectives, from identifying patient characteristics, signs and symptoms related to HF to mechanism of drug action and dosing regimens in HF. **I: Post-lecture and a pre-exam review.** To replace a 2-hour workshop on traditional patient paper cases that serves as a review of class materials and exam preparations.	193; 2nd-year Doctor of pharmacy.	1. n=193; A post-activity survey. 2. n=110; A follow up survey four weeks after the activity.
Nybo et al., 2020 (United States)	PP	Disaster preparedness (a health elective course) **LO:** To apply and assess knowledge based on four learning objectives on bioterrorism. **I: Formative assessment.** To educate students about bioterror preparedness.	28; 1st- and 2nd-year pharmacy students.	1. GRATs and IRATs on knowledge and comprehension of the content. 2. n=23. Students' attitudes survey.
Eric Nybo et al., 2020 (United States)	FO	First-year student orientation **LO:** To apply knowledge from the morning orientation session by answering assessment questions and to demonstrate proficiency in accessing the student calendar to identify co-curricular events. **I: Standalone.** An on-boarding activity to familiarise students with the pharmacy curriculum, the faculty and peer interactions, instead of traditional seminar sessions.	119; 1st-year pharmacy students.	n=119; Group assessments followed by a post activity survey.

Authors, year and country	Discipline	Topics, learning objectives (LO) and interventions (I)	Number and target size	Sample size and evaluation
Kavanaugh *et al.,* 2020 (United States)	PP	Pharmacy skills lab in diabetes management * Adaptation and transfer of diabetes-themed ER designed (Eukel *et al.,* 2017)	84, 3rd-year pharmacy students at North Dakota State University (NDSU); 43, Medical College of Wisconsin (MCW)	Comparison studies on NDSU and MCW students: 1. Pre- and post-activity knowledge assessments: NDSU, n=84. MCW, n=40. For MCW only: A post-six week survey, n=43. 2. Perception surveys. Both SOPs used the same surveys.
Nguyen, 2020 (United States)	PP	Drug information (DI) **LO:** To utilise DI resources and foster essential skills in pharmacy practice, e.g., conducting efficient systematic literature search and effective self-teaching on unfamiliar drugs and disease states. **I: Formative assessment**. To provide DI practices and assessment for skills (teamwork, communication and problem solving).	136; 3rd-year pharmacy students.	1. Pre- and post-knowledge tests. 2. n=64; A perception survey.
Berthod *et al.,* 2020 (Switzerland)	PD	Good Manufacturing Practices (GMP) for the chemotherapy preparation. **LO:** To test GMP knowledge based on the Pharmacopoeia Helvetica. **I: Standalone.** Teaching GMP by mixing both simulation and educational games.	72; Pharmacy staff (Senior and junior pharmacists, and pharmacy technicians).	1. Pre- and post-activity questionnaires then, 2. A post-activity questionnaire (one month later). 3. A satisfaction survey.
Cain, 2019 (United States)	PP	Pharmacy Management **LO:** To reinforce students' knowledge of the fundamental aspects of human resources pertaining to the law and the hiring process. **I: Post-lecture review.** To provide a proof-of-concept for a blended format that overcomes logistical issues in a large classroom setting.	141; 3rd-year PharmD students.	n=139; A post-activity survey and feasibility analysis.
Clauson *et al.,* 2019 (United States)	PP	Pharmacy Practice **LO:** To foster critical thinking, teamwork skills, and clinical knowledge in students. **I: Post-didactic content.** Prior to the final exam. To simulate a patient care experience to assess readiness for the APPE year.	62; 3rd-year pharmacy students (pre-APPE).	1. n=62; Pre- and post-activity tests then, 2. n=53; A post-activity survey.
Caldas *et al.,* 2019 (United States)	PT	Advanced Non-sterile Compounding elective **LO:** To perform calculations and use USP beyond-use-dating (BUD) for non-sterile compounding along with verification of several advanced dosage forms. **I: Review and reinforce didactic instruction.** The last class session. To replicate a non-sterile compound practical skill-based course, promote student engagement and evaluate the knowledge gain and student perceptions.	30; 3rd-year pharmacy students.	n=30; 1. Pre- and post-tests mapped to the course objectives. 2. A post activity perception-based survey.
Gordon *et al.,* 2019 (United States)	PD	Personal and Professional Development course **LO:** To familiarise students with new staff members and provide information about the university. To serve as an orientation for students working with their new teams in the new academic year. **I: Standalone.** A pre-academic activity to assess team dynamics using the StrengthsFinder 2.0 framework during student orientation week and provide a team-building activity.	127; 2nd- and 3rd-year pharmacy students.	n=117; Pre- and post activity surveys.

Authors, year and country	Discipline	Topics, learning objectives (LO) and interventions (I)	Number and target size	Sample size and evaluation
Eukel *et al.,* 2017 (United States)	PP	Diabetes mellitus disease management **LO:** To promote hands-on applications of diabetes-related skills through teamwork, communication, and the use of health records. **I: Standalone.** To complement and reinforce nine hours of independent didactic instruction in diabetes mellitus.	83; 3rd-year pharmacy students.	1. n=74; Pre- and post-tests. 2. n=79; A post-activity perception survey.

Note: PP = pharmacy practice; PC = pharmacology; PT = pharmaceutical technology; PD = professional development; FO = first-year orientation; IP = interprofessional course; C1 = cohort 1; C2 = cohort 2; GRATs = Group-readiness assessment tests; IRATs = individual readiness assessment tests; SOP = School of Pharmacy; APPE = Advanced pharmacy practice experiences; ACPE = Accreditation Council for Pharmacy Education.

To reinforce didactic content, Cain (2019) developed a blended ER as a review exercise for the didactic content on basic human resources laws and the hiring process. Students were overwhelmingly positive about being *"more engaged in thinking about the problems"* and indicated that they *"enjoyed the ER activity more"* than a typical classroom experience. Similar positive outcomes were reported for a post-lecture ER designed to review and integrate didactic instruction on diabetes management (Eukel *et al.,* 2017). The purpose of most educational ERs seems consistent with the observations in the review by Aburahma & Mohamed (2015) that "*the use of games in pharmacy schools was not intended to present new content, but to review or reinforce existing knowledge"*.

An educational ER can also be designed to replace traditional approaches used in content delivery. At the University of Minnesota College of Pharmacy, toxicology has been traditionally taught in a lecture format until recently, when Blue & Zaheer (2021) introduced ER as a pedagogical intervention for an active-learning, team-based activity in a large classroom setting. It also provided opportunities for students to apply their knowledge and practice clinical skills. Most students agreed that the ER activity enhanced their learning toxicology (Blue & Zaheer, 2021). Meanwhile, the development of standalone ER activity appears mainly for elective courses or professional development sessions. For example, a professional development session for preceptors at North Dakota State University (NDSU) was re-designed as a standalone ER in lieu of traditional approaches. Preceptors positively perceived the activity as an enjoyable hands-on experience through solving clinical-based puzzles (Richter & Frenzel, 2021).

In addition to improving learning, ERs have been utilised to enhance hands-on skills, teamwork and communication (Table I). For example, a team of investigators at Geneva University Hospital reported the successful design and implementation of a simulated clean room ER as a continuing education training of pharmacists and pharmacy technicians on good manufacturing practices (GMP). The Esclean Room game positively impacted participants' knowledge and confidence in GMP, even one month after the game (Berthod *et al.,* 2020). Korenoski and colleagues designed a toxicology-themed ER not only for students to learn the didactic content but also to help them understand, integrate, and apply various individual disciplines in acute pharmacy care scenarios. Reportedly, students felt more confident in managing a toxicologic emergency case after participating in the ER activity (Korenoski *et al.,* 2021). While didactic lectures remain valuable as a pedagogical method, an appropriately designed ER invention provides simulated scenarios, challenges and a conducive learning environment to apply the knowledge gained during the didactic instruction in clinical skills and practices. The common practices in an educational ER can be conveniently categorised into three distinct phases: Design and Development, Implementation, and Evaluation. Each phase will be discussed in detail in the following sections.

Common practices in ER design and development

Frameworks for creating educational ERs have been proposed (Clarke *et al.*, 2017; Tercanli *et al.,* 2021). The creation of an ER activity starts with the lead faculty member assembling a team (Clauson *et al.,* 2019; Davis *et al.,* 2021; Eukel & Morrell, 2021). The team members outline cognitive, affective and psychomotor objectives of the activity and align them to assessments, puzzles and gaming tasks. Ideally, these should stimulate low- and high-order thinking skills and promote group interactions (Aburahma & Mohamed, 2015; Arnab *et al.,* 2015; Cain & Piascik, 2015; Blue & Zaheer, 2021; Eukel & Morrell, 2021). The common practices in the design and development phase of ERs in pharmacy education are discussed below:

Faculty's role in Escape Rooms

In the studies included in this review, the faculty members assume certain roles before, during and after the gameplay. The common key roles of the faculty in an escape room activity are: 1) briefing, 2) observing, 3) monitoring, 4) facilitating, and 5) debriefing players. Before the gameplay, the faculty served as subject matter experts in creating content (Dittman *et al.,* 2021; Korenoski *et al.,* 2021), planned the scenario (Nybo *et al.,* 2020), developed puzzles (Eukel *et al.,* 2017; Nybo *et al.,* 2020), set up the escape rooms (Nybo *et al.,* 2020) and provided written guidelines and training to facilitators before the game (Dittman *et al.,* 2021). During the briefing, the faculty introduced players to the game and its rules (Caldas *et al.,* 2019; Nguyen, 2020; Richter & Frenzel, 2021). Videos (Clauson *et al.,* 2019; Nybo *et al.,* 2020; Richter & Frenzel, 2021), online information (Nybo *et al.,* 2020), including emails and pre-activity reading (Plakogiannis *et al.,* 2020; Cerenzio & Ocheretyaner, 2021; Dittman *et al.,* 2021) have been used in place of faculty's briefing.

During the gameplay, the faculty served as facilitators or gamemasters, observing and monitoring teams via live video stream (e.g., Google Hangout, Zoom) or patrolling the ER in-person. The faculty's observations include student skills demonstration, group interactions and dynamics. These observations would be used to provide feedback to students during the debriefing session and for future game iterations (Cain, 2019; Clauson *et al.,* 2019). Additionally, the faculty seems to take on multiple roles: communicating with students - when required (Eukel *et al.,* 2017; Nguyen, 2020), providing clues, hints, feedback, updates and links (Clauson *et al.,* 2019; Nybo *et al.,* 2020; Richter & Frenzel, 2021), serving as a timekeeper and keeping track of correct answers (Nguyen, 2020), answering questions on game rules (Cain, 2019; Nguyen, 2020), assessing team performance (Clauson *et al.,* 2019), and performed debriefing (Cain, 2019; Caldas *et al.,* 2019).

From these studies, it is clear that as gamemasters, the faculty serves as "a guide on the side", facilitating students' learning process during the gameplay (Nicholson, 2015; Veldkamp *et al.,* 2020). The gamemaster only intervenes to redirect students who were stuck or to provide more clues when requested (Clauson *et al.,* 2019) and keeps students on-task to prevent them from diverging, thus ensuring smooth teams' progression during the gameplay (Cain, 2019; Eric Nybo *et al.,* 2020; Veldkamp *et al.,* 2020).

After the gameplay, a faculty member serves as a debriefer. Debriefing allows players to decompress after the high-pressure activity, but its primary purpose is to provide a space for self-discovery through reflection and peer discussion on the game experience (Bauchat & Seropian, 2020; Veldkamp *et al.,* 2020). A variety of debriefing structures and techniques have been reviewed in the context of healthcare (Sawyer *et al.,* 2016; Bauchat & Seropian, 2020).

The majority of the studies in this review (15 studies) implemented a debriefing session or a small-group discussion. Debriefing durations of 10 minutes (Blue & Zaheer, 2021; Cole & Ruble, 2021; Oestreich *et al.,* 2021), 30 minutes (Caldas *et al.,* 2019) and one hour (Nybo *et al.,* 2020; Plakogiannis *et al.,* 2020) have been reported (Appendix A). Debriefing sessions involved: in-depth discussions on the activity, educational goals and content (Berthod *et al.,* 2020; Cain, 2019; Oestreich *et al.,* 2021), collecting feedback and alternative perspectives on specific issues (Cole & Ruble, 2021) and reviewing game elements, e.g. clues, puzzles (Berthod *et al.,* 2020). In the hands of a skilful and experienced debriefer, the discussions of these components are weaved together in a safe environment to encourage learner's self-exploration, active learning and, ultimately, enhance professional performance (Bauchat & Seropian, 2020; Richter & Frenzel, 2021).

Team size and logistics

Team size refers to the number of participants in a team or group. The number of players is an important consideration during the planning stage because team size is closely related to engagement, logistics and resources used during the implementation phase. Teams varied in size. The Esclean Room game grouped players in pairs (Berthod *et al.,* 2020). In most studies, the group size ranges from three to eight participants to maximise player interactions and immersion in the game (Appendix A) (Cain, 2019; Richter & Frenzel, 2021). Large teams tend to suffer from low engagement with gaming tasks, unequal contribution and, consequently, would give rise to "free riders" (Aburahma & Mohamed, 2015; Cole & Ruble, 2021; Eric Nybo *et al.,* 2020; Richter & Frenzel, 2021). Free riders are players who contribute little to the group's work but benefit from rewards or marks (Richter & Frenzel, 2021). A team of more than six players is likely to require extended playtime than a team of six (Veldkamp *et al.,* 2020).

Moreover, a large team complicates the logistics and resources needed for running an ER activity. Appendix A lists several resources used in these studies. Factors to consider are the availability of class time, learning spaces and their size, the availability of gamemasters or facilitators (faculty members, staff, students), gaming tasks (puzzles, locks, riddles), props and apps (video conferencing apps, Google Forms, QR code). It

is crucial to identify these resources early in the ER development phase.

As noted earlier, planning and designing educational ERs are resource- and time-intensive processes for many faculty members. Five studies specified the costs of developing an ER (Appendix A). The expenditures varied between USD 12 – 400 for purchases of puzzles, materials and props used in the activities (Cain, 2019; Clauson *et al.,* 2019; Baker *et al.,* 2020; Eric Nybo *et al.,* 2020; Nybo *et al.,* 2020). Besides the cost, nine studies revealed ER development time that ranges between 20 – 60 hours (Cain, 2019; Clauson *et al.,* 2019; Baker *et al.,* 2020; Eric Nybo *et al.,* 2020; Nguyen, 2020; Nybo *et al.,* 2020; Cole & Ruble, 2021; Oestreich *et al.,* 2021; Richter & Frenzel, 2021). Nybo and colleagues (2020) provided a feasibility analysis of the cost and time taken in creating a first-year orientation ER. The activity cost USD 260 and took 40 hours to develop. Out of the 40 hours, the game design and puzzle construction took 18 hours, followed by educational content creation (8 hours) and assessment writing (6 hours). The involvement of multiple investigators sped up the ER game development. This corroborates with reports by Nguyen (2020), who took nearly 30 hours and Cain (2019), almost 19 hours, respectively. Due to the significant time investment, Eukel and authors (2020) recommended overestimating the time for planning and organising the first iteration of an ER game. Four weeks prior to the activity is recommended (Eukel *et al.,* 2020). Once an escape room activity has been implemented, it can be re-used and adapted. Subsequent implementation mitigates the initial time and cost involved in the ER game design and development.

Game structures and puzzles

The construction of an ER game revolves around a simple game loop: overcome a challenge, solve a puzzle and earn a reward (e.g. a code to unlock a room, a clue for the next puzzle) (Nicholson, 2015; Eukel *et al.,* 2020). All ER activities are referred to as puzzles (Nicholson, 2015; Veldkamp *et al.,* 2020); sometimes, a large puzzle consists of solving smaller gaming tasks before unlocking the next puzzle. Appendix A lists various puzzles employed in the studies. One study intentionally incorporated distractors or red herrings to test students' understanding during the game (Oestreich *et al.,* 2021). Some studies in nursing and pharmacy ER games have provided detailed resources, e.g., blueprints for challenges with photos of locks, toolboxes and puzzles used (Berthod *et al.,* 2020; Blue & Zaheer, 2021; Hardie *et al.,* 2021; Sarage *et al.,* 2021).

As shown in Figure 1, an ER game structure consists of puzzles that can be organised in three ways: a) open, where puzzles can be solved in any sequence, b) sequential, when puzzles are presented and solved one after another in a linear sequence, and c) path-based structure involves a combination of sequential and/or open game structures (Nicholson, 2015; Tercanli *et al.,* 2020; Veldkamp *et al.,* 2020).
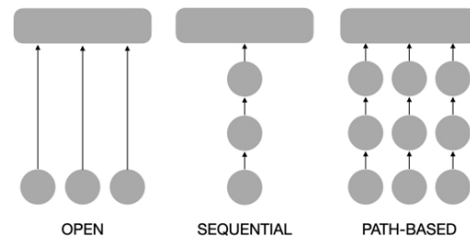
Note: The circles are puzzles, and the rectangles are meta-puzzles, which unlock by assembling clues from earlier puzzles–adapted from Tercanli and authors in 2021

Figure 1: Basic game structures of escape rooms: open, sequential and path-based.

A game structure can be intricately linked to the ER narrative and determines the experiential outcomes of the activity. The sequential game structure is the most common puzzle organisation reported in the included studies (15 studies) (Appendix A). Cain (2019) argued that the linear sequence was an intentional design element because of the instructional nature of the hiring process in the human resource topic. Korenski and authors (2021) constructed a toxicology-themed ER in a sequential game structure to ensure students follow a stepwise approach in a patient case analysis. Moreover, the game's linearity allows players to focus on 1-2 learning objectives per puzzle, and simplifies students' game progression, thus making it easier for facilitators to manage a large class (Cain, 2019; Nybo *et al.,* 2020). Instead of using a sequential game structure, more recently, Cerenzio & Ocheretyaner (2021) developed an open-structured ER on antimicrobial stewardship. At the start of the game, it presented student teams with a patient case and four treatment options. Selecting a treatment led to a set of questions that student teams had to solve and adapt accordingly. Alternatively, changing a game structure could influence the nature of team interactions and improves engagement. Adopting a path-based structure, a compounding ER designed by Caldas *et al.* (2019) consisted of three linear puzzles mapped to specific learning objectives and skills. Each puzzle had non-sequential 3-5 gaming tasks to encourage small group collaborations.

Pilot studies

Conducting a pilot test is a crucial step that reveals deficiencies in the ER game design and execution. Eight studies ran playtests (Cain, 2019; Clauson *et al.*, 2019; Gordon et al., 2019; Nguyen, 2020; Nybo *et al.,* 2020; Blue & Zaheer, 2021; Oestreich *et al.,* 2021). Reasons for pilot testing the activity include the identification of errors, reducing confusion or unintentional bottlenecks in gameplay, indication for additional hints or clues, and estimation of a realistic playtime. A lack of a pilot study could lead to frustration, slow progression, distractions and non-completion of the activity. Usually, faculty members and student pharmacists were recruited to participate as playtesters (Clauson *et al.,* 2019; Richter & Frenzel, 2021).

Common practices in the ER implementation phase

Figure 2 shows a timeline of the implementation phase of an ER game extracted from the reviewed studies. Typically, it is made up of five sequential steps: (1) a pre-activity knowledge assessment, (2) a game briefing, (3) the ER activity, (4) a post-activity knowledge assessment and perception survey, and (5) a debriefing (Clauson *et al.,* 2019). Steps (2) and (5) have been discussed earlier, so this section focuses on the remaining steps and elements of the ERs.

Note: The five steps are: (1) a pre-activity test assessment, (2) a game briefing, (3) the ER activity, (4) a post-activity knowledge assessment and perception survey, and (5) a debriefing.

Figure 2: A timeline of a typical educational ER activity during the implementation phase consists of five steps, numbered (1) to (5)

Game organisation

Educational ERs have been conducted in physical (e.g., in locked rooms), online (e.g., Zoom, Google Forms) and hybrid modes, which combine physical and online puzzles. Previous live, physical escape rooms have been successfully implemented in instructional settings of 100 participants or less (Eukel *et al.,* 2017; Kavanaugh *et al.,* 2020; Richter & Frenzel, 2021). Eukel and the team conducted a live, diabetes-themed ER over four days for 83 third-year pharmacy students (Eukel *et al.,* 2017). For successful implementation of three simulated clinical environments, Clauson and the team (2019) required 13 game masters to man 62 students across six rooms.

For a large enrolment class, Cain (2019) implemented a 45-minute blended ER activity that needed only three facilitators to manage 142 students. Similarly, Dittman and colleagues successfully implemented online ER activities by utilising Google Forms and google drive as the platform. Initially conducted as a face-to-face activity for Cohort 1 (510 students, eight facilitators), the activity was then adapted as asynchronous remote ER activity for Cohort 2 (523 students, no facilitator needed) during the COVID-19 pandemic (Dittman *et al.,* 2021).

Using an online platform (e.g., Google Forms) enables upscaling of hybrid and remote escape rooms for large classes (Cain, 2019; Plakogiannis *et al.,* 2020; Blue & Zaheer, 2021; Cerenzio & Ocheretyaner, 2021; Dittman *et al.,* 2021;). Additionally, digital escape room templates from Breakout EDU, S'cape and Genially are available. Regardless of the mode of delivery–online or hybrid–students perceived the escape room games as valuable learning experiences (Cain 2019; Blue & Zaheer, 2021; Cerenzio & Ocheretyaner, 2021; Dittman *et al.,* 2021).

Playtime

An ER game requires participants to solve gaming tasks and puzzles within a time limit. The limited playtime in ERs gives a sense of urgency and keeps them on-task. The playtime of the studies in this review lasted between 30 to 120 minutes (Appendix A). Figure 2 illustrates a typical ER activity with a playtime sweet spot of between 40 to 60 minutes (11 studies). At the outset, an ER playtime in an academic course is often determined by the availability of classroom time (Blue & Zaheer, 2021; Cain, 2019). For continuing education (CE) sessions, the playtime seems to be determined by the required CE hours (Cole & Ruble, 2021). Pilot studies are, therefore, crucial to establishing a realistic playtime.

Evaluation

The impact of the ER game is evaluated mainly on 1) students' learning, 2) fostering teamwork and collaboration and 3) engagement and satisfaction. In terms of students' learning, 11 studies assessed participants' knowledge gain via pre- and post-tests (Table I). Most studies found significant gains in participants' mean test scores (Eukel *et al.,* 2017; Caldas *et al.,* 2019; Baker *et al*., 2020; Nguyen, 2020; Richter & Frenzel, 2021). Clauson and authors (2019) unexpectedly found a decrease in the post-activity test score compared to the pre-test score. The decrease was attributed to the higher weightage of the pre-test scores and the timing of the ER activity (a day before the start of final exams). In a longitudinal study of the diabetes-themed ER activity, Kavanaugh *et al*. (2020) found a strong knowledge retention rate (98%) in the results of post-game and 6-week post-game surveys in a cohort of pharmacy students at the Medical College of Wisconsin.

To evaluate the outcomes of ERs on students' perceptions of teamwork and satisfaction, most studies utilised questionnaires using Likert-type scales. Some studies included open-ended questions to solicit students' feedback (Baker *et al.,* 2020; Blue & Zaheer, 2021; Oestreich *et al.,* 2021). The majority of studies reported high participants' satisfaction and good engagement with teammates and the game. Out of 20 studies, 8 administered only post-activity perception surveys (Table I). Three studies employed modified perception surveys developed by Eukel and authors (2017) (Caldas *et al.,* 2019; Kavanaugh *et al.,* 2020; Plakogiannis *et al*., 2020). Plakogiannis and authors (2020) took a step further and conducted a longitudinal post-activity satisfaction survey in two instances: immediately and four weeks after the activity. Statistically, students' positive perception of the ER activity remained unchanged over time.

Unlike most studies, Frenzel and colleagues (2020) as well as Oestereich and authors in 2021 conducted focus group interviews of students who participated in the game. As noted in the earlier section, the faculty were also involved in direct observation of players' behaviours during the activity (Eukel *et al*., 2017; Caldas *et al.,* 2019; Nguyen, 2020; Nybo *et al.,* 2020), either in-person or via live-stream. In summary, studies in this review employed: 1) pre-/post-tests followed by a post-activity perception survey, 2) solely post-activity perception surveys, 3) focus group interviews, and 4) direct observation to evaluate the ER game and its impact on students' learning, teamwork, engagement and satisfaction.

Discussion

This review examined twenty studies that employed ERs as an educational intervention in pharmacy education. A description of the common practices of educational ERs in terms of the design and development, implementation, and evaluation methods was provided. At the heart of a well-designed educational ER game is a blend of cooperative and game-based learning. It provides the conditions and environment to cultivate and increase intrinsic motivation in learning, which is best explained by self-determination theory (SDT) (Zainuddin *et al.,* 2020). SDT is a theory of motivation that assumes humans are innately curious and interested in their own growth. It argues that learners' intrinsic motivation is sustained by fulfilling their psychological needs for a sense of autonomy, competence, and relatedness (Niemiec & Ryan, 2009).

To put the SDT into context, educational ERs require learners to work together while satisfying their needs for: autonomy (use their own ways to solve puzzles), competency (by unlocking puzzles to progress), and relatedness (by accomplishing a common goal, i.e., the entire team escapes the room*) (*Akl *et al.,* 2013; Zainuddin *et al.,* 2020; Bakkum *et al.,* 2021). Additionally, puzzles not only stimulate and provide challenges to the cognitive domain, but also could pique the senses and movements, thereby promoting visual, auditory, tactile, and kinaesthetic learning (especially in a physical ER activity). Thus, an ER activity could appeal to learners of different learning preferences (Nicholson, 2015; Cain, 2019; Tercanli *et al.,* 2021). In general, most studies reported high learners' satisfaction with the ER activities, which were described as enjoyable and engaging (Cole & Ruble, 2021; Dittman *et al.,* 2021; Oestreich *et al*., 2021).

Despite positive student outcomes, there are several drawbacks and challenges to educational ERs. As discussed above, designing an escape room activity is complicated, costly, and time-intensive (Eukel *et al.,* 2020). Thus, the reluctance of pharmacy educators in developing and implementing an ER activity is expected. Besides that, participants with no or limited previous experience with the activity reported having a more difficult time understanding and solving puzzles (Clauson *et al.,* 2019). On the other hand, those who were more experienced appeared to be more likely to succeed in the activity (Caldas *et al.,* 2019). Additionally, participants reported feeling rushed, overwhelmed, and stressed due to the fixed time limit and the competitive nature of the activity. These factors might hinder participants' game progression (Caldas *et al.,* 2019; Clauson *et al.,* 2019;

Richter & Frenzel, 2021); thus, a pre-game practice ER has been suggested (Clauson *et al.,* 2019). Other drawbacks were unequal players' contributions, not all teams completing the activity on time (Richter & Frenzel, 2021) and unclear roles, which affected team performance (Cain, 2019).

Despite some limitations above, this review suggests the potential use of ERs in pharmacy education, especially in teaching or exposing pharmacy students to pharmacy practices such as the management of infectious diseases, diabetes and heart failure (Eukel *et al.,* 2017; Kavanaugh *et al.,* 2020; Plakogiannis *et al.,* 2020; Cerenzio & Ocheretyaner, 2021), pharmacy management (Cain, 2019), drug compounding (Caldas *et al.,* 2019), and drug information services (Nguyen, 2020). Our findings showed that pharmacy students generally accepted and positively perceived educational ERs. In real practice, diseases management and drug compounding could not tolerate mistakes as it would cause poor patient outcomes. In contrast, mistakes in practices such as pharmacy management and drug information services may result in organisational issues and medication errors, respectively. Therefore, educational ERs may provide a platform for students to learn and make mistakes without negative implications. Educators may also enhance students' learning through the provision of feedback, thus improving students' confidence and preparedness in real practice. Additionally, due to the nature of educational ERs that require teamwork and problem-solving to escape the room, the activity provides the conditions that enhance collaboration, communication and critical thinking skills deemed important for pharmacy graduates.

Recognising the promising utility of games, the 2013-2014 report of the Academic Affairs Committee of the American Association of Colleges of Pharmacy (AACP) recommended the use of games to develop essential skills in pharmacy students (Cain *et al.,* 2014; Cain & Piascik, 2015). This may explain the high number of educational ERs implemented in the United States. Globally, the pharmacy profession has undergone tremendous changes in meeting the needs of modern health care systems, resulting in the shift from a product-oriented to a patient-focused profession. Such changes signalled evolving, diversified, and extended roles and responsibilities of pharmacists in healthcare settings (International Pharmaceutical Federation (FIP), 2017). The COVID-19 pandemic further catalysed the rapid transformations in online education and digital health technologies (Mohamed *et al.,* 2020; FIP, 2021). These changing landscapes reflect the need for new pedagogical tools to form "bridges" between integrated pharmacy curriculum

and developing future-ready competencies and skills in the pharmaceutical care workforce (Awaisu & Mottram, 2018; Aref *et al.,* 2021). To this end, educational ERs have emerged as an innovative, enjoyable, and engaging pedagogical tool with the potential to invigorate and help drive pharmacy education forward in the 21st century.

Limitations of the review

The review was conducted in a "non-systematic" manner; thus, it is prone to risks, biases and benefits (Ferrari, 2015; Sawyer *et al.,* 2016). Despite the limitation, the authors have undertaken a thorough review of current and pertinent articles on educational ERs in pharmacy education and, where relevant, relate them to broader ER studies in nursing, medicine, and education. However, the synthesis and analysis of the literature were limited by missing information and vague descriptions of some escape room interventions and the exclusion of articles in non-English languages.

There are some potential limitations of the studies reporting the impact of the education escape room games in pharmacy education. Most were not randomised, controlled trials–these remain the gold standard in establishing evidence of the effectiveness of an intervention (Aburahma & Mohamed, 2015; Thomas *et al.,* 2015). Debates are still ongoing concerning potential ethics on randomisation and blind allocation of an educational intervention. Apart from the diabetes-themed ER (Eukel *et al.,* 2020), the majority of the studies conducted the ER activity at their own institutions. Some studies used a small sample size. Several were pilot studies. Most studies only described the effectiveness of ERs using surveys based on students' perceptions. These factors may limit the generalisation of the results. As such, the reviewed studies provided insufficient evidence for firm conclusions on the effectiveness of educational escape rooms. Future studies should consider robust study designs to validate the effectiveness of educational escape rooms as a pedagogical tool.

Conclusion

In the era of pharmaceutical care, pharmacists who are competent and have strong communication, teamwork, and problem-solving skills are highly valued. While solid evidence of ER effectiveness is still lacking, educational ERs have the potential to provide an interactive, enjoyable, and engaging learning environment that is conducive for pharmacy students and pharmacists to gain knowledge and develop essential professional skills. This review presents an

overview of common practices and outcomes of educational ERs across pharmacy disciplines to help educators design, develop and implement the ER activity. Broader adoption of ERs in pharmacy schools should be sought in countries other than the United States. Future development of online and hybrid models of educational escape rooms is warranted to improve access to quality education and training in pharmacy education.

Conflict of Interest

The authors declare no conflict of interest.

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Appendix A: Summary of Escape Room designs, resources and puzzles

References	ER Game Setting	Resources	Gaming Tasks
Cerenzio & Ocheretyaner, 2021 (USA)	• Live online using Google Forms. • Open game structure. • Team size: Six members (30 groups). • Briefing: Email and pre-activity reading. • Playtime is not specified. • Post-activity discussion.	Resources: Nil Apps: Google Forms Cost: Not specified Development time: Not specified	Students needed to solve a patient case study by choosing a regimen from four different antibiotic regimens.
Richter & Frenzel, 2021 (USA)	• Live ER using combined digital and practical (clinical-based) escape room puzzles. • Sequential (digital) and open structures (paper-based). • Team size: 4-5 preceptors (4 teams). • Briefing: 18-sec video • Playtime: 45 minutes • Debriefing: Ten minutes	Resources: Preceptor handbook, round tables, videos, Papers, Stickers. Apps: Google Forms, QR codes Cost: Minimal (not specified) Development time: Approx. 60 hours	One digital escape room and one practical escape room (five puzzles). Puzzles: Digital locks, Rebus puzzle, Sudoku, Ciphers, Maze, Riddles, Hidden objects. Note: Participants stayed put at tables; facilitators moved around the teams.
Cole & Ruble, 2021 (USA)	• Live escape rooms • Sequential structure • Team size: 68 participants/group (two groups with three sub-groups each) • Briefing: Five minutes • Playtime: 40 minutes • Debriefing: Ten minutes • Q&A: Five minutes	Resources: Army men figurines, printed images, UV flashlights, cups, Scrabble letters. Apps: Nil Cost: Not mentioned. Development time: Approx. 20 hours	Eight different puzzles in eight bags containing components of the root cause analysis fishbone. Solved puzzles led to lock codes to unlock the bags allowing analysis of medication errors and eventually completing the fishbone diagram.

References	ER Game Setting	Resources	Gaming Tasks
Dittman *et al.,* 2021 (USA)	Cohort One: Live in-person ER • Sequential structure • Team size: Five-six students (88 groups). • Briefing: Facilitators prompted teams throughout the activity. • Playtime: 30 minutes • Debriefing: Yes, the duration was not mentioned. Cohort Two: Remote ER • Sequential structure • Team size: Five-six students (107 groups). • Briefing: Nil • Playtime: Start / Completion time. The fastest group wins. • Group reflection	Resources: Small-group collaboration classrooms, shared laptops for Cohort 1. Apps: Multi-sectional Google Forms and Google Suite Video conferencing apps for Cohort 2 Cost & Development time: Not mentioned	Four "rooms" or sections using Google Forms. The rooms contained a mix of open-ended questions and scenarios. When combined, these led to key codes for inter-professional student teams to escape.
Korenoski *et al.,* 2021 (USA)	• Live ER • Sequential structure • Team size: Three-four students (Five-six teams). • The length of the ER activity was not specified.	Resources: A patient toxicology case study, UV flashlights, invisible ink, locked boxes and hasps (learning game kits). Apps: Nil Cost and development time: Not specified	The number of gaming tasks was not specified. Additional clues and patient information were locked in boxes. Correct answers released the codes to unlock alphanumeric locks.
Oestreich *et al.,* 2021 (USA)	• Live ER • Sequential structure • Team size: 10-11 students (two groups). • Briefing: Nil • Playtime: 50 minutes • Debriefing: Tem minutes	Resources: Two identical small-group conference rooms, conference tables, wall-mounted digital monitor, locked boxes. Apps: Nil Cost: Not specified Development time: 48 hours	The ER had six tasks and a decoy to distract or hamper the students' progression. Note: The ER development required six volunteers. The ER game execution needed eight staff.
Blue & Zaheer, 2021 (USA)	• Synchronous, remote ER • Sequential structure. • Team size: Eight- nine students (20 groups). • Briefing: Nil • Playtime: 90 minutes • Debriefing: Ten minutes	Resource: A poisoned patient case. Apps: Zoom video platform and Google Forms Cost and development time: Not specified	Five puzzles. Scenarios and a case study, calculations, graphic ciphers, random codes. Note: The toxicology ER was manned by two faculty members and a postgraduate, where they went in/out of the virtual rooms in Zoom.
Baker *et al.,* 2020 (USA)	• Live leadership ER. • Sequential structure. • Team size: 24 students (6 teams). • The length of the ER activity was not specified.	Resources: Locks, flashlights, paint, playing cards, lab spaces. Apps: Nil Cost: ~USD250 Development time: 40 hours	Five puzzles. Codes, matching photos, a playing card suit and locks. Note: The ER development was piloted by 4th-year pharmacy students.
Plakogiannis *et al.,* 2020 (USA)	• Virtual escape rooms • Sequential structure. • Team size: Eight students (24 teams) • Briefing: Email • Playtime: One hour • Debriefing: One hour	Resources: A patient case study, two classrooms. Apps: Google Forms Cost: Not mentioned Development time: Not mentioned	Five clinical-based virtual rooms, with the sixth room being a physical puzzle. A combination of decoding and data hunt, coded messages, pigpen cipher, dose calculations and interpretive puzzles. Note: 1. The heart failure ER used two identical classrooms. 2. Lectures notes were allowed during the game.

References	ER Game Setting	Resources	Gaming Tasks
			3. Hints were announced at 15-min intervals.
Nybo *et al.,* 2020 (USA)	- Live escape rooms - Sequential structure. - Team size: six-eight students (four teams) - Briefing: A pre-recorded video of ER game and its rules. - Playtime: 45 minutes - Debriefing: One hour	Resources: Information sheets, videos, Kansas-inspired theme-based large classrooms (songs, vinyl album covers, background music), Kansas vinyl album covers, lockboxes, props, and poster printing. Apps: QR code, Google Forms Cost: USD160.31 Development time: 32 hours over three months.	Three rooms and ten tasks. Puzzles: Maze boxes, hidden information sheets, locks, maps, a compass and code board, hidden coordinates and data hunts. Note: 1. A week prior to the game, the students were provided learning objectives and a pre-game reading assignment. 2. One free hint was provided; an additional hint would incur a one-minute penalty, thus slowing down students' escape.
Eric Nybo *et al.,* 2020 (USA)	- Live escape rooms aided by online apps. - Sequential structure. - Team size: 30 students (four groups, each with sub-groups of seven-eight students) - Briefing: Game rules - Playtime: 60 minutes - Debriefing: Nil	Resources: A large lecture hall of 160-people capacity and posters. Apps: Google Forms, QR codes Cost: USD260 Development time: 40 hours over four months	Eight learning outcomes with three tasks (Personnel Bingo, Scavenger Hunt and Capstone Assessment) using lockboxes, worksheets and posters/QR codes. Note: 1. The first-year on-boarding ER game required five faculty members and two 4th-year students as guides. 2. Hints were provided during the game. 3. Students use their own smartphones, tablets or laptops.
Nguyen, 2020 (USA)	- Live escape rooms - Sequential structure - Team size: Five -eight students - Briefing: Yes, on the game structure and patient case. - Playtime: 45 minutes - Debriefing: Yes, no time specified.	Resources: A patient case with a list of medications, signs and symptoms and comorbidities; a small room classroom, an iPad. Apps: Zoom, Examsoft system Cost: Not mentioned Development time: 30 hours	Five tasks. Puzzles: a number code, unscramble letters, a jigsaw puzzle / Hidden text and a riddle. Note: Students were allowed to use their own laptops or tablets during the DIcipher ER activity.
Berthod *et al.,* 2020 (Switzerland)	- Live escape rooms - Sequential structure. - Team size: two participants. - Briefing: Yes, the game goals and rules - Playtime: One hour - Debriefing: Yes, no time specified.	Resources: An actual chemotherapy production zone converted to Esclean Room ER, prescriptions, production materials, a vertical laminar flow and padlocks. Apps: SurveyMonkey Cost: Not mentioned Development time: weeks, but not specified	Twenty-three questions on Good Manufacturing Practices. Theoretical questions, clues and combination locks.
Cain, 2019 (USA)	- Blended format escape room–paper-based clues followed by online puzzles. - Semi-linear structure. - Team size: five - six (24 teams) - Briefing: five minutes - Playtime: 45 minutes - Break: Ten minutes - Debriefing: Ten minutes	Resources: Large classroom auditorium, boxes, manila envelopes, combination locks, papers. Apps: QR codes, Google Forms in Google Drive folders Cost: Approx. USD12 Development time: Approx. 19 hours	Ten puzzles of different types and difficulties using riddles, clues and locks. Note: 1. A hint would incur a one-minute penalty, thus slowing down their escape. 2. Two course instructors and a post-graduate student monitored and facilitated the ER activity.
Clauson *et al.,* 2019	Live escape rooms	Resources: Three room settings–	Three settings. Puzzles of different

References	ER Game Setting	Resources	Gaming Tasks
(USA)	• Sequential format. • Team size: five - six (12 teams) • Briefing: Pre-recorded video on the game, game rules, instruction and an introduction to the patient. • Playtime and Debriefing: 120 minutes in total (a debriefing usually takes 30 minutes)	ambulatory care, community pharmacy and in-patient pharmacy, locks, boxes, pill bottles and laminated prescriptions. Apps: Nil Cost: Approx. USD400 Development time: Not disclosed	types and difficulties; clues and locks. Note: 1. The ER development was piloted by the faculty and 4th-year pharmacy students. 2. Each student team had one free clue with no time penalty. An additional clue incurred a 1-minute time penalty added to the escape time. 3. Six rooms were used, and 13 facilitators (faculty, staff and students) in the ER operation. Two ER parallel sessions were held.
Caldas *et al.,* 2019 (USA)	• Live non-sterile compounding ER • Open, non-linear format. • Team: 7-8 students (4 teams) • Briefing: Yes, an introduction to the game rules • Playtime: 40 minutes • Debriefing: Not specified.	Resources: Two identical classroom settings. Apps: Zoom video conferencing for online proctoring of the escape rooms Cost and development time: Not specified	Three tasks. Puzzles: Word lock, word jumble, cryptogram, coded messages, numeric and directional locks, diagram and physical puzzles. Note: 1. Three faculty members were involved. 2. Three clues were allocated for each team without penalty.
Gordon *et al.,* 2019 (USA)	• Live team building ER • Sequential format • Team: four – five students (four teams) • Briefing: Yes, an introduction to the game rules • Playtime: 60 minutes • Debriefing: Yes Total activity time: Two hours.	Resources: Paper-based puzzles. Apps: Nil Cost and development time: Not specified	Four gaming tasks. Puzzles: Word search, mapping picture puzzle, data hunt, a word riddle, a picture cipher and a code puzzle. Note: 1. Two researchers manned the ER activity and provided hints where needed. 2. Two pilot tests were performed, first by two students to determine time limits for puzzle completion. The second was conducted by three groups of 5-6 pharmacists to assess the scaling-up of the activity. 3. Incentives: Prizes to the first three teams.
Eukel *et al.,* (2017 & 2021); This diabetes-themed ER also were used in the studies below: Frenzel *et al.,* (2020); Kavanaugh *et al.,* (2020).	• Live diabetes management ER • Sequential structure. • Team: 5 students (about 16 teams) • Briefing: Nil • Playtime: 60-75 minutes • Debriefing: Yes Total activity time: Approximately two hours	Resources: Thematic room setup, survival kit, simulation videos, props (an insulin syringe, insulin pen, lunchbox), placebo dosage forms, online medication references, iPads and printing costs. Apps: Google Hangouts (free) for live monitoring Cost: Approx. USD100 for the first year, no cost in the subsequent years to continue conducting the activity Development time: 20 hours (as described in Eukel *et al.*, 2021 and 2017)	Five tasks. The final task required putting together clues from the previous four. Ciphers, jumbles, coded messages, jeopardy, combination locks, rebuses, Sudoku puzzle and data hunts. Note: 1. Each student team received a survival kit containing four hint cards and three iPad passes. Additional hints could be requested – no penalty incurred. 2. Students signed a confidentiality agreement so as not to reveal the logistics and solutions of the escape room.