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From Play to Pedagogy: A Structured Topic Modeling Analysis of Escape Rooms Research

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***Abstract*— Escape rooms have evolved from recreational activities to engaging educational tools, combining storytelling, puzzle-solving, and teamwork. Despite their popularity, research on escape rooms remains highly decentralized with no clear focus or pathway. To shed some light on this growing field, this study analyzes 1,051 published articles on escape rooms using natural language processing, specifically keyword analysis and structured topic modeling. Our study addresses four key research questions related to (1) commonly used phrases, (2) research topics, (3) the evolution of these topics, and (4) their interconnections. We identified 24 distinct topics categorized into design and development, field of application, participants, and technology. The analysis reveals an almost exclusive focus on educational applications (>90%), particularly in healthcare and STEM education, highlighting soft skills and practical knowledge development. Based on our findings, we provide a research agenda where we highlight future research opportunities which include expanding research methods, incorporating generative artificial intelligence and easing the barriers to adoption for teachers.**

***Index Terms*—** escape rooms, game-based learning, structured topic modeling, review.

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I. Introduction and Background

ESCAPE ROOMS —as defined by Nicholson [1]— are "live-action team-based games where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal (usually escaping from the room) in a limited amount of time" (p. 1). In the last decade, escape rooms have become a popular entertainment activity due to their unique combination of storytelling, puzzle-solving, teamwork, and mysterious atmosphere [2], [3].

In a typical recreational escape room, a person would book an appointment at a physical escape room facility of their choice for a team of players (friends, family, colleagues, etc.). At the time of the appointment, the players would meet with the game master, who would walk them through the escape room rules. Then, players usually watch a video in which the final objective of the escape room is disclosed, as well as the time allocated to accomplishing this objective and why. Subsequently, the game starts, and the countdown begins. Players are placed inside a closed space and need to explore their surroundings to find clues that point them in the right direction toward accomplishing their final objective. This is often achieved through solving a series of tasks or puzzles that players need to work on collaboratively, using their time and resources wisely. Sometimes, help mechanisms are in place to aid players in case they get stuck, for example, through a help button that allows them to interact with the game master. The game outcome is one of two: either the players manage to achieve the final objective in the allotted time, or else the countdown is over before that, and therefore they "lose". Many variations of the game exist, for example, by establishing a competition between two teams to see who solves the escape room first.

Although there are no official global statistics on the number of escape rooms worldwide, unofficial sources such as the database maintained by Top Escape Rooms Project [4], reports 314,782 escape rooms at the time of writing. The US Escape Room Industry Report [5] has been collecting data about escape rooms in the United States for the last decade. According to this report, there were only two dozen escape room facilities in the United States in 2014. There was an impressive early growth (317% in 2015 and 800% in 2016) followed by a stabilization in 2019. During the COVID-19 pandemic, the number of open facilities decreased by 4.3% in 2020, and by 7.5% in 2021. The

industry stabilized again by 2022: as of December 2023, there were 1,950 escape room facilities. A recent report values the escape room market at USD 2.6 billion in 2023, and it is expected to reach USD 6.8 billion by 2030 [6].

The first instance of a recreational escape room, as we know them nowadays, cannot be exactly pinpointed. It is often attributed to the SCRAP publishing company, which hosted one of these games for teams of between 5 and 6 players in a bar in Kyoto (Japan) in 2007. The new gaming paradigm quickly spread throughout Asia and made its way to Europe and later to Australia and America [1]. Even though escape rooms can be —allegedly— only played once, the shift in tourism trends from the 3S (sea, sun, sand) tourism to the 3E (entertainment, excitement, education) [7] has made escape rooms become an unexpected touristic attraction since players are eager to discover new experiences while traveling [2]. In fact, some escape rooms have been created as activities in museums [8] or cultural heritage sites [9], exploiting the uniqueness of each city or region.

Tabletop escape rooms soon appeared as a more accessible and portable adaptation of the traditional recreational "physical room" format. The tabletop version condenses the escape room experience into a compact box or kit that can be played at home or in any location the players choose, instead of relying on dedicated physical rooms and elaborate setups. As such, their success lies in recreating the cognitive, game and collaborative dynamics of on-site recreational escape rooms without the spatial and logistical constraints of a dedicated venue. Key representatives of this trend are "EXIT: The Game series" (ca. 2016) and Unlock! (ca. 2017), which popularized the tabletop recreational escape room format worldwide.

The rise of online gaming has allowed escape room designers to transcend physical barriers and develop fully virtual recreational escape rooms [10], such as "Escape Academy" [11]. Recent advances in the use of immersive technologies (e.g., augmented reality and virtual reality) have also led to more embodied alternatives such as "I expect you to die" [12], one of the classic VR recreational escape rooms.

Inspired by the success of recreational escape rooms, educators started integrating the escape room concept into their teaching, which led to the rise of educational escape rooms. Educational escape rooms are games designed with educational purposes in which the participants, usually organized in teams, must solve a series of puzzles within a specified time frame by discovering clues, accomplishing tasks, and applying field-specific knowledge and skills [13]. Most initial implementations of educational escape rooms were physical, adapting available spaces for the activity. Tabletop escape rooms have garnered a lot of interest as well to address the limitations of finding and adapting a dedicated space, which can be challenging in educational institutions [14]. For example, BreakoutEDU kits include physical locks, boxes, and clues that teachers can customize to align with the intended learning objectives and thus easily bring the escape room experience to classrooms without requiring complex setups [15]. In recent years, a large share of educational escape rooms have been developed virtually, mostly triggered by the COVID-19 pandemic as a way to allow participants to play remotely [16]. These virtual educational escape rooms developed during the pandemic also seem to remain useful in the post-pandemic era [17]. In addition, the virtual format has also facilitated scaling up and reusing the game in large groups of students at no additional cost.

Since the mid-2010s, educational researchers have sought to evaluate the pedagogical value of educational escape rooms, and, as a result, these games started to appear in the scientific literature [18]. The range of pedagogical applications is constantly growing, ranging from practicing soft skills such as teamwork and communication (e.g., [19]) to putting field-specific knowledge into practice, especially in the healthcare domain (e.g., [20]). Several literature reviews exist about escape rooms in education. The first-ever review is by Fotaris and Mastoras [21] and discusses the value and potential of escape rooms as teaching activities from a sample of 68 articles. Vedlkamp et al. [22] reviewed 39 studies and found a misalignment between pedagogy and game design as well as between perceived and actual learning. A recent meta-analysis of 33 studies [23] found that escape rooms are highly effective educational activities across fields, with large effect sizes. Several other reviews zoom in on the application of educational escape rooms to specific fields, such as healthcare [24] and STEM [25], or into specific delivery formats [26].

II. Study Motivation

The rapid expansion of escape rooms from mere recreational activities to complex educational interventions across several academic disciplines has resulted in a large number of studies and made escape room research a highly decentralized field that is hard to capture within traditional systematic reviews. For that purpose, scientometric studies are well-positioned to capture a whole research field through the analysis of research metadata. Scientometrics methods have grown to include several modern techniques, such as natural language processing. In doing so, scientometrics offers a better approach to the analysis of textual data compared to the commonly used keyword count methods.

In this article, we aim to map the thematic structure of the existing research in escape rooms and its evolution over time to discover the underlying research trends and directions of the field. We do so by following a natural language processing approach to the existing literature's metadata, which combines keyword analysis and structured topic modeling. Our research questions are as follows:

- RQ1: What are the commonly used phrases in escape room research?
- RQ2: What are the distinct topics covered by escape room research?
- RQ3: How have the research topics evolved throughout the years?
- RQ4: To what extent are the research topics interconnected to one another?

The remainder of the article is structured as follows. First, we describe the methodology used to retrieve, process, and analyze the data. Then, we follow with the results of the study. We then

provide a discussion section in which we reflect on the study findings. Lastly, we provide a research agenda based on the gaps identified in our findings, in which we propose several avenues for future research.

III. Methods

To retrieve the corpus of research related to escape rooms, we searched the Dimensions database using the query "escape room*" in the articles' titles and abstracts. The search was performed on March 10th, 2024. We chose the Dimensions database since it provides a wider coverage compared to other traditional databases (such as Scopus or Web of Science). The metadata of a total of 1,209 records were retrieved. We further narrowed them down to 1,051 articles after selecting only those records in the English language.

Our next step was to use the R library *UDpipe* [27] to preprocess the retrieved articles' titles and abstracts. To focus the analysis solely on metadata such as the title and abstract articles is the typical approach followed in scientometric articles such as ours [28], [29]. First, *UDpipe* was used to perform tokenization or, in other words, dividing the text into smaller units (most commonly words) to facilitate analysis. The next step was part-of-speech (POS) tagging, which means classifying each token obtained from the previous step according to its grammatical category (e.g., pronoun, verb, adjective, noun). Lastly, *UDpipe* was used to perform lemmatization, which entails reducing each word to its dictionary form (e.g., from plural to singular, verb forms to infinitive, etc.). This type of pre-processing is preferred to other more traditional techniques like stemming, which have been proven not adequate for performing structured topic modeling [30].

After the preprocessing stage, we performed two analyses. We first performed **keyword analysis** by inspecting the most frequent phrases (sequences of words) found in the pre-processed titles and abstracts. For this purpose, we used *UDpipe* again since it is capable of identifying phrases with a certain combination of POS tags using regular expressions. In our case, we chose noun phrases —as recommended by the package developers— to identify the phrases that carry the most meaning.

Then, we applied **structured topic modeling** to identify distinct research topics. Structured topic modeling is a clustering technique that allows identifying themes in a corpus of text data [31]. It has been used extensively to analyze research topics using articles' metadata [32], [33]. Structured topic modeling is complementary to keyword analysis since it provides a more in-depth understanding of the underlying text patterns within the articles' metadata. On the one hand, keyword analysis allows to identify sequences of words that commonly appear in existing research. On the other hand, structured topic modeling goes one step further by pointing out the thematic connections in a certain area of research. To perform structured topic modeling, we used the R library *stm* [34], which uses the Latent Dirichlet Allocation algorithm in combination with a variational Expectation-Maximization algorithm. As is the case with most clustering algorithms, the optimal number of topics is not known a priori, and therefore several models consisting of different numbers of topics (ranging from 5 to 35) were estimated. To decide on the best solution, we used a combination of quantitative fit indices (semantic coherence and exclusivity) and qualitative criteria based on the judgment of two of the authors (with expertise in escape room research and structured topic modeling) aiming to maximize coverage and interpretability while minimizing topic overlap. A consensus was reached on 24 distinct topics. The topics were given a representative name and divided into categories to facilitate analysis.

To understand the **temporal evolution**, a plot of each topic and the encompassing category was created using the frequency of each topic over time. The frequency of articles for a given year and topic was computed as the sum of the gamma coefficients for the topic of each article published in that year. To understand the **relationship between topics**, a network was constructed in which the nodes are the topics and the edge between two nodes represents the two topics co-occurring within the same article. We considered a topic as present in an article if the gamma coefficient was over the 95th percentile (0.23). We built the network using fractional counting [35] to account for the number of topics per article. We plotted the network using the Gephi visualization tool [36]. The topic network was partitioned through Louvain modularity decomposition: topics that co-occur frequently were assigned to the same community (and colored the same in the network plot) [37].

IV. Results

A. Descriptive Statistics

The retrieved dataset contains 1,051 articles in the English language published between 2016 and 2024. The number of publications has held a steady growth since the inception of the field (Fig. 1A), with an average growth rate of 38.86 articles per year (SD = 22.14).

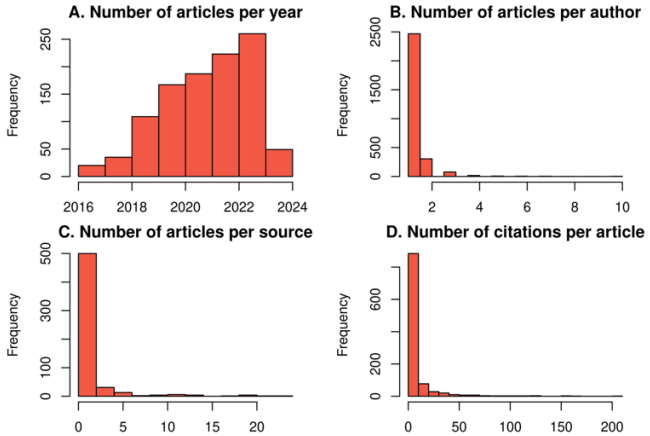

Fig. 1. A. Histogram of the number of articles per year. **B.** Histogram of the number of articles per author. **C.** Histogram of the number of articles per source. **D.** Histogram of the number of citations per article.

There are 2,882 distinct authors in the dataset, with a mean number of articles per author of 1.21 (SD = 0.65), indicating a

sparse research field with most authors having one single publication and few authors having a large number of publications on the topic (Fig. 1B).

The number of distinct sources is 567, with an average of 1.85 articles per source (SD = 2.76). This also hints at a scattered research field with no clear publication outlet for escape rooms (Fig. 1C). The average number of citations per article is 6.94 (SD = 18.19) with only 32 articles having more than 50 citations, and 11 having more than 100 (Fig. 1D).

B. Phrases

The analysis of the **most common phrases** (RQ1) in the title and abstracts revealed several recurring topics to which researchers draw their attention. Fig. 2 shows the 50 most used phrases. The most used phrase is **problem solving**, which refers to one of the most cited skills that escape rooms foster as learning activities. Around this topic are other commonly used phrases to describe **soft skills** that can be strengthened when playing escape rooms, such as **critical thinking**, **communication skills**, **teamwork skills**, and **team building**.

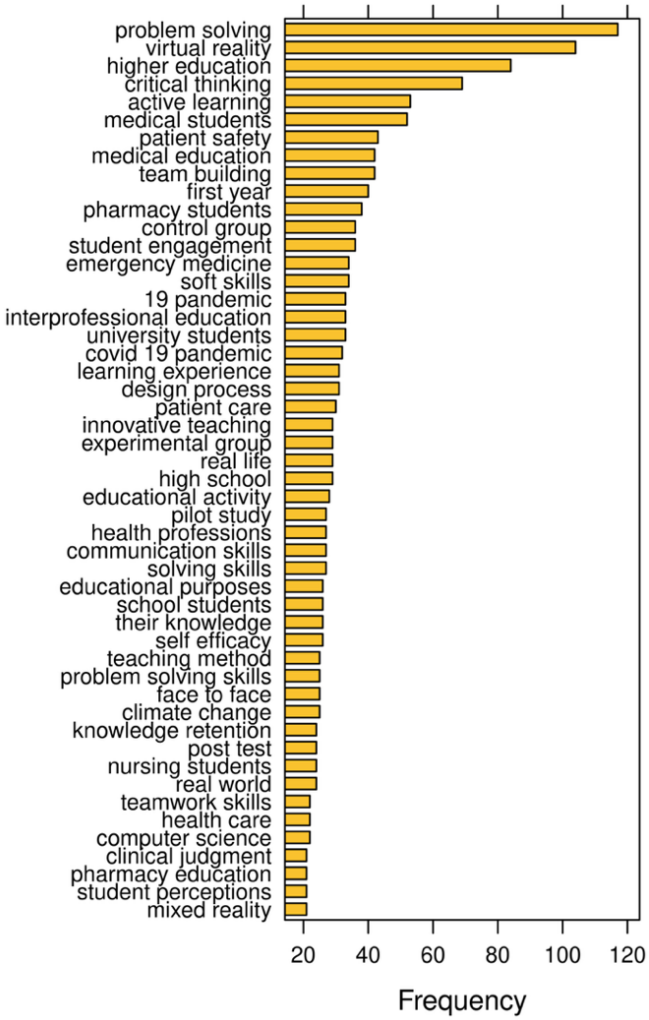

Fig. 2. Phrase Frequency.

Educational contexts in which escape rooms are conducted are frequently mentioned, with a predominance of **higher education** or **university students** (especially **first-year** students) and less so **high school students.** Within higher education, many commonly used phrases refer to **healthcare** education in general: **patient safety**, **medical education**, **pharmacy students**, **emergency medicine**, **interprofessional education**, **nursing students**, **clinical judgment**, etc. Mention of other fields was absent among the top phrases, with the exception of **computer science** and sustainability education (**climate change)**.

The second most mentioned phrase was **virtual reality**. This term along with mixed reality (in the last position) are the only references to technology among the top terms. A possible reason for this is that "virtual reality" or "mixed reality" are well circumscribed terms that barely have any synonyms, whereas other terms used to refer to technologies have not been used consistently (e.g., online, digital, web, etc.). There were several mentions of the **COVID-19 pandemic** as a catalyst of online escape rooms, and of the term **face-to-face** as their physical counterpart. Lastly, several of the most used phrases were related to the escape room evaluation, such as **control group** and **experimental group**, **student engagement**, **pilot study**, **self-efficacy**, **post-test**, **knowledge retention,** and **student perceptions**.

C. Topics

Topic terms

Applying structured topic modeling to the articles' metadata resulted in 24 distinct topics of escape room research (RQ2). We group these topics into 4 categories for ease of reporting (Table 1). Subsequently, we describe each of these categories and their corresponding topics.

Design and development

In the category of ***design and development***, we find topics related to all the aspects of designing the different elements of an escape room, the design process itself, and the materialization thereof into a playable game through development. The first topic is **context,** which refers to the setting where an escape room takes place, which mostly applies to educational escape rooms. Initially, educational escape rooms were conducted as physical activities in the classroom either by conditioning the room or by using tabletop alternatives such as "breakout boxes" —which require students to open a locked box instead of escaping a room—as a way to address the space limitations e.g., [38]. Since the COVID-19 pandemic, online educational escape rooms started to emerge as an engaging form of active learning in remote education e.g., [39]. The next topic, **design process,** deals with the steps for designing an escape room, with an emphasis on piloting, prototyping, and iterating [40] and following a participatory approach involving relevant stakeholders from early on in the design process [41]. Again, this strand of research is mostly related to educational escape rooms since the owners of recreational escape rooms usually do not disseminate this type of knowledge in scientific venues. Closely related is the topic of **development**, where several frameworks for educational escape room development have been proposed such as EscapED [42] —for creating escape rooms in higher education settings—, GERF [43] —for virtual educational escape rooms—, COMET [44] —

for interprofessional escape rooms, or Room2Educ8 [45] —a development framework inspired on Design Thinking, which has been extended recently to incorporate generative artificial intelligence for escape room content creation [46]. This topic also encompasses existing theoretical frameworks such as Community of Inquiry [47] that are used as a foundation to design theoretically-grounded educational escape rooms.

The next topic covers specific **design elements** that are representative of escape rooms, such as clues —i.e., the pieces of information that guide players throughout the game and hint them about what to do at each moment— and puzzles —i.e., the challenges that players must solve during the game—. Two topics revolve around puzzles: one is **puzzle design**, which again encompasses some of the aforementioned development frameworks but, in the case of educational escape rooms, with a focus on the difficulty of aligning game mechanics and pedagogy (e.g., [48]). **Puzzle content**, on the other hand**,** refers to the materialization of the puzzles into an artifact, which can be physical, for example, requiring to assemble a physical object [49], or virtual, for example, using Google Forms to enter a password [50]. Last, but not least, the topic of **narrative** refers to the storyline that acts as a common thread; it gives meaning to the escape room puzzles and immerses players in the game. The focus on narrative and storytelling is one of the few aspects that has been more central in recreational escape rooms [51], [52] than in educational escape rooms, although narrative remains an important component in the latter as well [13].

TABLE I

TOPICS IDENTIFIED USING STRUCTURED TOPIC MODELING ALONG WITH THE MOST FREQUENT TERMS PER TOPIC

Category	Topic	Terms
Design and development	**Context**	online, classroom, traditional, engage, puzzle, box, class, session, active, design
	Design process	design, process, reality, museum, user, real, object, child, prototype, physical
	Development	digital, science, design, development, technology, experience, create, develop, stem, environment
	Design elements	school, project, puzzle, classroom, skill, design, develop, clue, player, subject
	Puzzle design	puzzle, design, develop, idea, framework, time, knowledge, related, create, approach
	Puzzle content	puzzle, team, content, engage, explanation, google, focus, develop, hunt, orientation
	Narrative	design, narrative, experience, immersive, role, immersion, child, create, space, local
Field	**Chemistry & lab**	chemistry, laboratory, team, teamwork, skill, chemical, lab, experiment, science, effective
	Clinical simulations	simulation, patient, safety, clinical, report, team, care, level, nurse, communication
	Nursing	nursing, skill, critical, health, strategy, experience, nurse, practice, clinical, innovative
	Healthcare	care, nurse, pediatric, patient, emergency, knowledge, stroke, staff, clinical, virtual
	Language	language, player, english, cultural, aim, time, design, experience, video, context
	SDGs	change, skill, collaboration, knowledge, tool, climate, development, gamification, sustainable, business
	Library	library, university, information, engineering, playful, skill, create, instruction, experience, design
Participants	**Emotion**	experience, emotion, analysis, mental, online, health, customer, industry, effect, people
	Motivation	gamification, motivation, methodology, strategy, subject, process, degree, increase, experience, tool
	Team behavior	behavior, social, team, information, avoidance, data, environment, metaverse, search, interaction
	Interprofessional teams	knowledge, interprofessional, pharmacy, team, perception, complete, pre, survey, post, assessment
	Team training	team, training, skill, cybersecurity, scenario, nurse, require, development, technique, competence
	Evaluation	test, experimental, effect, questionnaire, evaluation, nursing, conduct, impact, control, data
Technology	**VR**	virtual, reality, experience, technology, user, player, environment, application, awareness, security
	AI	agent, environment, theory, flow, simulation, knowledge, transfer, level, model, social
	Robotics	team, robot, performance, human, model, trait, influence, impact, cognitive, interaction

Field of application

Our analysis revealed several educational fields in which educational escape rooms have been most frequently applied. Gamifying STEM education has been a major area of research in educational escape rooms. For instance, Vergne et al. [53] used a series of analytical puzzles that students have to solve to escape a room to make **chemistry** more enjoyable. Peleg et al. [54] used escape rooms to motivate students to neutralize harmful chemicals, which the authors used to bring fun into chemistry education. Similarly, healthcare was strongly present in our dataset with three topics that included **clinical simulations**, **nursing,** and **healthcare** in general. Escape rooms provide a rich environment for the simulation of time-constrained clinical scenarios such as emergencies or situations where timely problem-solving is key to saving a patient. Examples include using clinical simulation and escape rooms to enhance teamwork and collaboration skills, as well as to provide a safe environment for students to practice hard clinical skills [55], [56]. Other examples include simulation of crisis scenarios where students had to manage resource allocation [56] or using simulated pediatric clinics [57].

Nursing students have received considerable attention from researchers and several applications exist of educational escape rooms in this field [58]. Examples include using escape rooms to teach nurses strategies for violence de-escalation [59], learning community health skills through a simulated emergency case (stroke) [60], or teaching students to *escape* a delirious geriatric case [60]. **Healthcare** researchers have emphasized several skills that educational escape rooms enhanced, which include teamwork, collaboration, decision-making, problem-solving, critical thinking and interprofessional skills [55], [57].

The field of **language** teaching and learning has also adopted educational escape rooms. Proof of this is the multiple research studies that have focused on the most innovative approach for engaging students in immersive and interactive learning experiences when learning a foreign language in face-to-face and online environments [61]. Based on our dataset, these educational escape rooms typically involve a series of puzzles that require students to use their language skills to progress. Also, these have been demonstrated to significantly contribute to language acquisition, cultural education, and motivation [62]. Shakeri et al. [63] point to the value of collaborative experiences in escape rooms, as these require students to communicate, collaborate, and solve problems, which promotes language use and social interaction among learners. Language teaching and learning are intrinsically linked to culture; thus, escape rooms have served as innovative platforms for exploring cultures and languages [9].

Educational escape rooms have also been widely used for teaching topics related to the **Sustainable Development Goals (SDGs)** defined by the 2030 Agenda for Sustainable Development adopted by all United Nations Member States. According to our dataset, their use has been particularly prominent in teaching topics associated with SDGs 4 (quality education), 11 (sustainable cities and communities), and 13 (climate action). Among the educational escape rooms addressing quality education, there are examples of interventions aimed at developing soft skills (e.g., [64], [65]), promoting the safe and responsible use of digital technologies (e.g., [66]) and increasing literacy on novel technologies like artificial intelligence (e.g., [67]). The topics related to sustainable cities and communities taught through escape rooms include, among others, sustainable mobility [68] and sustainable development [69]. Regarding the climate action goal, most of the educational escape rooms addressing it are themed around climate change (e.g., [70]–[72]), although other topics have also been tackled, such as environmental sustainability [73].

Lastly, another field in which educational escape rooms have successfully been used is that of **libraries**. The experiences analyzed here, adaptable to in-person, hybrid, and online formats, try to connect students with library resources [74] and services [75] or to engage teenagers with literature while encouraging library visits [76].

Participants

The third category relates to ***participants*** and focuses on studies exploring how escape rooms directly affect players' **emotions**, **motivation**, and **team behavior**. The first topic is **emotion**, as research demonstrates that escape rooms are considered effective tools for generating joy, satisfaction, and fun, which overall influence players' attitudes towards, for instance, mental health awareness [77], [78] or STEM subjects [79]. The topic of **motivation** may be considered vital when it comes to implementing educational escape rooms in any context, as gamified learning experiences like these are shown to engage students more deeply than traditional methods, promoting active learning and intrinsic motivation across various disciplines: healthcare leadership and management education [80], or information literacy in business and entrepreneurship [81], among others. Studies analyzed in this demonstrate how escape rooms have positively impacted students' attitudes [82], **team behavior** and skills [83], and problem-solving abilities [84], thereby contributing to more effective educational practices.

Because educational escape rooms are used to promote teamwork, research has studied how these can be used as versatile and effective educational tools across various, mainly healthcare disciplines. We have grouped these experiences within the field of **interprofessional teams**. Studies showed positive outcomes such as improved immediate recall [85], favorable student perceptions [86], and enhanced interprofessional collaboration skills. Notably, educational escape rooms were successful in teaching complex subjects like diabetes management [87], nonsterile compounding, sepsis treatment, antimicrobial stewardship [88], and opioid use disorder [86], demonstrating their adaptability and potential for augmenting traditional healthcare education methods.

Along the same line, one of the fields within this category is that of **team training**, as innovative methods like escape rooms have been used to enhance communication, decision-making, and overall teamwork capabilities. The hands-on approach favored by escape rooms offers an alternative to traditional didactics in fields such as disaster preparedness [89] or cybersecurity [90]. Some studies suggest that while the use of escape rooms is enjoyable and fosters a range of soft skills, the learning may not always translate directly to expected outcomes without proper guidance and structured reflection [91].

Lastly, the topic of **evaluation** is central to this category, as educational escape rooms are frequently assessed to ascertain whether they improve students' knowledge and skills acquisition [23]. Most evaluations have found that educational escape rooms lead to better retention of knowledge [92]–[96]. Others have pointed out that this gamified experience can lead to lower levels of anxiety in the classroom [97].

Technology

In the ***Technology*** category, three main topics were identified: **virtual reality (VR)**, **artificial intelligence (AI)**, and **robotics.**

Among the technologies employed to conduct escape rooms, **virtual reality (VR)** and other related technologies stand out. VR has been used in multiple studies identified in our search [70], [98]–[100] in which a number of VR devices like headsets (e.g., Meta Quest, HTC Vive, Google Cardboard, etc.) or controllers are employed. Moreover, augmented reality (AR) and mixed reality (MR) are other approaches that can be used to develop escape rooms. Some examples of escape rooms conducted with these technologies can be found in both the recreational [101] and the educational [102] domains. Lastly, many escape rooms are mostly performed with the support of other —not as immersive— digital technologies. This trend has been more obvious in educational escape rooms, where authors present virtual escape rooms made digitally (e.g., [103], [104]) not using VR, but other web-based technologies. Lastly, studies like [105], in which the use of web-based educational escape rooms and VR escape rooms are compared, are of special interest since they allow the identification of advantages and disadvantages associated with each type of technology to develop escape rooms

digitally. In any case, it seems clear that technology provides a suitable alternative for creating escape rooms that transcend physical barriers [106].

The topic of **artificial intelligence (AI)** revolves around using an escape room as a benchmark to evaluate the performance of the algorithms used for Multi-Agent Reinforcement Learning (MARL) [107], to evaluate performance in sequential social dilemmas [108], [109], or in agents learning transferable knowledge across different settings [110]. Another strand of research is exemplified by Reig et al. [111], who evaluated the user perceptions of the help received from different intelligent agents in escape rooms (operationalized as complex problem-solving situations), concluding that users may prefer an embodied robot or a disembodied voice over a virtually embodied agent.

Lastly, the topic of **robotics** is quite related to that of artificial intelligence. In this topic, robots are tested in the escape room context, for example, successfully playing the role of the escape room moderator [112], [113], teaming up a robot with a real participant to explore the effects of robot failure severity [114], or comparing a robot with a human actor suggesting that they can be effective alternatives in escape rooms [115].

Topic trends

Most categories of topics show increasing trends (RQ3) yet with various magnitudes (Fig. 3). The *field* category may be the fastest-growing category in our dataset. This growth is perhaps driven by the increasing interest from healthcare education researchers (e.g., nursing, clinical simulation, and medical training). Similarly, the *participants* category shows a fast-growing and consistent trend over the years. Such growth may be driven by heightened interest and endorsement across different fields of application and objectives, as well as an increasing demand for rigorous evaluation of the benefits of escape rooms.

The fastest-growing topics are *motivation*, *evaluation*, as well as many topics related to healthcare such as *nursing*, *clinical simulations*, and *interprofessional teams*. The development category shows an overall growing trend and a varying mix of trends in the included topics. There is an obvious fast-growing trend in the *context* topic indicating a rising interest in highlighting the virtual vs. physical location of escape rooms. Similarly, we see *motivation* upgoing trends reflecting the increasing interest in using escape rooms to boost students' motivation. The technology category was the smallest in our data, and the trends are similarly up going especially in the topic of VR and related technologies. Possibly such an increase is driven by the growing interest in virtual escape rooms and the interest in achieving immersion using *virtual reality*. Overall, escape rooms are spreading fast to other fields and contexts and their usage is increasing across the full spectrum of applications driven by an interest in taking advantage of the possibilities of gamification and enhancing students' skills and motivation.

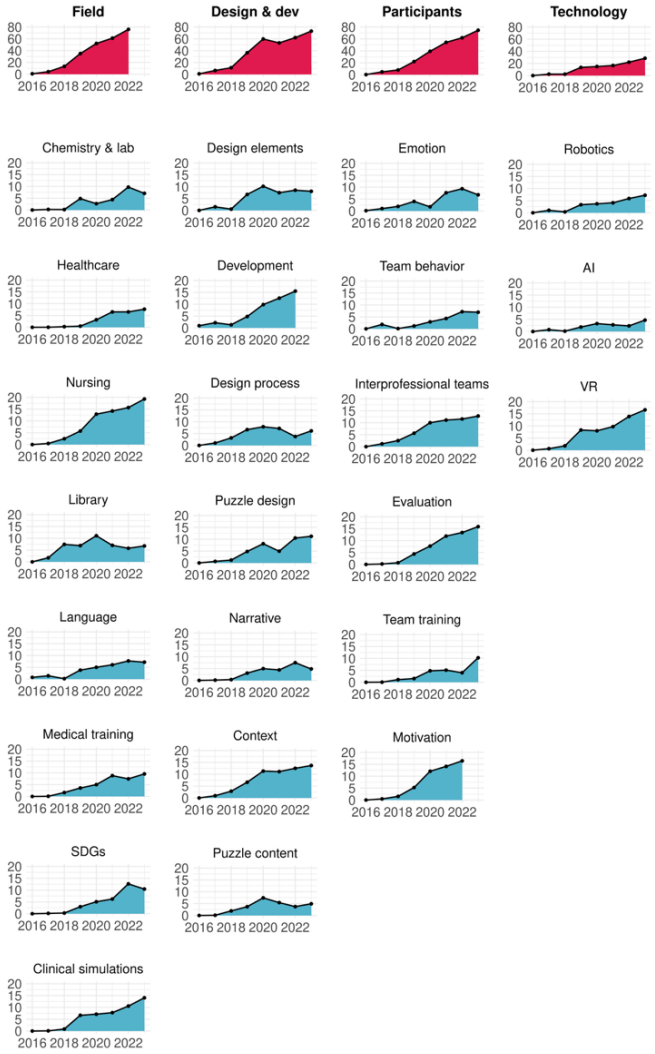

Fig. 3. Article frequency by year weighted by topic gamma. The top row shows the yearly evolution of each category. Underneath is the yearly evolution of each topic contained in the category

Topic co-occurrence

The co-occurrence network in Fig. 4 shows how topics co-occur together (RQ4). The network of co-occurrence of topics shows four communities that were colored differently to show their distinction. The **green** community includes puzzle development, design, motivation, and evaluation. We see that motivation is strongly connected to evaluation, indicating the practice of evaluating educational escape room experiments across several fields and design elements to assess their efficacy. The **blue** community includes strongly connected medical and healthcare topics as well as interprofessional teams, indicating the common use of escape rooms to allow teams to acquire communication and teamwork skills, which is crucial in medical fields. The **orange** community includes a diverse group of topics that can be grouped together under the umbrella of exploration of escape rooms into different fields (e.g., SDGs) and the use of new technologies (e.g., VR, AI,

robotics). The smallest community (**purple**) is composed of topics related to context and content and can be thought of as customization groups. Overall, there is a picture of a tripartite structure where the design and content of escape rooms are created and experimented in several fields, and later the effectiveness of these escape rooms in achieving their intended objectives is evaluated. This aligns well with the observed cycle of research, particularly in educational escape rooms, where initial contributions are focused on the novelty effect, whereas later contributions are more mature and include more rigorous research design and evaluation.

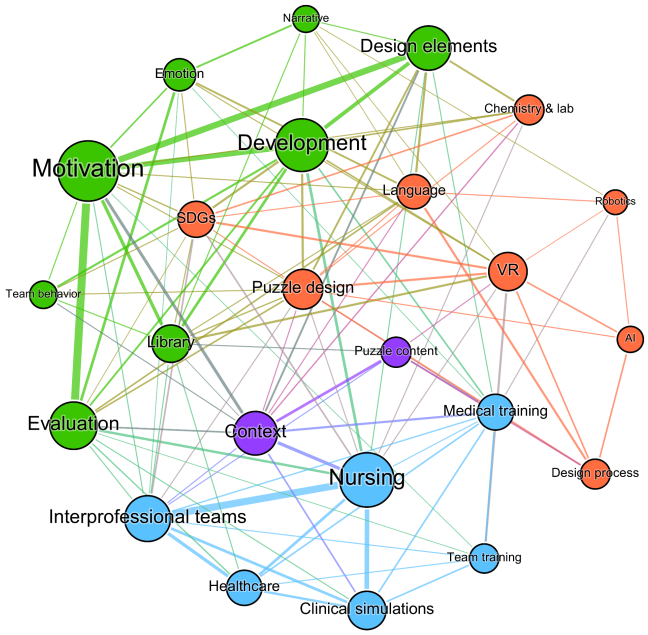

Fig. 4. Co-occurrence network of topics using fractional counting. Node size is proportional to the topic frequency, edge thickness indicates frequency of co-occurrence, and colors indicate communities of topics that most frequently co-occur together, according to Louvain modularity algorithm.

V. Discussion

In this article, we used keyword analysis and structured topic modeling to map the field of escape rooms and offer a bird's-eye view of research topics, their evolution over time (from 2016 and 2024) as well as the interactions between these topics.

Our results show that there has been a clear dominance of research on escape rooms in educational contexts (91.5% of all studies). In the meantime, escape rooms performed for their original purpose —recreational purposes— or for other objectives (e.g., tourism, team-building) have received less attention from researchers despite their stronger presence in everyday life. This may be explained by the fact that educational researchers —and society at large— are looking for opportunities to motivate and engage students in learning activities or to acquire soft skills or possibly by the fact that research on novel approaches in education is more active than other fields. Another reason why research on entertainment escape rooms is scarce might be the business owner's interest in keeping the content and characteristics of their escape rooms a secret since it constitutes their competitive advantage [1].

Given that most of our findings pertain to educational escape rooms, we focus on this particular application of escape rooms hereinafter. Within the educational context, our results have shown that healthcare has dominated the research landscape on educational escape rooms [24]. In general, healthcare education is a very active research field in which novel educational practices are not only continuously implemented but also rigorously investigated and published. This prevalence in healthcare may be explained by the idea that escape rooms provide a risk-free opportunity to put clinical skills to the test [116], practice communication in interdisciplinary teams, and recreate time-constrained situations such as emergency cases. In other words, escape rooms as a platform are rich in features that are in high demand in healthcare training.

Other educational fields have also been represented, such as STEM and language learning, although not to the same extent. Many fields are lagging in adoption, especially within the social sciences and humanities. A possible reason might be the lack of skills or training opportunities, the lack of time and resources or, quite possibly, the difficulty in puzzle design among some of these non-technical fields. Another finding was that higher education has been the most common research context. This is not a surprising finding since escape rooms —as recreational activities— are mostly played by adults [1]. Since the main mechanic of this type of game is finding clues to escaping from a room with little or no guidance, this arrangement might prove challenging for children who are used to more guided activities. Similarly, escape rooms in K-12 have been less present in academic literature although there are several implementations in many schools. This dissociation between practice and research may be explained by the fact that higher education is a research-intensive context (especially medical education) compared to the teachers at schools who may have constraints of time or curriculum commitments.

Several topics were devoted to the design and development of educational escape room content and game elements. This is reflected in the multiplicity of frameworks that have been developed to guide researchers and educators throughout escape room creation, although there is not one clear dominant framework. Our findings point out that design has been mainly connected to the context of application (e.g., location, field, subject, etc.). We also observed that design and development were tightly connected to evaluation and motivation, indicating the constant experimentation and assessment of this novel learning activity. Still, the evaluation of educational escape rooms has revolved around measuring participants' perceptions through questionnaires and, increasingly, knowledge acquisition through pre-posttest studies. Experimental studies comparing the effectiveness of educational escape rooms with that of other activities are far less common [23]. In other words, a majority of articles could be classified as a "Marco Polo" study ("I went there and I saw this") where escape rooms are reported as an innovative teaching method with less focus on its rigorous evaluation [117].

Both the keyword and topic analysis revealed the effect of the COVID-19 pandemic on escape room research, mainly in education, triggering a shift towards the online format with the objective of engaging remote students in team activities during lockdown to enhance their motivation [118]. We see a wide range

of technologies used to implement virtual escape rooms. For example, some researchers have used generic tools, such as Google Forms, which do not foster the immersive and engaging aspect of escape rooms, whereas virtual reality has become an increasingly prominent choice among tech-savvy designers. From the topic network, we can see that technology-related topics are not highly connected to topics corresponding to specific educational fields. This points to a misalignment between technological advancements in the field and their evaluation in pedagogical terms.

The temporal trends and the average growth rate of escape rooms are telling a clear message: escape room research is growing at a very fast pace, where we see research on escape rooms doubling in less than three years. Almost every topic category and the subtopics were up-trending, although with varying degrees. The pattern of adoption, experimentation and evaluation indicates that escape rooms are in the early stages of a field forming and shaping over time. Therefore, we expect future adoption in different fields and maturation of methods and applications which constitute an opportunity for researchers.

VI. Possible Avenues for Future Research

In view of the current landscape of research on escape rooms, it is clear that there are several gaps in the existing literature, and therefore many opportunities arise for future research which we propose in this section.

First, recreational escape rooms have received very little attention research-wise. Although escape room owners do not typically engage in research, recreational escape rooms serve as research settings for studying teamwork dynamics, communication patterns, and decision-making under pressure. Recreational escape rooms can also be examined from a socio-cultural and economic perspective, as they reflect broader trends in leisure and tourism.

Secondly, although education has been the dominating setting for escape room research, many educational areas have not received due attention, especially in humanities and social sciences. These areas are known for involving more open-ended tasks that might be hard to implement in the form of deterministic puzzles in an escape room.

Perhaps, with the rise of artificial intelligence —especially large language models— we will see a rise in applications in so-far neglected fields since they would enable the implementation of open-ended puzzles. Artificial intelligence can also be helpful for scaffolding or providing hints in self-paced learning environments where escape rooms take place unsupervised, such as MOOCs or professional development modules, which are also areas that have not been explored in the existing research.

Thirdly, escape room evaluation has been dominated by surveys and questionnaires analyzed with basic descriptive and inferential statistical methods. It is worth noting that no research instruments have been proposed (and validated) specifically targeted at escape rooms, but rather adaptations of the gameful experience (GAMEX) questionnaire [119] or ad-hoc surveys have been the most widely used. Moreover, researchers, for the most part, have failed to capitalize on more advanced analytical methods that would provide greater insights into students' gameplay or team dynamics, such as social network analysis or sequence and process analysis [120], [121]. Furthermore, the use of multimodal data, including sensor data, video, and audio, could provide information on players' facial expressions, verbal utterances, physical location, and physiology, which would allow gathering deeper insights into many important dimensions such as players' emotions, team dynamics, and problem-solving strategies [122].

Fourth, an important research avenue for the future of the field is exploring the barriers to the adoption of educational escape rooms. These might be teachers' skill gaps or resource constraints (time, materials, space). Moreover, the increasingly central role of digital escape rooms might have increased the technological barrier. Although VR seems to be an increasingly popular technological choice, it might be increasing the entry barrier for teachers, and there is still not enough evidence that it has greater pedagogical benefits. Exploring alternative technologies with a smoother learning curve is a line of research worth pursuing. Moreover, capitalizing on existing field-specific education technology as a building block for developing escape rooms might be another way of facilitating adoption, for instance, virtual patients for healthcare education or virtual laboratories for science education. Furthermore, the use of generative artificial intelligence for scenario and character generation can also help overcome some of the design barriers [46].

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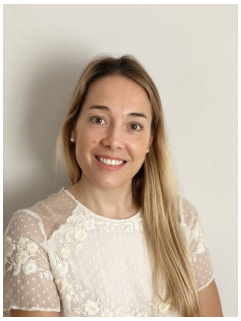

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