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Room2Educ8: A Framework for Creating Educational Escape Rooms Based on Design Thinking Principles

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Abstract: By immersing learners in a playful, interactive, and engaging experience, Educational Escape Rooms (EERs) have been found to enhance learners' motivation, help them to develop 21st century skills, and improve knowledge acquisition. As research into EERs is still in a preliminary phase, no unified framework about how to design them has been established yet. Additionally, existing frameworks rarely validate the quality and efficacy of the frameworks themselves in terms of usability and usefulness. Therefore, the present paper proposes Room2Educ8, a learner-centred framework for EER design that follows Design Thinking principles. It provides detailed heuristics for empathising with learners, defining learning objectives and constraints, adding narrative, designing puzzles, briefing and debriefing participants, prototyping and playtesting, documenting the whole process, and evaluating the EER experience. A mixed-methods internal validation study based on Instructional Design model validation was conducted with 104 postgraduate students between 2018–2022 to assess the framework's integrity and use. The study findings suggest that Room2Educ8 can be proposed as a valid tool for developing a wide range of EER types that cover a variety of topics. Its well-described and practical steps make it appropriate for educators regardless of a lack of prior experience in EER design.

Keywords: escape room; game-based learning; gamification; design thinking; educative innovation; framework; technology-enhanced learning

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1. Introduction

Escape rooms (ERs) are emerging as a new type of learner-centred activity designed to enhance students' learning and 21st century skills in primary, secondary, higher education, and professional development programs [1–3]. An educational escape room (EER) can be defined as an instructional method requiring learners to participate in collaborative playful activities explicitly designed for domain knowledge acquisition, skill development, or behavioural change so that they can accomplish a specific goal (e.g., participants must escape from a physical or virtual room, solve a mystery, find a hidden item, prevent a disaster, break into a vault, etc.) by solving puzzles linked to unambiguous learning objectives in a limited amount of time [4].

Escape room puzzles can be categorised as: (1) cognitive, which make use of the players' thinking skills and logic; (2) physical, which require body movements or the manipulation of artefacts to overcome a challenge; and (3) meta-puzzles, i.e., puzzles that combine results from previous puzzles and are often connected to the narrative in key points of the gameplay [5]. Common puzzles involve unlocking locks with keys and combinations, assembling physical pieces together, unveiling hidden text that reacts to light or heat, interpreting complex ciphers hidden in the text, matching directional locks with directional clues from maps, counting items, placing transparent sheets on top of each other and rotating them until they line up to form letters, navigating mazes, searching for physical objects, or identifying patterns [6].

There are various game types that can be used to enable an EER to fit into different classroom settings, including the following [7]:

1. Pop-up escape room, which is a temporary ER that uses the same game format as a traditional ER but is only deployed for a short time;
2. Puzzle box, where the players are working to open a series of locked boxes, usually played on a tabletop, instead of getting out of a room;
3. Puzzle hunt, which is a paper-based series of puzzles, also usually played on a tabletop, and suitable for large groups;
4. Digital escape room, which is a virtual room where the players use technology (e.g., phones, tablets, computers, websites, apps, VR/AR, QR codes, etc.) to open a series of digital locks usually made from online forms or password-protected documents. This is a cost-effective and easy-to-setup solution that became very popular during the COVID-19 pandemic. It can be conducted individually or in groups, and it is the preferred EER type when large numbers of students must play at the same time;
5. Hybrid game, which combines elements of other game types to provide players with a game experience that matches their engagement with it [8];
6. Serial story, which is a series of self-contained, mini-ERs connected by a larger narrative or unifying theme (such as TV episodes) that take place on a regular basis over a longer period of time.

EERs have been used to introduce, foster, demonstrate, assess, or integrate students' content knowledge and skills [5] into a wide variety of academic disciplines, such as healthcare [9–11], STEM subjects [12,13], computer science [14–16], chemical engineering [17], pharmacy [18], physics [19], mathematics [20], chemistry [21], radiology [22,23], biology [24], sex education [25], teacher education [26], music [27], cultural mediation [28], etc. Additionally, in creative courses students have been asked to become "makers" [29] and develop EERs as a means to demonstrate and improve their creative, artistic, design, and problem-solving skills [30,31]. EERs can leverage the benefits of "competition, challenge, imagination, exploration of the environment, goals to be achieved, interactions (with people and objects) and security" [32]. By immersing learners in a playful, interactive, and engaging experience, EERs enable them to recall, apply, and advance their knowledge [33]. Puzzles within an EER are problem-based and require communication and team-working skills, which are considered intrinsic parts of the way in which adults learn [34], while a robust storyline helps to set the stage, and post-game reflection helps to solidify the learning goals. Various systematic and meta-analysis reviews indicate that, due to their playful nature which favours positive behaviour [35], EERs can enhance learners' motivation, engagement, and time management, increase confidence in critical thinking and decision-making, encourage lateral thinking, improve knowledge acquisition and academic performance, and help in developing logical, spatial, creative, linguistic, interpersonal, and collaborative competencies among players [4,5,33,36]. They can also be designed with elements that simultaneously serve visual, auditory, and kinaesthetic learners, thus covering all learning styles. Additionally, EERs can encourage social interaction, which is very important in the new era of increased hybrid delivery brought upon by COVID-19 [37].

Despite appearing to be a superficial form of entertainment, escape rooms can be grounded in sound educational theory and, when used effectively, act as a low-cost, high-impact resource for a variety of learners. EERs emphasise collaborative learning with activities that require teamwork and communication, force interdependence among multiple individuals who share a clear goal, and provide a built-in opportunity for rapid and unambiguous feedback [1]. From a pedagogical point of view, EERs are based on a social-constructivist approach [38]. Learners construct their own knowledge based on real-time experiences of advancing through several levels of progressive challenges in the escape room; they are called to face new and often complex problems, which can be solved by interacting with their peers and getting support from their tutor. The latter not only provides instructional scaffolding to the learners by facilitating their interaction with the material and with each other [4,13], but also closes the learning loop in a structured debrief,

in accordance with simulation best practices [10]. Generation Z students who are considered multimodal learners [39], autodidactic, and are actively seeking activities that make them feel involved [40] will benefit significantly from having several different mediums or channels of information. This experiential and collaborative activity coincides with many of the features associated with a socio-cultural approach to learning [35] and motivates players to practise with hands-on examples as an effective way to increase skill retention.

EERs can also be used within the revised framework of Bloom's Taxonomy to include all six categories of cognitive processes by which thinkers encounter and work with knowledge, comprising "remember", "understand", "apply", "analyse", "evaluate", and "create" (Figure 1). Involving learners in higher levels of cognitive activities can positively impact the levels of engagement and knowledge retention among them [33].

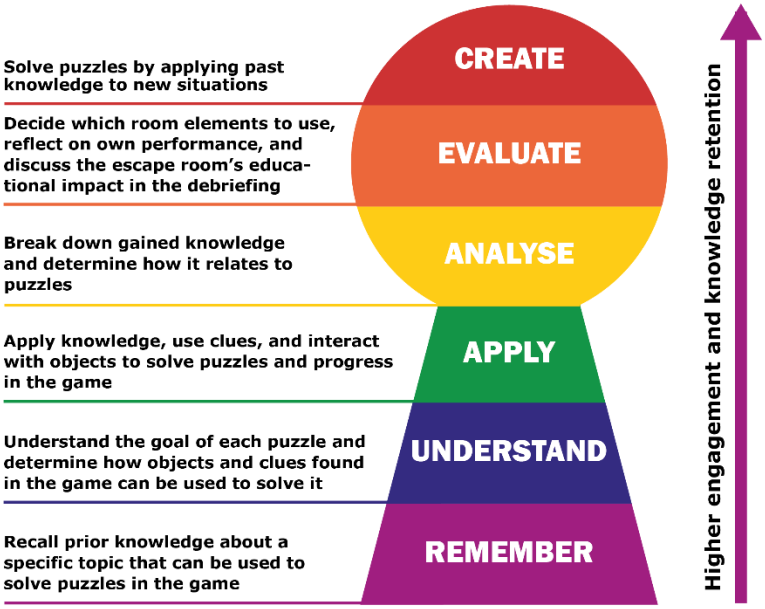

Figure 1. Analysis of EERs within the revised Bloom's Taxonomy framework (Adapted from [33]).

EERs frequently expose participants to real-life scenarios with puzzles that fit into the story and involve interacting with a lot of objects in realistic ways, thus bringing greater authenticity to the activity and making it more immersive [32]. Because storytelling is often an entertaining, visual, experiential, and emotionally evoking activity, learners are much more likely to retain the course content taught in story format settings [41–43]. The fact that stories evoke emotions adds to their learning effectiveness; learning experiences associated with emotions are more easily stored [44] and appear to be remembered vividly and accurately, with greater resilience over time [45].Therefore, interactive storytelling is slowly becoming a key factor in EERs. As stated in [46], "a story does what facts and statistics never can: it inspires and motivates".

In an EER that recreates real-life circumstances, participants will also be able to reflect on their own life. Students can experience a situation in which they need to respond to high-stake situations, trust their own and their colleagues' competence, work together as a team, settle differences in opinions, and handle both time constraints and the consequences of not working fast enough [47]. Role playing provided by EERs enables great awareness and ensures a good assimilation of messages. This approach aligns with the paradigm of narrative-centred learning environments [48], which are defined as "a class of game-based learning environments that contextualise educational content and problem solving with interactive story scenarios".

When the EER activity takes place in the environment in which it would normally be applied, e.g., when a medical-themed EER is set up in an actual hospital, it aligns with the situated learning theory [49], which states that situated or scenario-based learning should take place in the context and environment in which it is going to be used. When used as a method of simulation-based education (SBE), EERs can be mapped effectively to Kolb's experiential learning cycle, which suggests that despite individuals' preferred learning methods, experiential interaction with materials produces positive learning outcomes [50]. EERs permit active experimentation in a safe environment, prior to undertaking concrete experiences "in the wild" [51]. Debrief and reflection are essential to learning in Kolb's cycle, and the real value of the EER could be argued to be purely these elements, similarly to other types of SBE [1].

The thrill and excitement of playing an escape game are the results of endorphins being released. Endorphins are the body's natural painkiller. They can also lower stress and anxiety levels, and even create a sense of euphoria. Combined with other neurotransmitters, this helps create an ideal environment for focused learning [52]. Furthermore, in the same way that games help stimulate the production of dopamine, a chemical that is considered to play a key role in motivation, affect, prosocial behaviour, and learning [52,53], EERs that access the same methodologies could result in learning–reward cycles [54] by reinforcing neuronal connections and communications during a learning activity [55]. Finally, unlike the one-size-fits-all lecture, EERs can also be balanced to be appropriate to the learners' skill level [56] to prevent them from becoming frustrated or bored, thus allowing them to experience "flow" or optimal experience, i.e., a highly focused mental state leading to immersion and high performance that is likely to emerge when learning activities are challenging but feasible, have precise goals, and provide clear feedback about performance [57,58].

Researchers have begun to build upon the notion of teachers as designers of learning experiences for students [59]. EERs have the potential to enable new forms of teaching, as evidenced by the rapid increase in publications related to the use of escape rooms for educational purposes, but their design and development for specific learning contexts is a time-consuming task [4], especially for educators without any prior experience in game design. As research in EERs is still in a preliminary phase, no unified framework about how to design them has been established yet. There is a need for frameworks, methodologies, or guidelines especially aimed at EERs [5,25,32,47,60] that could help educators not only in creating these new learning environments, but also in developing design dispositions [61] that will help them adapt to the complexity of teaching in the 21st century [59,62].

EscapED was the first theoretical framework to provide a methodology for creating EERs and interactive game solutions for learning and behaviour change within higher education settings [63]. It consists of six sequential steps (Participants, Objectives, Theme, Puzzles, Equipment, and Evaluation), with each one of them being broken down into other areas for developers to consider at the start of designing their EER. Although the escapED framework has informed the development of various EERs, either in its original form, e.g., [14,15,21,64], or in a modified version, e.g., [26,65], its quality and efficacy in terms of usability and usefulness for developers who wish to use it has not been validated yet.

Another methodology for designing Serious Escape Games for teaching is SEGAM [32]. SEGAM describes how to approach various aspects related to EERs such as constraints, pedagogy, parameterisation, tests, and background. It divides an EER into several levels, with each level representing a stage of the game and having at least one associated riddle that corresponds to one or more educational objectives (diagnostic, formative, summative, or discovery of a notion). However, this methodology was not evaluated and was used to develop only a single EER which was played by 20 students.

Eukel and Morrell presented a cyclic design process to create, pilot, and evaluate EERs that includes five steps: Design, Pilot, Evaluate, Redesign, and Re-evaluate [66]. While this approach offers some generic advice on EER development, it appears to be a simplified and iterative adaptation of the waterfall project management methodology. The provided information for each step lacks depth and there is no evaluation of the proposed method.

Nicholson and Cable [7] proposed a framework that enables the setting of specific learning objectives and individual learning outcomes for students in an escape game by mapping them against seven dimensions (Setting, Social, Story, Skills, Strategy, Simulation, Self) in order to build a cohesive interactive story that provides learning opportunities. Although the authors give instructions on how to build an EER using this framework, they do not provide any information about the framework's own evaluation.

The COMET framework was developed as a step-by-step approach to designing escape room exercises that would meet specific medical knowledge, skills, attitudes, and safety objectives while considering the unique dynamics of an interprofessional team [67]. It comprises five components (Context, Objectives, Materials, Execution, and Team Dynamics) and was piloted in a one-hour workshop aimed at enabling small groups to collaboratively design an interprofessional escape room. Although the COMET framework received generally positive feedback from the participants, its evaluation was very limited due to the small sample size (N = 16) and therefore its generalisation will require further reliability and validity testing.

Despite their different approaches, the aforementioned frameworks share one thing in common: they rarely validate the quality and efficacy of the frameworks themselves in terms of usability and usefulness, opting instead to assess the impact on learning of a single prototype escape game that was developed using the particular framework. To address this issue, this paper proposes Room2Educ8, a user-centred, conceptual framework for EER design following design thinking principles that can be adapted to any subject and escape room type. A mixed-methods internal validation study based on Instructional Design model validation was conducted to assess Room2Educ8's integrity and use.

2. Room2Educ8 Framework

Room2Educ8 is a conceptual framework that can be easily tailored to fit any subject, set of learning outcomes, and class size by adjusting the escape room type, the puzzles, and/or the narrative. It was specifically designed to offer educators guidance in creating robust EER experiences and has been developed iteratively with pilot testing and refinements of individual elements since 2018. Room2Educ8 is based on design thinking, a process that has already been used as an instructional design method for the development of course content or teaching material [68], in curricular development [69], and as a teaching strategy to achieve subject-specific learning goals [70].

Room2Educ8 aims to allow practitioners to develop their creative confidence, which is required for game-based learning to be fully realised [71], by engaging in hands-on projects that focus on building empathy, promoting a bias toward action, encouraging ideation, and fostering active problem-solving [72]. Its iterative process can be described as a cycle of (1) empathising and observing, (2) defining the problem, (3) contextualising, (4) designing puzzles, (5) briefing and (6) debriefing the participants, (7) prototyping and playtesting, (8) documenting the design process, and (9) evaluating the EER experience (Figure 2). Designers can carry these stages out in parallel, repeat them, reflect, and circle back to a previous stage at any point in the process [73]. These stages were influenced by a typical design thinking process of (1) empathising and observing, (2) defining the problem, (3) creating ideas, (4) prototyping, and (5) testing [74]. Although no prior game design experience is required to use the framework, Room2Educ8 users may benefit from participating in a regular escape room before they start designing their own.

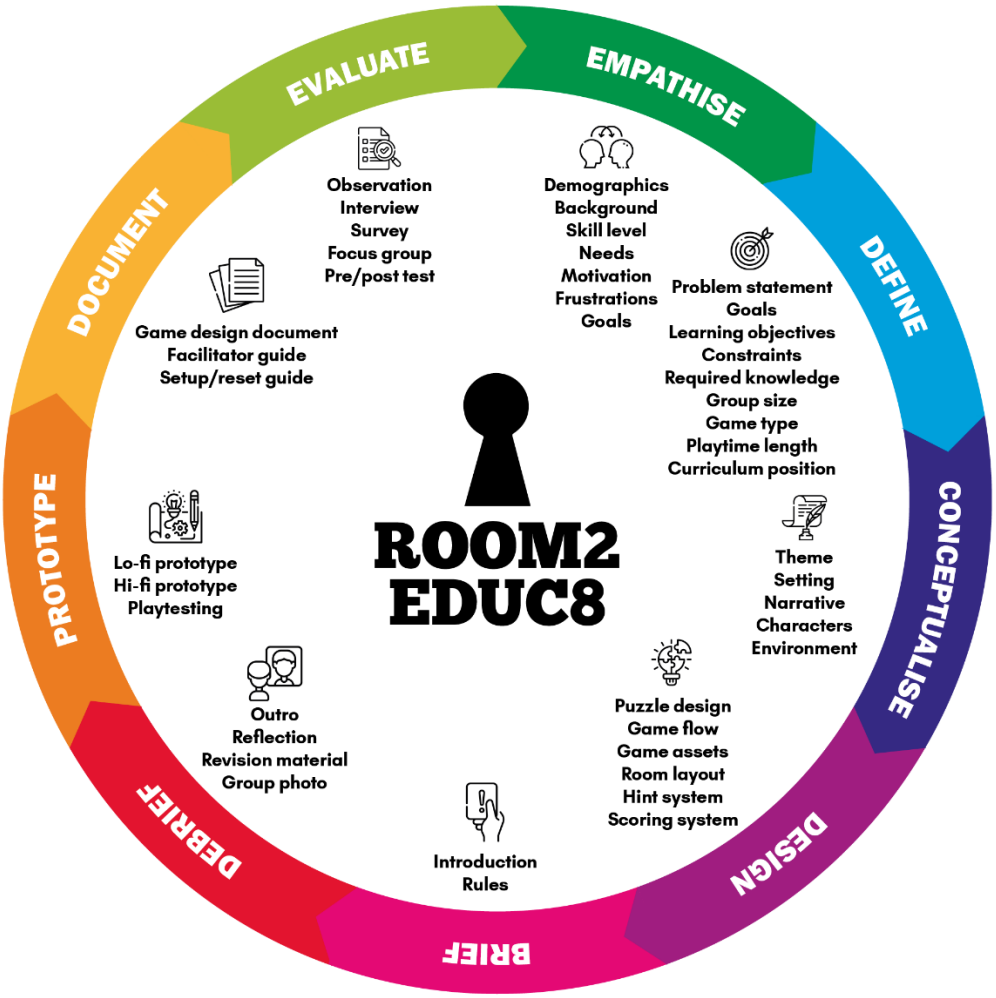

Figure 2. Room2Educ8 framework.

2.1. Empathise

The first step of Room2Educ8 calls for EER designers to gain an understanding of both the people they are designing the EER for and the problem they are trying to solve. Empathising, i.e., intellectually recognising or vicariously experiencing the feelings, thoughts, or attitudes of others [72], is essential, because EER designers create learning experiences for people with given wants and with characteristics different from their own, while often working in design teams composed of people with different skill sets and interests which can affect their prioritisations of interests [75]. Understanding the participants corresponds to the regular "learner analysis" included in most Instructional Design models [76].

EER designers can utilise techniques such as focus groups, interviews, observations, and surveys [77], as well as data from academic records to collect information about their learners. The collected data can then be analysed to identify trends and segments within the overall learning audience. Significant groups of the latter can then be segmented to build learner personas, i.e., fictional characters who represent certain traits and qualities of the target audience for whom the learning experience is designed for [78]. These should be kept in mind throughout the design and development of the EER as they can help designers to identify and understand the learning objectives, challenges and preferences of their learners and tailor the escape room experience with them in mind. A learner persona usually includes a fictionalised name, photo, demographic information, short biography, leadership and character traits, academic needs, primary goals, motivations, frustrations, learning preferences, digital fluency, and relevant quotes from interviews (Figure 3).

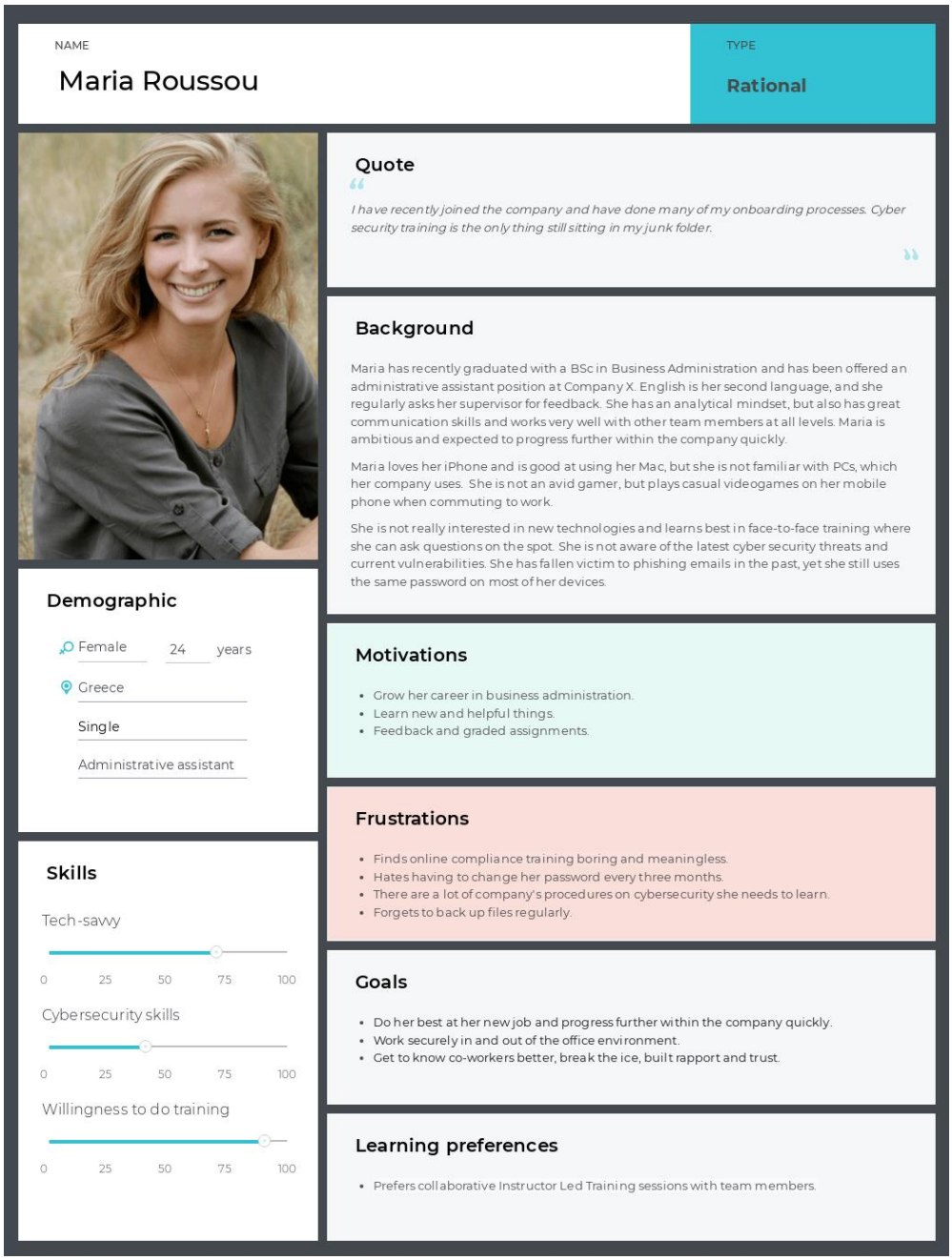

Figure 3. Sample learner persona for EER about cybersecurity awareness training.

2.2. Define

The second step of Room2Educ8 synthesises the findings from the empathise stage and carries them into a series of brainstorming sessions to define the following set of constructs that should be closely considered when designing an EER: problem statement; goals; learning objectives; constraints; required knowledge; group size; game type; playtime length; and game position within the curriculum.

A problem statement identifies the gap between the current state (i.e., the problem) and the desired state (i.e., the goal) of a process or product. One way to approach defining a specific problem is to frame it from the learners' perspective and identify the "whos", "whats", and "whys" that exist in the space around the issue, such as asking who is experiencing the problem, what the problem is, and why it matters. An example problem statement is the following: "Employees at a university (who is affected?) need an engaging,

memorable, and easy-to-understand Security Awareness Training based on real-life scenarios (need) because they are bored and distracted by their organisation's tedious e-learning training (what is the problem?), thus becoming a big security risk (why does it matter?)".

Defining the problem should be followed by setting up S.M.A.R.T. (Specific, Measurable, Achievable, Relevant, and Time-bound) goals [79], starting with outlining the overall purpose of the EER. Most educators implement EERs to explore an active learning environment, preview, review, or practise material, increase students' motivation and/or engagement, foster learning, and/or develop teamwork and communication skills [5]. Once goals are established, designers should break down what they want to accomplish into smaller, more specific objectives that will help them reach the goal of the room. By answering questions such as those in Table 1, designers should get a sense of direction and know whether the EER could be developed by a single person or would require a team.

Table 1. Questions to help define SMART goals for EERs.

Goal Type	Question
Specific	What is the overall purpose of the EER? What are the learning objectives this EER is going to support? What type of EER will be developed (e.g., physical, digital, hybrid, etc.)? If the EER is physical, where will it be located (e.g., outdoors, in a classroom, lab, library, office, etc.)? What knowledge is required to succeed in the game? Is it explicit, assumed, retrievable, or a mix? How many participants need to play at the same time? Will the game be played by small groups, or does it need to be scaled up? Where will the EER be positioned in the course curriculum (e.g., as a stand-alone activity, at the introduction of a course, during a course in addition to a lecture, as an assessment, or as a serial story)? How will the game be monitored? Will you develop alone, or will you co-create with the target audience? Will the story be stand-alone like a full movie or framed as an episode with a continuous narrative arc? Will the EER be used as a formative or summative assessment tool?
Measurable	How can you quantify or qualify that the learning objectives have been met? How much staff time do you have available to run the activity? How will the designer know when the game is successful?
Attainable	Does the goal require the right amount of effort? Is there a sufficient budget to develop the EER? Are the necessary resources available (e.g., space, props, equipment)? Do learners have the necessary skills to play the game? Are there any language barriers that may prevent non-native speakers from playing the game? Are there any tasks that may prevent participants with differing levels of mobility or with sensory impairments from playing the game? How many learning outcomes are sufficient without overloading participants?
Relevant	Why is achieving each learning objective significant?
Time-focused	What will be the duration of the game? How much time will be available for self-reflection after the game? How many sessions will be necessary to involve all participants? What is the deadline or time restraint to develop the EER?

Unlike recreational escape rooms, EERs must align with specific and purposeful learning objectives to be effective [80]. These are details of what the participants should have learnt by the time they have finished the EER. Learning objectives should be written in such a way that educators can readily assess if they have been completed. They may describe specific content knowledge and content-related skills (e.g., clinical skills), general skills (e.g., practising or developing teamwork and communication skills, situated problem-solving, critical thinking, reasoning skills, empathising, delegation), affective goals (e.g., performing under pressure, increasing situational awareness), or a combination of them [5]. It is good practice to include learning objectives that everyone should be able to achieve, some trickier ones that most will, and some stretch goals that very few will achieve [81]. Determining

the topics that will be covered in the game and creating tangible objectives allows for the development of an evaluation strategy to assess the players' learning experience [63].

Identifying the constraints that may affect the game's development is also crucial so that designers can focus on suitable ideas and ensure the EER's feasibility. Typical constraints in educational environments that can heavily influence how the EER activity will be developed include time (e.g., the available time to develop the game; the available time for the whole activity to take place, including time to set up, brief, debrief, reset, and facilitate the game), location (e.g., the room should be located as close to the participants as possible), space (e.g., the room may be small or there may be multiple rooms available), game scale, budget, class size, resources, language (e.g., will non-native speakers be able to solve cryptic crossword puzzles?), neurodivergent learners, and curriculum (e.g., do the EER's learning outcomes align with the curriculum?). Tutors are vital for the EER experience, as they usually play the role of the game master whose duties include introducing participants to the game's rules and story, monitoring the team's progression, providing hints during gameplay, and facilitating the debriefing session after the game. Therefore, staff availability should also be considered.

It is accepted practice that any knowledge needed to solve a puzzle in a commercial escape room will be provided within the room itself (e.g., the periodic table, music scales, Morse code, etc.) [82]. However, escape room activities have been proven effective for assessing students' knowledge, applying previously taught information to gain a deeper understanding [10], or practising information retrieval skills. Therefore, designers should decide what knowledge is required to succeed in the game. This can be explicit (i.e., students are given all of the relevant information needed within the game world—no prior subject-specific knowledge is required), assumed (i.e., students are being tested or assessed on what they already know), retrievable (i.e., students use information retrieval skills to find what they need in the real world), or a mix [7].

A key element to having a positive EER experience is doing it with the right group size so as to keep the players in a state of flow [58] with enough puzzles to engage everyone in the group. The size of the group can alter how quickly players move through the game's puzzle path. The average group size for commercial escape rooms is 4.58 people [83]. With more participants, the game should become easier up until a turning point where people who are not engaged in the game are standing around and becoming bored and distracted [82]. However, in an educational setting class sizes are usually too large, classrooms are too small and underfunded, and timetables are too inflexible to allow for small teams to play an escape room without disruption [7]. Conducting escape room activities with large cohorts means that several sessions must take place, which can be a tedious and challenging task [4]. As a result, team size compromises often have to be made, which can affect student participation [3]. Choosing digital, portable, or quick and easy-to-set-up and easy-to-take-down escape room types that are more feasible for a classroom is one way to address these issues [84]. EER designers can refer to Table 2 to decide which escape room type is a better fit to their class sizes, learning outcomes, and time constraints.

The next thing for EER designers to decide is the game's *playtime length*, i.e., the time players spend on the puzzles, not including the briefing before the gameplay and the debriefing afterwards. A time limitation is commonly present in EERs to introduce an element of stress, excitement, and competition. In medical studies, the time constraint is considered not only as a game design aspect, but also an educational aspect, as collaborating under time pressure is a life-saving skill in medical professions. In other disciplines, the restricted time is a way to create social interdependence; everyone must solve all the puzzles in time, so learners are required to spend their time effectively and decide what to focus on. The teamworking and prioritisation practice can be seen as directly linked to developing leadership and management skills [81].

Table 2. Advantages and disadvantages of EER types (Adapted from [7]).

EER Type	Description	Advantages	Disadvantages
Pop-up escape room	A temporary EER using the same format as a traditional EER but only deployed for a short time.	Close to an immersive commercial ER experience. Good when simulating elements of the environment for learning outcomes. Easy integration of a human actor.	The small team size makes this unfeasible for the only in-class activity for a larger class. High resource cost in equipment and human engagement as host or actor.
Puzzle box	The players are working to open a series of locked boxes, usually played on a tabletop rather than based on getting out of a room.	Can be used with small groups or adapted for a classroom with multiple copies. Less expensive than a full room. Portable and can work well in a classroom environment. May be designed to be run completely on its own without the need for a facilitator.	May require many copies of the same materials for all groups. Reduced physical immersion and emotional engagement. Overwhelming to facilitate without a self-help hint and answer system.
Puzzle hunt	A paper-based series of puzzles, also usually played on a tabletop, and suitable for large groups.	Handles a large group of players well. Cheap if most puzzles are pen and paper. Can accommodate many groups of players. Several free online tools that facilitate this type of game are available.	Some types of physical puzzles are not feasible. Less immersive than games that use physical components. Overwhelming to facilitate without a hint and answer system.
Digital escape room	A virtual room where the players use technology (phones, tablets, or computers) to open a series of digital locks made from online forms.	Easy to setup (e.g., using Google Forms, Microsoft PowerPoint, Genial.ly). Cost-effective. Can be accessed by as many students as needed at the same time. Easy execution. Effective when one of the learning outcomes is to conduct research using online resources.	Usually less immersive than a physical EER. Potential loss of player-to-player engagement. Groups can be easily taken over by a single person if there is only one device per group. Technology can fail.
Hybrid game	An EER that combines elements of other game types to provide players with a game experience that matches their engagement with it.	Easier to design, as the format of the game can change according to the needs of the narrative and the learning outcomes. Can handle players better, as bottlenecking issues can be solved by using a different style of puzzle at these points.	Requires designers to create different types of puzzles. Can be difficult to test without a large group to identify bottlenecks. May be overwhelming to players who are not comfortable with learning multiple types of puzzles in one game.

Table 2. *Cont.*

EER Type	Description	Advantages	Disadvantages
Serial story	An EER that combines elements of other game types to provide players with a game experience that matches their engagement with it.	Easier to fit into a classroom schedule due to its shorter game length. Can be changed on a weekly basis according to student performance. Less overwhelming to get started with, as teachers can learn from design mistakes and improve future games.	Earlier content is forgotten if debriefing occurs only at the end of the game. Will take more time overall, as the setup and narrative will need to be repeated each week to get the players into the game.

The playtime of an EER ranges between 15 and 120 min, with most games using the 60 min time limit typically found in commercial escape rooms. In educational settings, it is important that as many students as possible reach all the goals in time, and frustration, dropping out, or trial-and-error behaviour are avoided. Therefore, when considering playtime length, designers should ensure that it allows for a sufficient number of puzzles to be used, offers ample time for students to work as a team, and fits into a classroom time slot [4]. Shorter games require less development time, but longer games can use more meaningful challenges that require more time and effort to be solved.

Finally, designers should decide the EER activity's position within the curriculum. EERs with learning goals solely focused on introducing a subject, general skills, or affective goals, are usually stand-alone activities (e.g., icebreakers, orientation activities to encourage student engagement with library services, induction week activities, playful ways to introduce people to STEM subjects, etc.). Conversely, EERs that are intended to foster content knowledge and related skills are embedded in a course curriculum, usually positioned in addition to lectures at the introduction of the course, at the end of the term to keep the motivation going to the last minute, or to mark a special event in the calendar. EERs with formative assessment goals are positioned mid-term or before the exams [5], while EERs that follow an episodic format may run periodically (e.g., on a weekly basis) for a whole semester. It is recommended to run only one or two EER activities with each class per year, so that the novelty does not wear off.

2.3. Contextualise

The third step of Room2Educ8 is to place the EER in a particular context which gives meaning to the activities the learners do, provides an authentic reason for escaping, and links the puzzles together in a cohesive storyline so that participants can identify with the game experience and build personal motivations to complete the game [63]. Context includes theme, setting, characters, narrative which contextualises knowledge and skills needed, and environment.

A theme is a necessary component for maintaining the fiction contract with the participants as it ties the puzzles and decorations together and sets the EER's tone, look, and feel [9,85]. It is critical to select the theme early in the design process, as it will dictate the rest of the decisions made about the game, such as the setting, characters, and the tone of the puzzles. More importantly, it will enable designers to target specific competencies and skills. For instance, as well as being fun, a highly imaginative theme can also encourage creative thinking. Mystery themes (e.g., uncovering a murderer) are good for working on problem-solving and decision-making skills. They often prioritise attention to detail and tend to have a more focused and serious feel. EERs with a scientific or technical setting (e.g., a science lab or a factory) can help teams to develop abilities such as strategic planning and delegation. Finally, horror themes are effective in fostering team-working skills under pressure. They encourage adaptability and quick thinking, while also testing the participants' resilience.

The time period and place where the game will be set should be decided next (e.g., a haunted house in Victorian England, a detective's office in New York during the roaring 1920s, a Pharaoh's tomb in Ancient Egypt, etc.), as this can determine what types of elements will be most appropriate to develop the puzzles from. Challenges that use the types of things that are typically found in that particular setting will feel more natural, thus helping immerse the participants in the game world.

A story should be created to support meaningful play [86] and provide an immersive narrative for the activity [1,11] that will be introduced and discovered by the participants in bits and pieces. This will help to solidify the game objective in the minds of the participants and add to the ambience of the game [87]. The story should encompass who the characters are, what conflicts they are facing, and where this is all taking place. A logline that covers the basic elements of a sample EER about raising cybersecurity awareness could be "the participants are a team of private investigators ("who") who use the opportunity of an invitation at their client's CEO's home ("where") to steal evidence of his involvement in the misappropriation of funds and bring him to justice ("what")".

Once EER designers have a story in mind, they should decide about the plot (i.e., how, when, and why everything happens) by asking themselves: Why are the participants in the room? How did they get there? What do they need to do to escape or succeed? What are the consequences of failure? What are the rewards? Why do they need to hurry? Why are there puzzles and clues in the room? Who put them there? How do they fit into the story? Who is the game's facilitator, why are they there, and why are they giving hints? Solving these challenges will make for a very immersive escape room experience that seamlessly integrates characters, story, and puzzles. Examples of basic plot frames that can be used for EER stories include the following [85]:

- Someone Kind (e.g., a rich relative with a will) or Evil (e.g., a psychopath) locked you in a room with a test of wits. If you can escape, you will get Something Good (e.g., money) or will not be killed;
- Someone Friendly (e.g., a mentor) needs your help to do Something Important (e.g., find the real murderer) to help them out;
- Something Bad (e.g., computer failure) happened. You are being framed or need to do Something Important (e.g., reprogram the computer to fix it) and escape;
- Someone Nefarious (e.g., a science corporation) locked you in a room. Luckily, Someone Friendly (e.g., a colleague) left a series of hidden clues that will help you escape.

It is important to keep the plot points in easy-to-understand bite-sized portions and let the beats drive the action and participants towards their goal. Integrating the time factor in the plot is also crucial; many EERs have a one-hour time limit, so designers should ask themselves what story they can tell that culminates in the participants reaching their objective in an hour. Setting up circumstances that generate emotion or presenting participants with dilemmas that play on their sense of justice and morality can make a story even more engaging.

Another consideration at this point is the characters that are part of the plot. In an EER, participants are expected to be an active part of the learning process, so they should assume the starring role (protagonist) in a story that they feel they are influencing, with an outcome they believe they can affect [7]. It is as a direct result of their decisions and actions that the narrative progresses. Once the role of the participants has been decided, the other characters need to be fleshed out as well. EER designers can have those characters communicate their wants and needs through puzzles and/or audio, video, photographs, or written messages integrated into the experience. Adding some complexity to antagonists or even evoking sympathy for them allows the game to have different endings with moral dilemmas, e.g., if the antagonist is a politician who has manipulated an election, but only to avoid a dictator coming into power, then the participants can either keep the secret or reveal everything. This choice may be a starting point for an ethical or philosophical discussion in the debriefing session. All endings need to reach the same learning outcomes, though. Allowing participants to make choices that have direct consequences on how the game

plays out gives them a sense of control over the game and their role in it [33]. Finally, the role of an ally who can provide the participants with hints, tools, and instructions to help them overcome these challenges is usually played by a tutor. This is an opportunity to guide the participants towards success and ensure that they have a good learning experience.

With compelling characters in place, the basic concept of the story needs to be structured into a series of events that the participants can follow. Rich narratives which do not require too much reading and fit the theme and the setting will keep an escape room from just being a random series of puzzles. Often EER narratives are "bookend" narratives, with most of the important story information communicated at the beginning and the end of the game [85]. The core story can be expanded using the model of dramatic structure put forward by German playwright Gustav Freytag in *Die Technik des Dramas* (1863). This model has become commonly known as "Freytag's pyramid". Its application to an EER is illustrated in Figure 4 as a 2D graph in which the x-axis shows progression through the story, and the y-axis shows emotional engagement or tension. The resulting curve depicts the typical dramatic arc rising and falling as a "pyramid" [88]. Freytag's model defines sections of dramatic action, separated by key events, which can be positioned and aligned to sections of the Three Act Structure of a beginning (setup of the conflict), middle (confrontation of the conflict), and end (resolution of the conflict) [89].

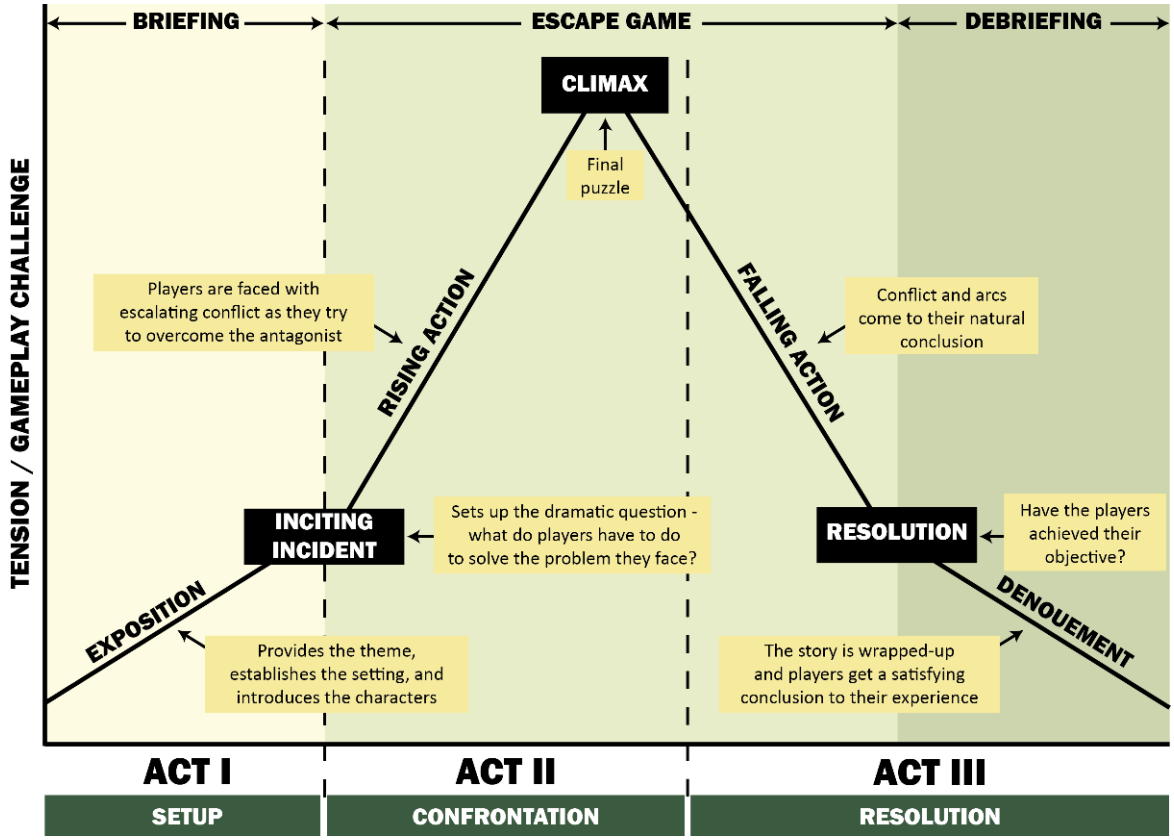

Figure 4. Dramatic structure of an EER according to Freytag's model.

Act I (beginning/setup for the conflict) starts with *exposition*, which offers background information about the main characters ("who"), the setting ("where"), and the circumstances or time period ("when") to prime the players for the rest of the story, as well as other contextual background information and lore relevant to the action. In an EER, these elements of theme and backstory are often presented during a pre-game introductory briefing by the game master or by a pre-recorded video introduction. The exposition is followed by the *inciting incident*, an event, occurrence, or action that pulls the protagonists out of their normal world and into the main action of the EER. Without it, the protagonists

would not become aware of the conflict, and therefore they would not have the opportunity to resolve it [89]. This sets up the *dramatic question*: What do the protagonists have to do to solve the problem they face? It is often presented to the participants by the game master just at the point that they enter the room and serves to set their objectives in the game. The success (or otherwise) of the participants in achieving the gameplay objectives will determine how the dramatic question is resolved in the narrative. The first act concludes with some turning point that launches the action into Act II.

Act II is where the *rising action* of the story occurs, in which the participants are faced with continuous, escalating conflict as they try to overcome the antagonist. This section of the narrative constitutes the majority of an EER experience, and typically has participants solve puzzles, discover items, and reveal new areas in pursuit of the goal [88]. A sense of increasing urgency can be created by a time countdown, dramatic theatrical music which increases with intensity as time runs out, audio cues from a character or pre-recorded messages, and lighting effects. The dramatic tension in the game increases higher and higher up to the *climax*, which is the emotional peak of the story. It signifies the final moments of the story's overarching conflict and can be represented as the final puzzle (e.g., cutting the wire to defuse the bomb). However, the game should not end immediately after the climax, as participants will not be able to experience the results of their actions in the game world and the story will not be concluded.

In Act III, Freytag's model identifies a period of *falling action* that results from the climax, which can still be exciting (e.g., having defused the bomb during the climax, the participants still need to escape the building) and should lead to the *resolution* of the dramatic question: have the players succeeded in achieving their objective? Finally, the story de-escalates in a *dénouement*, where the events of the climax wind back down into normal life. An outro video at the beginning of the debriefing session that follows the game is an effective way to provide clarity, resolution, and closure by showing participants what happened at the very end of the story. If the EER is a serial story, the video can deliberately end on a cliff-hanger to create a sense of suspense and get everyone excited for the next episode.

As with the theme and narrative, the room's physical environment supports (or detracts from) the activities and overall learning outcomes. Choices about the decoration, physical props, lighting, technology, audio, video, and visuals of both physical and digital game spaces have narratological consequences and must follow the room's theme to prevent cognitive dissonance [90]. A selection of appropriate effects (and music if it makes sense to the environment) in a well-edited escape room soundscape adds another subtle but very effective layer of immersion to any game. Providing on-theme costume accessories and inviting participants to dress up is also an opportunity to encourage immersivity [85].

2.4. Design

The fourth step of Room2Educ8 involves designing the puzzles that the participants will have to solve to complete the game and meet the learning objectives, deciding upon the game's flow, creating the room layout, choosing appropriate game assets, developing a hint and/or a scoring system, and defining game rules. As every puzzle in an EER should align with a learning objective, designers must determine first which learning outcome each puzzle will support. They must also understand what the participants know before they start the puzzle, and what they should know after completing the puzzle. This will allow for the easier validation and assessment of whether the learning objectives have been achieved at the end of the game experience [63]. Puzzles are opportunities to engage the participants with the story in an interactive way, so the next step is to determine which part of the story the puzzle is aligned with, what the participants perceive about the story before the puzzle, and what they should understand about the story after the puzzle [7]. When creating puzzles, it can often be easier to look at any final meta-puzzle first and then work backwards from this.

Since numbers are often used in lock combinations, finding ways to manipulate numbers is an easy way to add layers of puzzles to an EER. The simplest way to do so is counting, e.g., have participants count how many there are of an object and make that number relevant. Other ways to add numbers to puzzles include giving participants a message written in letters and have them use the numbered keys on a phone to identify which numbers match the letters (e.g., GAME returns 4263), hide numbers in a block of text by replacing some letters with numbers (e.g., cand1e, mak3r, ba5ement, n0rmal), enter numbers into a calculator and then turn it upside-down to read a word (e.g., 35007 upside-down spells the word LOOSE), and use Roman numerals or binary numbers. To communicate letters and words, ciphers can be used to replace each letter with a different symbol, number, or letter (e.g., Caesar, Atbash, columnar transposition, A1Z26, ASCII code, Pigpen, Braille, Morse code, Scytale, etc.). Another common strategy to hide messages with letters is to take a block or line of text and call attention to specific letters or words (e.g., leave some letters in the line lowercase or uppercase, make certain letters a different colour than the surrounding text, place a dot or underline under important letters, etc.). Puzzles should be as self-guided as possible, make their goal easily understood, be clearly linked to clues, relate to the room's theme, propel the narrative, take less than 5 min to solve, and provide clear feedback when solutions are tested [85]. Having an obvious finished state permits the participants to feel successful and boosts their enthusiasm.

To help participants reach a state of flow [58], it is crucial to keep them in a sweet spot between frustration and boredom. If they are frustrated, they will give up because they cannot find a way to engage in the puzzle. Conversely, if participants are not challenged enough, they will get bored and equally give up caring about the game [82,91]. A solution to this is to rate puzzles according to the difficulty of the content and the puzzle itself; designers should make the first puzzle relatively easy to build the participants' confidence and set the stage for success [66,82], then provide them with puzzles of increasing difficulty to keep the tension high. A mix of manageable revision tasks with more difficult new tasks that require some research can maintain a balance between motivation and challenge. Using the design concept of flow helps to create the scaffolding that can take participants from what they already know and make them reach the learning outcomes [7]. Diverse puzzles which challenge participants in different ways as they move through the escape room (e.g., cooperative, logic, sensory, searching, physical tasks, etc.) can target a variety of learning approaches and are more likely to engage multiple team members [10], thus increasing the game's success rate.

Finally, puzzles should be designed with accessibility in mind [82]. Designers must consider how people with disabilities can navigate the game space. If having low lighting is key to the game experience, then using large text with an easy-to-read font and high contrast colours can combat frustration for participants. Similarly, if a puzzle needs to be solved using colours, it can become colourblind accessible by making it also solvable using shapes as well. It is important that participant actions within the room can be observed, as this can help to determine if deficits in a team's performance are due to poor puzzle design or poor teamwork [6].

A key aspect of EER design is ensuring that all individual puzzles contribute and form a greater whole. This essentially creates a puzzle path for participants to follow. When designing the game flow through which participants proceed during the game [86], a popular strategy is to follow a linear path structure, i.e., present to them one puzzle at a time. Solving it will then make the next puzzle available. Linear pathways are easier for participants to understand, the story flows better, and the game can be timed and paced, therefore less guidance is needed, and progression is easier to monitor [32]. Alternatively, in a non-linear game (i.e., a game that uses an open, path-based, or pyramid puzzle structure), multiple puzzles are available to participants all at once, and after all are solved, their outputs can be used to solve the final meta-puzzle. A flowchart showing how puzzles are connected as presented in Figure 5 is an effective way to visualise the puzzle structure.

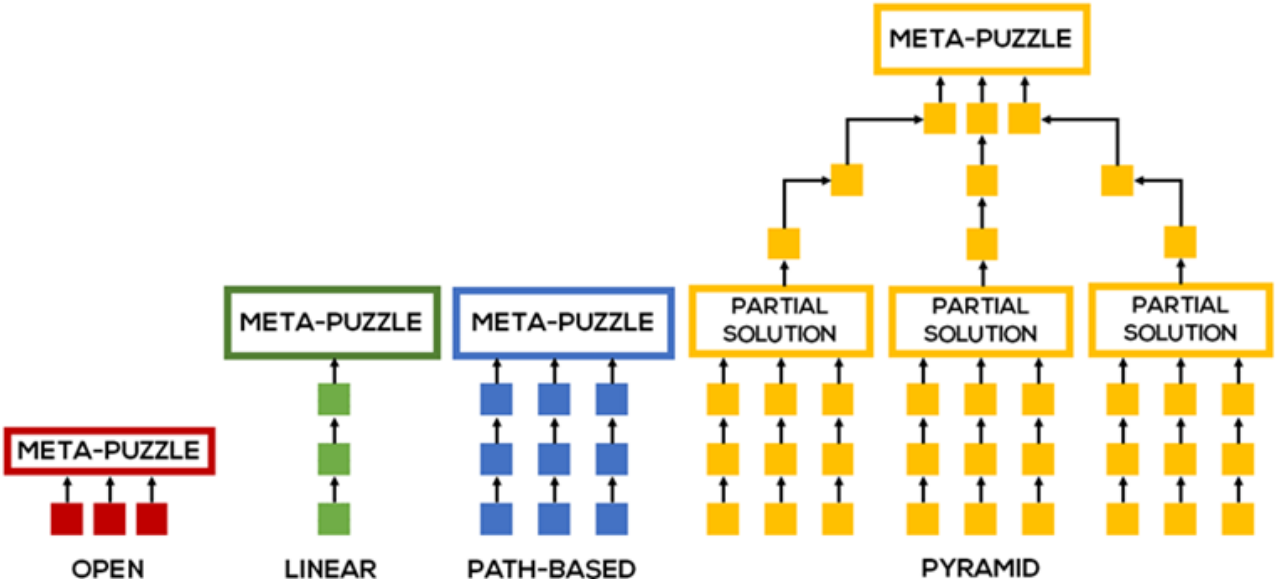

Figure 5. Puzzle structures in escape rooms (adapted from [83]).

To ensure that participants will not miss out on any activities in the game, it is recommended that EERs use a linear model where the entire team will engage with each puzzle together. If there are multiple puzzles available, they should be designed to provide similar experiences, so that as long as participants were engaged with one of the puzzles, they would be able to move closer to the learning outcomes [7].

A room layout with clue placements and arrangements of the puzzles, as well as a flowchart mapping out how players will navigate the room, can help to track the participants' progress and visualise the overall flow of the experience [9]. Cards may be used to provide details of each individual puzzle and its location in the room, starting objects in each location, what prompts participants to start each puzzle, what hints are available, and what clue/reward makes participants go to the next puzzle. These techniques are useful for checking for consistency in the room design, sharing the design with others, and resetting the room.

EER designers should consider any physical and/or digital assets that will be manipulated to solve the puzzles or will be used as clues. These should match the time period, the story, the characters, and the theme the game is set in. Game assets may include the room itself as a space, lock boxes and containers, locks that provide immediate and unambiguous feedback to players (e.g., combination, directional, letter, colour, padlocks, hasps, etc.), envelopes, UV markers and black lights, game tech (e.g., computers, smartphones, GPS, website, app, online answer box, projector, AR/VR, PA system, electronic props with motion detectors, sensors, RFID tags, Arduino, Raspberry Pi, etc.), decoders to validate participants' solutions, a clock or countdown timer to promote a sense of urgency, and narrative elements that embody the theme or setting (e.g., video, audio, printed documents, pictures on the wall, etc.). It is recommended to utilise assets that can be reused and/or are cheap to replace, as well as to produce refill packs with replacements for elements that are used during gameplay in case they are misplaced or malfunction. The physical placement of clues is also important, e.g., putting something above most people's reach when there is nobody tall on the team may cause frustration amongst participants [82]. The "one clue, one use" rule (i.e., each clue or prop is used only once to solve a puzzle and then is retired from the game) can improve the overall gaming experience, because once participants use a clue for a piece of information, they can set it aside and focus on the remaining clues to solve the remaining puzzles, thus reducing their cognitive load [85]. Red herrings (i.e., items that have been deliberately designed to look like puzzles and clues, intentionally forcing participants to waste time on items of no value) should only be used

if their existence ties into a learning outcome and the participants are trying to learn how to identify false information and false leads as part of the activity [7].

Sound and music should not be overlooked when designing EERs, as they can transform a game into a vivid and intense overall emotional experience. In-game sound effects are mostly used for certain events in the game, such as when participants receive a hint, or the countdown clock reaches the last minute of the game. These sounds may fit the room's theme in style, but they should be unusual enough to catch everyone's attention. Conversely, a music soundtrack should be subtle enough to let participants focus on the story without catching their attention.

An EER's success will frequently be built on its hint system. Hints provide an avenue to mitigate the unpredictability of human behaviour and give teams an outlet to progress past difficulties unanticipated by the EER developers [6]. They also help participants of varying levels have similar experiences when playing through a room. To foster a positive learning experience, it is crucial to develop an incremental hint system that offers help to participants when they are stuck and fits the theme and narrative organically. Incremental hints act as metacognitive support [92] in monitoring one's own progress, thus contributing to learners' knowledge-related self-confidence [25], and can be delivered to participants personally (e.g., via a TV screen, through the room's PA system, via a walkie-talkie or phone, on written notes, via an app/website, etc.) or by pre-set hints on apps/websites or on hint cards. Due to space limitations, it is also common for tutors to be present in the same room as the participants throughout the game in order to offer them hints. This approach should be undertaken with caution, however, as it may affect the participants' autonomy in learning [93] or reduce the experience of flow and immersion by interrupting the gameplay. Defining hint rules is recommended, especially for EERs with assessment goals, as hints can artificially influence performance if there are differences in their timing and specificity. A clear hint system with a limited number of hints available can also help the participants to build up resilience and independence, while helping the tutors to stop themselves from interfering. Common hint rules include: teams get a restricted number of hints; the first hint is free, but if more hints are needed, a time penalty is given; participants must earn a hint by passing a knowledge test, solving a puzzle, or finding hint cards or tokens; there is no hint limit, but participants must use a hint button with a cooldown timer; a pre-set hint can be used only if participants have not solved a particular puzzle by a certain time on the game clock [5]. A hint cheat sheet can also be used to provide systematic guidance on the type of hint that is necessary as well as the level of detail that should be provided to teams [6].

Finally, a scoring system can be used to tap into people's natural competitiveness and encourage them to do better. A final score can be awarded based on whether participants were able to finish the game, the time it took them to do so, the number of hints or clues they used to solve the puzzles, or the number of puzzles they solved [85]. Designers should consider whether there will be consequences to participants for any errors they make, e.g., miscalculating a medical dose may result in a two-minute penalty [9]. However, scores leading to tangible rewards (e.g., sweets, stickers, stationery, etc.) should be used cautiously as there is the risk that participants will focus on doing only what needs to be done (e.g., to figure out the code for the locks, instead of engaging fully with a puzzle), which can result in not achieving the learning outcomes. Grades and rewards may send the message that the EER is not going to be an engaging activity in its own right, but a task participants must perform only for the reward [7].

2.5. Brief

The fifth step of Room2Educ8 is for designers to consider how they are going to inform the participants about the EER's backstory, objectives, and rules. One of the best ways of doing this is to begin the narrative during a 5 to 10 min pre-game briefing. The briefing can be used to provide background information about the main characters, the setting, the time period, and the inciting incident, as well as set up the dramatic question: what do

the protagonists have to do to solve the problem they face? This prologue can be in the form of a pre-written script read by the EER facilitator or by the participants themselves. Alternatively, a pre-recorded video introduction can be used to give instructions to the participants and deliver the narrative components. Besides ensuring standardisation across teams and minimising task load on the facilitator, a video can add significantly to the immersiveness of the experience, make participants engage more naturally with the storyline, and heighten the sense of urgency for escaping from the room. Using tropes from films can make it easier to get the participants into the emotional state designers want them to be in when the game starts [82].

A list of rules should also be provided to participants. This may include information about the time limit for successful completion, forbidden items, hint and scoring systems, room boundaries, handling props and furniture, health and safety issues, areas and objects that are out of bounds (e.g., works of art on the walls, light fixtures, air vents, floor grates, etc.), case sensitivity of text entry fields, communication with the game master, acceptable behaviour, consent forms, etc. To deter cheating, facilitators can explicitly request that participants not engage in cheating behaviour in the room. Additionally, they can offer specific examples of behaviours to avoid while using vocabulary that suits the theme where possible, as this can add to the immersion. For example, instead of telling participants not to break the locks in a sci-fi-themed EER, facilitators can advise them "not to interfere with the spaceship's security system". Rules make the game, so it is important that they support the main goal of the EER without making it too hard or too easy to complete. Finally, in a physical EER, an area should be designated for participants to leave their belongings so that they do not have to carry them around during the game.

2.6. Debrief

The sixth step of Room2Educ8 is for designers to consider how they are going to make participants aware of the learning that occurred during the gameplay. Metacognition, i.e., students' ability to monitor, direct, and review their learning, is a powerful tool to get learners to think about their own learning more explicitly, usually by teaching them to set goals and monitor and evaluate their own academic progress [94]. Learning techniques that have been shown to promote metacognition and enhance memory formation include elaborating, verbalising, and sharing learnt information during and at the end of a learning session. A structured, facilitated debriefing upon the completion of the EER allows for reflection-on-action as described in Kolb's experiential cycle [50]. A good rule of thumb is to reserve one-third of the class time for reflection on the EER activity [7]. The gathered data can also be used in Room2Educ8's evaluation step to assess the game's success as a subject-specific educational activity and inform any further needed improvements to the overall experience. A recommended debriefing model is the Plus/Delta model which uses two columns; the plus column (+) refers to good behaviours or actions, while delta refers to behaviours or actions that need improvement or change in the future [95]. This technique allows learners to participate in the discussion and is easily utilisable by novice debriefers. More experienced facilitators can use the Advocacy Inquiry model from Debriefing with Good Judgement, in which an *advocacy* is an assertion, observation, or statement, whereas an *inquiry* is a question. When pairing the two together, facilitators act as conversational scientists, stating in their advocacy their hypothesis, and then testing the hypothesis with an inquiry. This is the generic approach that facilitators can use in any scenario: Step (1) notice a relevant result (e.g., something that happened during the EER experience); step (2) observe what actions seemed to lead to the result; and step (3) use advocacy–inquiry to discover the reasoning that produced this result [96].

To provide clarity, resolution, and closure to the story, the debriefing session may begin with an outro video showing participants what happened at the very end of the story, what they did in the game, why doing that was important, and how their actions improved the circumstances of the game's characters.

Next, a reaction phase will allow participants to express and defuse heightened emotions. They are coming out of a high-energy, stressful environment and will be thrilled or disappointed, so it is important to leave them with a positive impression of the EER experience [82]. Sometimes, they may not recognise the learnt skills that were necessary to succeed in the game or may be unable to identify how the lack of those skills led to an obstruction in the team's process. Therefore, the facilitator should guide participants in reflecting on their performance, the game content, the puzzles, the skills needed to solve them, and their overall experience, and then use this discussion to clarify the teaching points. For instance, participants may be asked to describe what they enjoyed about the game, their favourite or most challenging puzzle, a time when they felt particularly proud of themselves or their team, something new that they learnt during the game, how the game related to what they were learning, how solving a puzzle in the game related to solving a problem in the real world, one change that they would like to make to the game, or what they might do differently next time.

As participants may desire feedback on observed team-based skills, open-ended questions can be used to prompt dialogue about leadership, delegation, effective communication, situational awareness, and task assistance [35]. For example, participants may be encouraged to describe what they learnt about themselves during the game, how they contributed to their team, how they made sure their ideas were heard, how their team utilised everyone's strength, a moment when their team worked well together or became frustrated, how their team could have been more effective, and why their team succeeded or failed in completing the challenge. Designers should also have a plan for participant failure, e.g., decide whether the facilitator will disclose answers by guiding the participants through the uncompleted puzzles or will review learning objectives in the debriefing without revealing the EER's secrets [9].

The debriefing may be concluded by giving away revision material (e.g., a revision booklet) which summarises the key learning outcomes the participants explored during the game, and by taking a group photo (or a screenshot when the EER is digital). The group photo is arguably the only shareable thing about an escape room and most participants consider it an important part of the overall experience. It is recommended to give participants original props that fit the room's theme and optimise the photo for sharing on social media.

2.7. Prototype

The seventh step of Room2Educ8 is for designers to prototype and playtest the EER. Given the challenging nature of predicting human behaviour, prototyping efforts that utilise multiple teams during an EER's development are an effective tool to help estimate the length of time required to complete individual puzzles and the overall length of the game [6]. After developing the ideas and the puzzles, the design team should set out to create simple, cost-effective prototypes of their ideas from their ideation sessions of the previous steps. One large piece of chart paper can act as a surface for drawing a blueprint of the room. Sticky notes with quick descriptions can then be placed on the room's blueprint to mark out the locations of puzzles and clues. The puzzles themselves can be written on sheets of paper and brought out during playtesting when it is time to use them. The goal of the paper prototyping is not to perfect the puzzles but to catch any big errors, check that the puzzle logic makes sense, and that the overarching flow of the room works [82].

Once this internal playtesting has been completed, designers should make another lo-fi testable prototype and invite teams of varying sizes, backgrounds, and levels of prior experience with escape rooms to playtest it (e.g., 2-8 individuals with similar skill sets to the intended learners). They should then get their feedback (e.g., via interviews, questionnaires, etc.), return to the design process to solve any problems that came up during testing, and produce a more refined prototype. This cycle may be repeated several times, so it is recommended to use as few resources as possible in creating the early prototypes, as they will most likely be changed after one play.

Because EERs are usually team-based events, it is important that every participant contribute, otherwise they will feel like they wasted their time. Playtesting will reveal if there are enough puzzles for people who are visual, logical, physical, or other types of thinkers [82]. Each playtest should address issues about realistic playtimes, difficulty levels, puzzle mechanics, the relevance to learning objectives, the quality of hints, and the cohesive nature of the narrative. It is crucial for an EER to have a high win percentage, so testing individual puzzles, paper prototypes, and the full game at different stages, as well as the debriefing structure, will provide important feedback to improve the design and achieve game balance, accessibility, and playability [9].

A Feedback Capture Grid is a structured way of capturing user feedback systematically during playtesting sessions or organising the gathered feedback after the playtest. To start, designers should draw a grid on a piece of paper and divide it into four quadrants labelled "Likes" (positive feedback), "Criticisms" (negative feedback and criticisms about the prototype), "Questions" (questions that the play testers have asked as well as new questions the test session raised), and "Ideas" (any ideas that the testing session has sparked). Then, they should ask play testers to give specific and detailed feedback directly on the grid using sticky notes. Once the grid is full, designers can move into synthesising feedback into clusters or related common themes, brainstorm ideas on dealing with the most important issues, and then create an action item list.

2.8. Document

The eighth step of Room2Educ8 is for designers to consider how they are going to document the process of developing the EER. A highly descriptive game design document (GDD), created and edited throughout development, can help the design team to refine scope and production needs. A general anatomy of a GDD includes a game overview with general information about the EER and its learning objectives, followed by sections that describe each part of the design (e.g., puzzles, narrative, assets, etc.) in progressively more detail. The document should be consistent, thorough, and specific enough, including illustrations, flowcharts, diagrams, and every other information is required to build the EER, so that it can serve as a blueprint for designing other EERs. A GDD is expected to evolve together with the project as designers find new ideas, uncover new problems, and may even change the overall design while making the game. Therefore, it is important to plan from the beginning to update the documentation as development proceeds.

It is also recommended to produce two additional documents: (1) a facilitator guide, which should contain the learning objectives, briefing and debriefing instructions, game rules, room layout, a game walkthrough with clues and answers for each puzzle, rules, and/or pre-set times for providing hints; and (2) set up/reset instructions containing a visual depiction of the exact location of every object in the room accompanied by clear step-by-step instructions about how to set up and reset the game for another play-through.

2.9. Evaluate

The ninth and final step of Room2Educ8 is for designers to consider how they are going to evaluate the EER experience and assess whether the EER met its goals, objectives, and learning outcomes, what aspects of the game contributed to or detracted from this, and how the learning experience can be improved. The use of audio/video surveillance equipment or screen recording software to observe and record participants as they complete the room can serve as a data collection method to capture verbal utterances, team processes, and behaviours. However, it comes with the added need for reliable video coding which can be extremely time-consuming [6]. Alternatively, a researcher may watch the teams perform tasks in real-time and take notes. Learner feedback using post-activity interviews, focus groups, surveys, and the debriefing session are common methods to assess participants' perceptions. When the EER is used as a tool to assess knowledge and/or soft skills, learning gains can be measured by means of a pre-/post-/delayed post-knowledge test [5] and/or by a student performance score based on success rate, the number of puzzles solved, and

the number of hints requested. Ideally, studies should follow a mixed methods approach to evaluate an EER experience, as it will provide a better comprehension of their findings by triangulating results and thereby improving the validity of their conclusion. Finally, if students are asked to develop EERs as part of their coursework, they should be provided with a rubric showing the criteria upon which their EERs will be assessed.

3. Room2Educ8 Validation

3.1. Methods

A mixed-methods internal validation study based on Instructional Design model validation [97] was conducted to validate Room2Educ8. The study lasted 4 academic years (2018–2022) and employed a survey and focus groups to assess the framework's integrity and use. Ethical approval was not required for this study as it involved assessing the anonymised student feedback and knowledge from a teaching event. Prior to data collection, the students were informed about the nature of the study and the fact that the study results will be published, gave their consent, and were assured of their anonymity.

Since Room2Educ8 is based on Design Thinking principles, it was embedded in the teaching content of a 13-week-long compulsory module named "Design Thinking" for a postgraduate course in User Experience Design at a British university. This creative module was divided into a theoretical part where the lecturer traditionally exposed the curricular contents, and a practical part where the students became "makers" [29] and worked in groups of four to collaboratively create a one-hour EER experience for their coursework. The required deliverables were a fully working EER prototype (physical, digital, or hybrid) on one of three topics (cybersecurity awareness, information and communication technologies, or information literacy), a report documenting the EER's design process using Room2Educ8, a live demonstration of the EER, and a peer evaluation of each group member's contribution to the project. All students were given 13 weeks to complete the coursework and had to get a mark of 50/100 or higher to pass the module. The coursework was constructed with specific learning objectives in mind, mapped to outcomes from the module's specification document. These objectives included:

1. Critically understand the key principles and applications of Design Thinking for the creation of commercially viable interactive products;
2. Use research methods to build empathy for target audiences, identify customer needs, and translate them into product specifications;
3. Work as a member of a development team to design, prototype, and evaluate potential solutions for a wide range of challenges in both the digital and the physical realm;
4. Express and present design ideas in an appropriate professional format using written and oral communication skills;
5. Document and critically reflect on the use of design methods in specified settings.

Prior to being offered to students, the coursework brief had been peer-reviewed by two lecturers with backgrounds in user experience and game-based learning, respectively, to verify its suitability to the module.

Between the 2018–2022 academic years, four cohorts of 104 students in total (N = 104, 48 identified as male, 56 as female) aged 21–32 years old worked in randomly distributed groups of four and created 26 EERs (N = 26) for their coursework. A total of 14/26 were digital EERs, 8/26 were physical, and 4/26 were hybrid. A total of 16/26 EERs focused on cybersecurity awareness, 6/26 on information and communication technologies, and 4/26 on information literacy. Before studying this module, 26/104 students had previously completed an escape room, albeit noneducational (25%), 45/104 were only familiar with the escape room concept (43%), and 33/104 had never heard of escape rooms (32%). None of the students had any prior experience with EER design. A total of 25/26 coursework submissions received a grade of 50 or higher and passed the module (96% success rate), with 18/26 getting a distinction grade of 70 or higher (69%).

During the last week of every offering of the Design Thinking module, all groups of enrolled students presented the EERs they had developed for their coursework using

Room2Educ8 to the class. Each EER was then playtested by a group of three lecturers who employed the think-aloud protocol [98] to verbalise what they were thinking and doing as they played the game. The added dimension of having players share their thoughts, reactions, pleasure, and frustrations allowed the EER designers to understand the user experience of the game, uncover problems with puzzles, and highlight content that could be improved.

Once all EERs had been playtested, students were invited to participate in the framework's validation. Although this activity was voluntary and not part of the module's assessment, every student agreed to participate as it was an opportunity for them to experience the used research techniques which were relevant to their studies, have their voices heard, and discuss a topic of interest. An anonymised survey of 10 statements developed by the lecturer was employed to measure overall perceptions of Room2Educ8′s clarity, usability, and usefulness. The perception scale was a 5-point Likert scale ranging from "1—strongly disagree" to "5—strongly agree". To support or refute the quantitative findings from the survey, qualitative data were collected through 30-min-long semi-structured focus groups (four students per group) moderated by the lecturer and then analysed using content analysis [99]. Each individual focus group was made up of the four students who worked on the same EER. Indicative focus group questions are the following:

- Today's topic is using the Room2Educ8 framework to design EERs. What are your general feelings about it?
- What are your thoughts on using Room2Educ8 as a tool to practise Design Thinking skills?
- What are specific issues, concerns, or problems you have faced when using Room2educ8?
- What is your favourite aspect of Room2Educ8 and why?
- What positive experiences or outcomes have you had in using Room2Educ8 to design an EER?
- Are there any soft skills you have developed while using Room2Educ8?
- Can you suggest how to improve Room2Educ8?

The survey and focus groups were conducted once per academic year (four separate times in total), with a different cohort of students in each offering of the module. A total of 104 students (N = 104) completed the survey and participated in 26 focus groups (N = 26). Data from the student survey forms were transferred into a Microsoft Excel spreadsheet and descriptive analyses using the total, mean, and standard deviation of feedback scores were performed.

3.2. Results

Survey results in Table 3 indicated that the framework was very detailed, with clear and understandable steps (M = 4.25, SD = 0.83) that were easy to follow regardless of lack of prior experience in EER design (M = 3.89, SD = 0.96). It provided designers with a comprehensive view of EER design (M = 4.41, SD = 0.60) and could be used to develop a wide range of EER types (M = 4.02, SD = 0.74) covering a variety of topics (M = 4.09, SD = 0.66). Using Room2Educ8 increased confidence in EER design (M = 4.44, SD = 0.63) and helped designers to develop 21st century skills such as teamwork (M = 3.94, SD = 1.03) and empathy (M = 4.27, SD = 0.86).

The focus groups also yielded positive results that supported the survey findings. Sample responses are presented in Table 4. In virtually all focus group sessions, participants expressed their initial concerns when they received the coursework brief, as they could not see how designing an educational escape room fitted to the curriculum. However, once they had completed the development of their EER, they could make this connection. One participant stated, "I must admit that I was sceptical about this assignment at first, but by the end I could see how Room2Educ8 can be an effective tool to learn and practise Design Thinking skills." Another major concern was the lack of any game design skills or limited experience with escape rooms. For these participants, the major advantage of Room2Educ8 was its detailed and well-described steps. "Honestly, when we got the coursework brief, I

was sure I was going to fail. I don't play videogames and had no clue what an escape room was before taking this class. To my surprise, the framework with its clear steps made the development of the EER straightforward, even for a noob like me." Another participant added, "At first, I was overwhelmed by the large number of Room2Educ8 steps, but the detailed instructions made them easy to follow." Using Room2Educ8 was also regarded as an effective way to develop teamwork and organisational skills. "I had never met these guys before and was unsure about what to expect. I am not a fan of groupwork, but we gelled very well, and everybody contributed to the project." Finally, the user-centred focus of the framework contributed to honing communication and empathy skills. "The empathise stage has definitely helped me to improve my listening and interview skills. I also got to understand how users feel and why."

Table 3. Survey results (N = 104).

#	Survey Statement	Mean	SD
1.	I feel that each step in Room2Educ8 was easy to understand	4.25	0.83
2.	I believe that all steps in Room2Educ8 are necessary	3.95	0.89
3.	The use of Room2Educ8 helped me to get a comprehensive view of EER design	4.41	0.60
4.	Room2Educ8 can be used to design a variety of EER types (e.g., physical, digital, etc.)	4.02	0.74
5.	Room2Educ8 can be used to design a variety of EER topics (e.g., STEM, history, etc.)	4.09	0.66
6.	Room2Educ8 can be used to design EERs regardless of prior experience	3.89	0.96
7.	The use of Room2Educ8 increased my confidence in designing EERs	4.44	0.63
8.	I plan to reuse Room2Educ8 to design any future EER	4.04	0.99
9.	Room2Educ8 has helped me to work effectively in groups	3.94	1.03
10.	Room2Educ8 has helped me to get a deeper understanding of the people I am designing for	4.27	0.86

Table 4. Sample focus group responses.

Topic	Response
Clarity	"At first, I was overwhelmed by the large number of Room2Educ8 steps, but the detailed instructions made them easy to follow."
Usability	"Although I had never heard of escape rooms before taking this class, Room2Educ8 made designing an EER pretty straightforward."
Usefulness	"I must admit that I was sceptical about this assignment at first, but by the end I could see how Room2Educ8 can be an effective tool to learn and practise design thinking skills."
Communication	"Despite being rather shy and quiet as a person, designing an EER with Room2Educ8 increased my confidence and made it easier for me to express my ideas and communicate with my classmates."
Teamwork	"This was an excellent activity for team members to get to know each other. We gelled very well, and everybody contributed to the project."
Motivation	"That was by far the most fun I had in an assignment. I will definitely use Room2Educ8 to design my next EER, this time in VR."
Formality	"According to the framework, we had to connect every puzzle to a learning objective, and that required a lot of effort."

4. Discussion and Conclusions

As EER design is usually a time-demanding and complex task, the rationale for developing Room2Educ8 was to translate EER design into practical steps that educators and other interested parties with no prior experience with the escape room format could reasonably implement for their own teaching practice. Its prescribed nature also makes it approachable for experienced commercial escape room designers who are considering moving into serious games territory and want to create educational experiences.

According to the study findings, the framework enables the mapping of learning objectives against puzzles and narrative to build a cohesive interactive story that provides contextually immersive learning experiences. Educators and researchers can use Room2Educ8 with any core content subject to develop EERs that reinforce or teach critical concepts using auditory, visual, and kinaesthetic modalities. A framework based on

design thinking has the potential to initiate an innovation aspect and be a useful tool for teacher professionalism, as it can contribute to the development of the creative and adaptive capacities of the escape room designers by encouraging innovative and reflexive thinking [61]. The design thinking approach fosters many of the desirable traits identified as 21st century competencies [100], thus enabling framework users to acquire knowledge, skills, and attributes needed for collaborative problem-solving. Using Room2Educ8 may also contribute to the development of judgement, self-reflection, and practical wisdom, as it seeks to improve the learning experience in an inclusive way by incorporating the views and insights of the learners themselves. The human-centredness of such a framework can serve to nurture qualities necessary for social interaction and the cultivation of empathy. Therefore, Room2Educ8 can also be used by students to design EERs as part of a multi-week project to promote soft skills.

A limitation of this study is that, although the expected target audience for Room2Educ8 is mostly educators, it was used and validated by postgraduate students on a Design Thinking course who did not have a background in education studies, so the framework lacks evidence of widespread use. A broader sample of participants would be a truer reflection of the framework's value; therefore, future works will include similar trials with education students, pre-service teachers, and professional practitioners already working in the education sector in order to observe any similarities or differences towards already tracked reactions to the proposed framework. Another limitation is that students were asked to evaluate the framework in front of their lecturers before their coursework grades were released. Although participation in the framework's validation was voluntary, this "educator bias" may have influenced the students' answers. Room2Educ8 has been used to design EERs covering basic topics on cybersecurity, information and communication technologies, and information literacy. To support the notion that the framework is applicable to any subject, future work should include using Room2Educ8 to design EERs that cover a broader variety of topics, including technically applied courses. Finally, Room2Educ8 was only validated internally, i.e., its validation focused upon the integrity of the framework and its use. To support the study findings, a follow-up external validation addressing the effects of using the framework—the developed EERs themselves, and their impact on learners—will be conducted in the future.

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