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You escaped! How did you learn during gameplay?

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Abstract

This study investigates the influence of the educational game design elements *immersion*, *collaboration* and *debriefing*, on fostering learning with educational escape rooms. We based the design of the escape room on an educational game design framework that aligns the learning goal and the game goal, that is, escaping from the room. One-hundred-and-twenty-six students, aged between 16 and 20 played the escape room. Measures for learning were pre-and post-tests. The game experience was measured through questionnaires, classroom observations and interviews with students and teachers. The results show a knowledge gain between pre-and post-test. Correlational analysis showed that all three design elements contributed to students' appreciation of the escape room, whereas only immersion had a direct contribution to knowledge gain. Based on the qualitative data it appeared that the used escape boxes contributed most to perceived immersion. Immersion helps students focus on each other and the tasks. Also, a narrative with distinct roles for each student helped to evoke immersion. Unexpectedly, these roles also scaffolded collaboration except for students in the school that engaged in a collaborative learning pedagogy. The study confirms the usability of the framework for game designs, based on theories for the design of physical and hybrid educational games.

KEYWORDS
collaborative learning, escape rooms, game-based learning, hybrid learning spaces, problem-based learning, secondary education, student engagement

INTRODUCTION

Game-based learning, in which games are used to motivate students and foster their content knowledge and skills, is subject to increasing research and review studies (Backlund & Hendrix, 2013; Baptista & Oliveira, 2019; De Freitas, 2018). In this context, the adaptation of the popular recreational 'escape room' by teachers is a worldwide, spontaneous phenomenon in education (Veldkamp, Knippels, et al., 2021). The time-constrained and problem-based puzzles require active, collaborative participants, which makes an escape room an interesting setting for teachers (Nicholson, 2018). The teaching of content knowledge and skills in authentic contexts is especially attractive for teachers in Science, Technology, Engineering and Mathematics (STEM) education. Both students and teachers perceive that while participating in escape rooms, students are more engaged, active and learn more compared to regular classes (Cain, 2019; Clauson et al., 2019).

Although teachers and students are generally enthusiastic about the implementation of escape rooms in education, the outcomes on the acquired content knowledge are disappointing (Veldkamp, van de Grint, et al., 2020). As the current educational escape rooms are mostly copycats of recreational escape rooms and not grounded in educational or game theories, there is room for improvement. In this study, an escape room was evaluated, which was developed using a design-based approach and a framework grounded in theories on game-based learning and persuasive game design. This study aims to explore how important educational game design elements: immersion, collaboration, debriefing and foster learning in a hybrid escape room for STEM.

Escape rooms in education

Escape rooms are gaining popularity as learning environments in all levels of education and for various educational purposes (Fotaris & Mastoras, 2019; Sanchez & Plumettaz-Sieber, 2019). Embedded in the course curriculum, escape rooms are designed to explore an active learning environment, which is said to increase students' motivation and/or engagement and domain-specific skills and knowledge while fostering teamwork and communication skills (Veldkamp, van de Grint, et al., 2020).

Similar to recreational escape rooms, educational escape rooms combine hands-on and mind-on activities incorporated in a quest and to be solved with a team in a limited time (Nicholson, 2015). In education, each of the escape room characteristics is not unique on its own. However, the combination seems unique and appealing to teachers, as they want

Practitioner notes

What is already known about this topic

- The escape room as a learning environment appeals to teachers of different disciplines, ages, gender and teaching experiences.
- Teachers implement escape rooms to create active (hybrid) learning spaces, where learners need a combination of knowledge and skills to solve the subject-based activities.
- Students and teachers perceive that while participating in escape rooms, students are more engaged, active and learn more compared to regular classes. The assumption is that escape rooms support collaboration and automatically collaborative learning.
- Review studies on educational escape rooms show that a systematic evaluation is usually absent, disputable or indicates no knowledge gain.
- Teachers design their educational escape rooms based on digital escape games and/or their experience as players of escape rooms.
- For *digital* educational games, important game design aspects are researched.
- Three main challenges in designing educational games are (1) the participants' transition from the real world to the game world, (2) the alignment of game design aspects and educational aspects and (3) the transfer from attained experiences and knowledge back into the real world.

What this paper adds

- This paper evaluates an educational game design framework for escape rooms, focussing on the above-mentioned main challenges in designing educational games.
- It investigates the influence of the educational game design elements *immersion*, *collaboration* and *debriefing*, on fostering learning with a hybrid educational escape room.
- It informs that all three design elements contributed to students' appreciation of the escape room, whereas only immersion had a direct contribution to knowledge gain.
- The used hybrid escape boxes contributed most to the immersion; scaffolding students to focus on each other and the tasks.
- Students' collaboration was successfully fostered. However, it scarcely led to collaborative learning *during* gameplay, due to lack of discussion and reflection needed for deeper understanding.

Implications for practice and/or policy

- The educational escape game framework would help educators creating immersive games, which not only confront learners with meaningful contexts but also give learning gains.
- The educational escape game framework would help researchers focussing on important and difficult aspects of designing and implementing educational escape rooms to develop and research more effective escape rooms.
- In guidelines on creating *immersion* in educational escape games, the notion of physical objects is lacking. In this hybrid escape room, the physical objects such as escape boxes were the most powerful in creating immersion. In addition, the use of sound design in escape games in classrooms seems overrated.
- Debriefing after the gameplay is perceived necessary to discuss common misunderstandings, to make connections between the topics in various puzzles and to add more content to interest high-achieving students.

to create authentic environments with meaningful activities and room for failure for their students (López-Pernas et al., 2019).

Secondary science students appreciate the diversity of puzzles, their problem-solving and discovery nature, and the need for physical attributes and collaboration (Peleg et al., 2019; Vörös & Sárközi, 2017). These are characteristics of exploratory and problem-based play. To attract both girls and boys in the underlying science content and skills, both types of play are needed (Kinzie & Joseph, 2008). When tested for gender bias, no gender bias was detected in any of the questions that addressed the escape room activity (López-Pernas et al., 2019).

In educational escape rooms, students are cognitively, behaviourally and affectively engaged (Hermanns et al., 2017; Veldkamp, Knippels, et al., 2021). A meta-study on engagement in education showed that engagement positively influences academic achievement. Cognitive engagement is related to a deep level understanding of content. Behavioural engagement is associated with the development of basic skills and prevents dropping out. Affective engagement encompasses positive and negative emotions and influences the willingness to do work (Fredricks et al., 2004). None of the reviewed studies comprised an intervention that evoked all these aspects of engagement, unlike escape rooms.

The escape room as a learning environment appeals to teachers of different ages, gender and teaching experiences (Veldkamp, Knippels, et al., 2021). The attraction for STEM teachers seems to be the teaching of content knowledge and skills in authentic contexts such as crime scenes (Ferreiro-González et al., 2019; Healy, 2019), secured laboratories (Peleg et al., 2019; Vergne et al., 2019; Watermeier & Salzameda, 2019), computer networks (Borrego et al., 2017; Ho, 2018), or students following the historical footsteps of a scientist during his discovery and its consequences in time (Dietrich, 2018). In medical escape rooms, the required collaboration and communication skills are part of students' professional skills. Seto's study (2018) showed that it was feasible to assess collaboration skills and reflect on them afterwards with students. For content knowledge, review studies on educational escape rooms show that the evaluation is usually absent, disputable or indicates no gain (Fotaris & Mastoras, 2019; Veldkamp, van de Grint, et al., 2020). The discrepancy between perceived and actual learning of content knowledge is in line with other findings in pioneer studies on educational games (Garris et al., 2002), practical work (Abrahams & Millar, 2008) and inquiry-based science instruction (Minner et al., 2010). These and similar studies showed that the interventions appeared not to be effective without active linking of knowledge during the intervention or reflection afterwards. A plenary reflection or debriefing, after the gameplay, is implemented in 40% of all educational escape rooms (Fotaris & Mastoras, 2019) and in half of the physical ones (Veldkamp, van de Grint, et al., 2020).

A current trend in educational escape rooms is upscaling the game with the use of technology in order to play the game with a whole class or course at the same time (Blankenship et al., 2021; Shvalb & Harshoshanim, 2020; Strippel et al., 2021). Technology is mostly implemented to structure the game, validate answers (Ross, 2019), supply pre-set hints (Veldkamp, Daemen, et al., 2020) and/or immerse students in outside world contexts, which are out of reach or potentially dangerous (Cheng & Annetta, 2012; Janonis et al., 2020).

Theoretical grounding of educational escape rooms

Teachers develop escape rooms based on their experiences with recreational escape rooms and/or video escape games, and/or refer in their game design decisions to pedagogical or game principles, such as autonomy and immersion (Veldkamp, van de Grint, et al., 2020). Due to the game-like properties of escape rooms, we may resort to educational game theories. The potential for game-based learning in science education is to bring authentic science-related environments in the classroom, promote collaborative problem solving and provide an effective learning environment, according to Li and Tsai's review (2013). For example, Cheng and Annetta developed a game to let students 'experience' the effects of drugs in a virtual authentic environment. Students' knowledge improved and their attitude to drugs changed (2012). In the game design, it appears important to integrate learning and playing, without losing what is enjoyable about games (Ke, 2016; Vandercruysse & Elen, 2017): simulations, role play, humour, surprise, puzzles, storytelling and mystery (Whitton, 2018). Consistency in the game context (time and place), the character of the players, the activities, the tools and the props are advised. This prevents cognitive dissonance, fosters immersion and therefore engagement of the players (Nicholson, 2016).

Essential aspects of educational games for engaging and learning are the players' identity and role during gameplay, immersion, discovery-oriented experience, interactivity (including collaboration, autonomy and ownership), progression and increasing complexity, scaffolding learning (including repetition, feedback, rewards and debriefing) and alignment with the curriculum (Annetta, 2010; Ávila-Pesántez et al., 2017; Ke, 2016; Lameras et al., 2017). A review showed that although most GBL research is related to digital games, physical or hybrid educational escape rooms can address the above-mentioned aspects (Veldkamp, van de Grint, et al., 2020).

GBL reviews stress an understanding of the relations between educational and game design aspects for engagement (Connolly et al., 2012; Jabbar & Felicia, 2015) and learning (Ke, 2016; Van der Linden et al., 2019). A review study on common practices in educational escape rooms regarding specific educational and game design aspects draws the same conclusions (Veldkamp, van de Grint, et al., 2020). An educational design framework was used to understand the data on the synthesized practices in educational escape rooms; see Figure 1.

The framework addresses the different alignments needed in a successful educational game. Van der Linden et al. (2019) emphasized that the learning goal should be leading in the design of an educational game, and it needs to be ensured that the game goal can only be reached when the desired learning goal is reached. Additionally, a learning goal can only be achieved when supported with an adequate pedagogical approach, and the game goal by adequate game mechanics. Moreover, during iterations of the design process, the focus should be on aligning the pedagogical approach with the game mechanics, as it appears to be the most essential and difficult step.

Applying this to, for example, medical escape rooms, the alignment is strong as the game goal and learning goal both comprise rescuing patients by setting the right diagnoses and administering the right interventions (Veldkamp, van de Grint, et al., 2020). Less aligned are goals on mathematics skills and unlock handcuffs, as one can try brute force when running

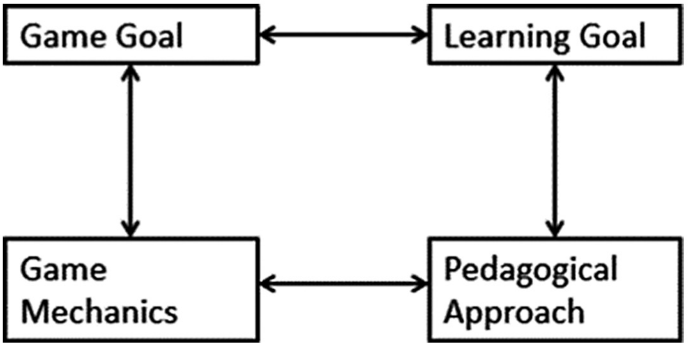

FIGURE 1 Design framework on alignment between game goal, learning goal, pedagogical approach and game mechanics (Van der Linden et al., 2019)

out of time. In addition, it was concluded that pedagogics such as collaborative learning do not align with game mechanics such as a sequential puzzle organisation in combination with a team size of six or more. Students were more active and collaborative when the used puzzle organisation created positive social interdependence.

For the design of educational escape rooms, the available models comprise step-by-step procedures (Botturi & Babazadeh, 2020; Clarke et al., 2017; Eukel & Morrell, 2021; Guigon et al., 2018). However, design challenges for educational games are not considered. Veldkamp, Merx, et al. (2021) described in a framework the three challenges that inform the design of an educational escape room. Additional to aligning game and educational aspects, the challenges are the participants' transition from the real world into the game world and the transfer from experiences and knowledge obtained within the game world back into the real world. These two challenges are addressed by Visch and colleagues (2013) in their persuasive game model. Persuasive game theory presumes that participants' beliefs, attitudes and behaviour in the real world can be transformed by a game. The enjoyable and immersive game world can persuade and help players to behave in ways they experience as difficult or unsafe in the real world. Acquired beliefs, attitudes and/or behaviour can then be applied in the real world; the ultimate goal of persuasive games (Jacobs et al., 2017). However, an explicit transfer to the real world is needed and often neglected in game design (Visch et al., 2013). Other than Van der Linden's framework, this model does not focus on the gameplay as such but describes the participants' transition from the real world into the game world and back. Hence, the combined frameworks cover all three design challenges in one framework for educational escape rooms; see Figure 2.

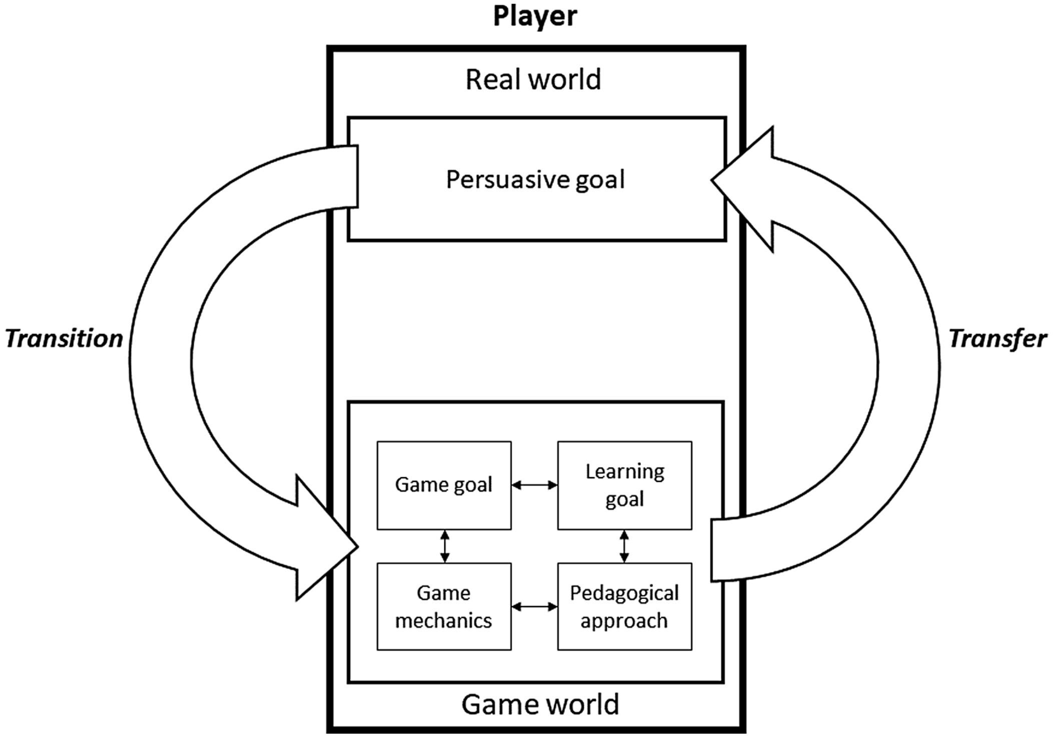

FIGURE 2 An educational game design framework for escape rooms, focussing on the three main challenges (1) the participants' transition from the real world to the game world, (2) the alignment of game design aspects and educational aspects and (3) the transfer from attained experiences and knowledge back into the real world (Veldkamp, Merx, et al., 2021)

In secondary education, the students' transit from the science class into the game world is not as voluntary as in a recreational game. To persuade students, immersion is important. Immersion is the process where someone is lured into a story or problem (Douglas & Hargadon, 2001), gets engaged, solves challenges and finishes the game (Hamari et al., 2016). Immersion correlates with improved learning outcomes in science GBL. However, more immersion in the game leads only to higher game scores, but not to higher learning outcomes (Cheng et al., 2015). Ermi and Mayra (2005) distinguish sensory immersion, challenge-based immersion and imaginative immersion. Sensory immersion implies the audio-visual properties of a game, the extent to which the surface features of a game have a perceptual impact on the player. Challenge-based immersion entails immersion in the cognitive and motor aspects of the game that are required to meet the presented challenges. Finally, imaginative immersion refers to the immersion within the imaginary world created through the game and depends on the richness of the narrative structure of the game. However, in a classroom, the possibilities for scenery and props, which are important for immersion are limited. So, which immersive design elements are crucial for luring students into STEM game tasks?

STEM escape rooms aim at collaborative learning. In collaborative learning environments learners are engaged; working together to formulate questions, discuss ideas, explore solutions, complete tasks and reflect on them (Kozlov & Groβe, 2016; Srinivas, 2011). Learners interact to reach a shared goal (Dillenbourg, 1999). The environment needs to provide students with the opportunity to discuss and to bear responsibility for their learning and participation (Laal & Laal, 2012; Yücel & Usluel, 2016). In STEM escape rooms, collaborative learning is fostered with supportive game mechanics fostering collaboration, such as adequate puzzle organisations and team sizes (Veldkamp, van de Grint, et al., 2020). However, to what extent collaborative learning is fostered during escape room gameplay is unknown.

To improve the transfer of the acquired knowledge and skills from the game world to the real world, debriefing is needed (Sanchez & Plumettaz-Sieber, 2019; Watson et al., 2011). Watson et al. (2011) see teachers as agents bridging the game world and the real world. The debriefing after an educational game is a complex process as the experience and knowledge need to be decontextualised and institutionalised for future contexts. Therefore, teachers need to discuss the game experience and puzzles, link puzzles to learning goals and content, and discuss the learning for broader application (Sanchez & Plumettaz-Sieber, 2019).

A systematic review on escape rooms in STEM education urges to research which game elements exactly influences students' science learning in a positive way (Lathwesen & Belova, 2021). In our study, we researched to what extent the game elements, immersion, collaboration, and debriefing, foster learning in educational escape rooms. These game elements address the main challenges in designing effective escape rooms; see Figure 3. So, for an escape room activity in secondary science education, the following research question was explored: how do immersion, collaboration and debriefing contribute to the appreciation of and learning with an escape room?

METHOD

Study design and data collection

A mixed-method study was carried out. The activity was played in the first two Dutch secondary schools reacting to an announcement in a newsletter. The six classes had a total of 126 pre-A-level students grade 10–12, aged 16–20 yrs. To determine whether learning actually took place, a pre-test/post-test was deployed. The pre-knowledge test was administered just before the students played the escape game, and the post-knowledge test was administered after the debriefing.

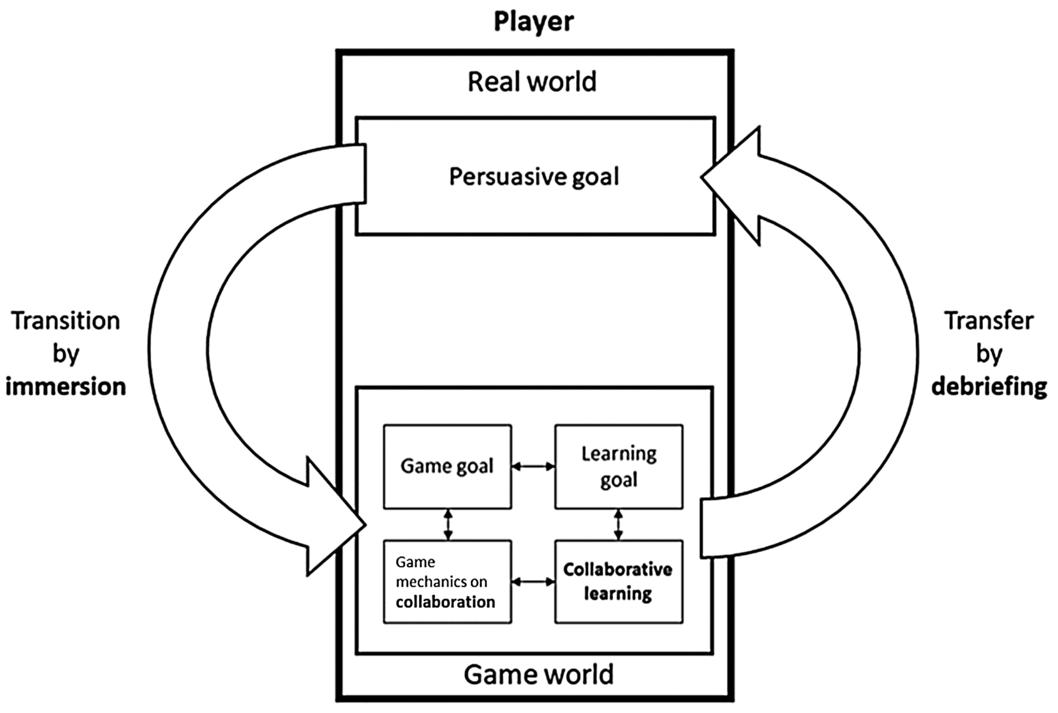

FIGURE 3 The educational game design framework for escape rooms educational aspects, highlighting in bold the foci of research (adapted from Veldkamp, Merx, et al., 2021)

TABLE 1 The various data sources and numbers

Data source	Number female, male, other
Students—pre-test/post-test	126 68, 57, 1
Students—experience questionnaire	126 68, 57, 1
Students—interviews	14
Teachers—interviews	5
Classroom—observations	6

To study how the game design elements, immersion, collaboration, and debriefing, influence learning in a physical escape room, various data sources were used: experience questionnaires, interviews with students and teachers, and classroom observations (see Table 1).

The statements for the experience questionnaire were either adopted or adapted from other studies or developed by the authors (see Appendix B, Table B1). A 5-point Likert scale was used, ranging from 'totally disagree' to 'totally agree'. The pre-test/post-tests, the experience questionnaire and interview questions (see Appendices A–C) were pretested on two students using a think-aloud protocol (Jääskeläinen, 2010). Consequently, a few questions in the experience questionnaire were rephrased.

Before the start of the class, the researcher randomly chose one of the five escape boxes to observe. During gameplay, every student standing around the box was observed once a minute, using a predefined coding scheme (see Table 4). Another researcher performed the role of game master (GM) monitoring and guiding the teams who got stuck, due to technical or cognitive difficulties. The teacher had no described role and observed all teams informally. For the semi-structured interviews, a non-random sampling strategy was used, since the teachers and students participated on a voluntary basis. From each class, students were interviewed in small groups, with a total of fourteen students.

Data analysis

Answers given by the students on the pre- and post-knowledge tests were graded; one point for every correctly answered question and zero points for every incorrect or 'I don't know' answer. To determine the reliability of the pre- and post-knowledge test, the calculated Cronbach's alpha was, respectively, 0.78 and 0.72. Without question T13 (see Appendix A), which showed no correlation with other questions, the post-knowledge test Cronbach's alpha increased to 0.74. A Wilcoxon signed-rank test was used to determine whether the content knowledge of the students had increased on the test average.

In the experience questionnaire, 18 out of 21 items addressed the design elements, with a Cronbach's alpha of 0.81. Data were analysed using descriptive statistics and Spearman's rank correlation test. On the classroom observations, descriptive statistics were used.

All interviews were recorded, transcribed verbatim and analysed independently by two researchers following Boeije (2010), using immersion, collaboration, collaborative learning, debriefing and learning outcomes as sensitising concepts in NVivo 12. For the students' interviews, the inter-rater reliability testing showed 96.6% agreement for the students' interviews, with a Cohen's kappa for the elements immersion of 0.92, collaboration 0.90 and debriefing 0.94. For the teachers' interviews, the inter-rater reliability testing showed 98.6% agreement, with Cohen's kappa's for immersion of 0.80, collaboration 0.67, collaborative learning 0.89 and debriefing 0.91.

Description of the escape box design and narrative

The learning goals addressed immunology for grade 11, involving concepts and mechanisms on immunisation, B and T cells, antibiotics and the differences between bacteria and viruses. Extracurricular goals covered knowledge of the approach One Health, which recognises that the health of people and animals are interconnected, and a multidisciplinary approach is needed to defeat zoonoses, such as Q-fever.

The escape room activity was developed from scratch in three design cycles using design-based research (Bakker, 2018). The resulting escape boxes were co-created with students, who were close to the target group's real world and game world (Veldkamp, Daemen, et al., 2020).

The escape box has changeable fronts; see Figure 4. An educator can choose six out of the eight available fronts to compile a new game setting. The fronts offer various tools, such as a laptop screen, a magnet board, buttons linked to an embedded microcontroller system (microchip) and hatches with locks. Puzzles placed on each side of the fronts put players face to face with each other and stimulate them to collaborate. The storyboard option in Microsoft PowerPoint was used to structure the game, support the narrative and supply authentic movie clips. In addition, it revealed pre-set hints for teams lagging and teams could continue their game, while others finished.

The storyline covers the rise and fall of a Q-fever epidemic in goats caused by the bacteria *Coxiella burnetii*. The main character is an animated bacterium. The staged newscasts with authentic material of a Q-fever epidemic in the Netherlands (2007–2011) inform the team on the epidemic, and its course as a result of the team's actions. In the 'multidisciplinary' team, students wear clothing according to their unique role in the narrative, such as a livestock

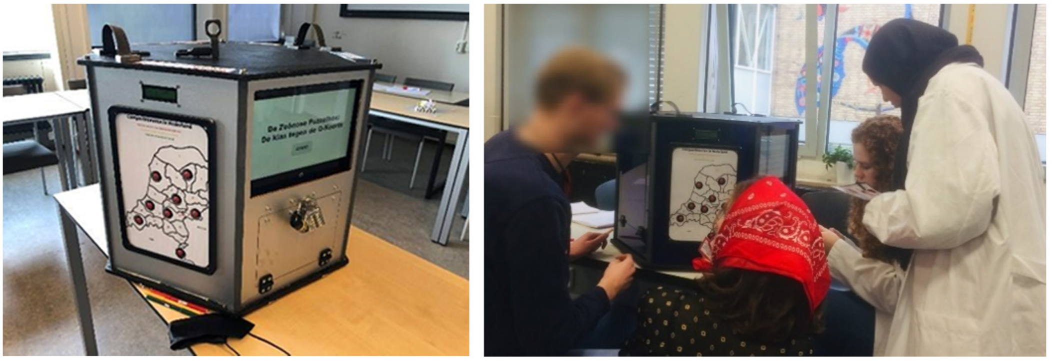

FIGURE 4 (a) The escape box featuring on the left front buttons linked to an embedded microchip, and an LCD screen for the question and feedback. The right front shows the laptop screen with an interactive PowerPoint. (b) Students dressed according to their role, playing the game

farmer, veterinarian, general practitioner, government, or civilian; see Figure 4b. The game started plenary, presenting game rules and a newscast introducing the epidemic with the students as a multidisciplinary rescue team. The game ended when students achieved the game's goal, or after 45 minutes.

Addressing the three design challenges

1. Alignment of goals, game mechanics and pedagogy: The game goal is the multidisciplinary team's defeat of the epidemic. To achieve this game goal, knowledge on immunology needs to be applied to puzzles supporting the game goal and covering the learning goals (for more details, see Appendix D). Laal and Laal (2012) researched fundamental elements of collaborative learning: positive interdependence, face-to-face interaction, individual accountability, social skills and group processing. The social dependence needed is scaffolded by game mechanics, such as the time restriction, resource dependence as some information is related to a specific role and the organisation of the puzzles as in some phases multiple puzzles need to be solved at the same time (see Appendix E).
2. For the transition to the game world, the following immersive elements were implemented: a narrative with a call for action to the students in distinct roles, appropriate clothing, authentic video material and a sound design. The escape box was designed to stimulate students to gather around with consequently less distraction by their surroundings.
3. To improve the transfer of learning from the game world to the real world, a debrief was designed based on research of Sanchez and Plumettaz-Sieber on debriefing in educational escape rooms (2019). The teachers guided the debriefs, as they could link the topics to previous and coming lessons and knew their students best.

RESULTS

Appreciation of the activity

The first step in a research on the contribution of implemented game design elements on the learning with an escape room was to determine whether learning actually took place.

The means of the pre-test/post-test scores are $M_{pre} = 7.8$, SD = 3.5; $M_{post} = 15.0$ (14.95), SD = 2.8 showed a significant increase in scores (Wilcoxon's $Z = -9.8$, $p < 0.0001$). In the experience questionnaire, students answered positively on the question on the appreciation for the game (Q1), on average 4.5 out of 5-point Likert scale. The question on future escape rooms (Q2) averaged to 4.3. Additional analysis (Mann–Whitney *U* testing) showed no gender preferences.

Results on the contribution of educational design elements on the appreciation and learning with an escape room

To study the influence of perceived immersion, collaboration and debriefing on the learning of students with an escape room activity, an experience questionnaire, classroom observations, student interviews and teacher interviews were conducted (see Table 1).

Table 2 shows the results from the experience questionnaire. The high means (3.9 out of 5) for the items on immersion and collaboration indicating that students felt very immersed and perceived that had worked very well together. The mean for the debriefing items is slightly lower (3.7 out of 5).

As the data were not normally distributed using Kolmogorov–Smirnov's test of normality, non-parametric tests were used. The Spearman's rank correlation coefficients showed that students who experienced strong immersion, also experienced strong collaboration and

TABLE 2 Descriptive statistics for the perceived immersion, collaboration and debriefing items in the experience questionnaires

Category	Mean	SD	Mode
Immersion	3.9	0.5	
T3	3.42	1.00	4
T4	3.66	0.99	4
T5	4.17	0.92	5
T6	4.28	1.12	5
T7	4.40	0.84	5
T8	3.48	1.03	4
T9	4.14	1.02	5
Collaboration	3.9	0.6	
T10	4.50	0.71	5
T11	4.35	0.92	5
T12	4.50	0.78	5
T13	3.87	1.00	4
T14	2.98	1.43	3
T15	3.33	1.05	4
Debriefing	3.7	0.7	
T16	3.70	0.98	4
T18	3.29	1.17	3
T19	3.92	1.01	4
T20	3.76	1.03	4
T21	3.66	0.96	4

Abbreviations: Q, Question; SD, standard deviation.

TABLE 3 The Spearman's correlation coefficients on relations between the students' appreciation of the activity (Q1), their willingness for this type of activities in the future (Q2), their experiences on immersion, collaboration, debriefing and their knowledge gain

Future	0.650**				
Immersion	0.457**	0.459**			
Collaboration	0.424**	0.506**	0.348**		
Debriefing	0.480**	0.402**	0.487**	0.337**	
Knowledge gain	0.203*	0.108	0.180*	0.088	0.108
	Appreciation	Future	Immersion	Collaboration	Debriefing

*Correlation is significant at the 0.05 level (2-tailed); **correlation is significant at the 0.01 level (2-tailed).

TABLE 4 Partial correlations between the students' knowledge gain, their appreciation of the activity (Q1), their willingness for this type of activities in the future (Q2) and controlling for their experiences on immersion, collaboration, and debriefing

Future	0.049	0.452**
Knowledge gain		0.138
	Knowledge gain	Appreciation

**Correlation is significant at the 0.01 level (2-tailed).

scored high on the appreciation of debriefing ($p < 0.01$), see Table 3. The appreciation of the activity was even more strongly related to experiences of immersion, collaboration and appreciation of debriefing. Additional analysis (Mann–Whitney *U* testing) showed no gender preferences for any of the studied variables.

Immersion

The questions Q5–7 and 9 from the experience questionnaire showed the highest means (4.2–4.4) and modes (all five), meaning that students felt not distracted by teammates or the surroundings and focussed on the game by means of the box; see Table 2. The score on elements of sensory immersion (Q8 ‘videoclips, clothing and props’) was lower (3.5). The elements related to imaginative immersion (Q3), and challenge-based immersion (Q4) were lower (3.4–3.7) than the scores on the role of the box (4.2–4.4), but still indicating a positive influence on immersion. The Spearman's rank correlation test indicates that students’ experience of immersion shows a positive small correlation with the knowledge gain during the activity ($p < 0.05$); see Table 3. This means that students' experience of immersion influences learning, although the influence is small.

Collaboration

Questions Q10–12 showed the highest means (4.5, 4.4, 4.5) and modes (all five), demonstrating an experienced high degree of communication and collaboration in the teams. The means of the questions (Q14, 15) indicating the perception of collaborative learning were the lowest of all items, respectively 3.0 and 3.3, both with a standard deviation of 1.0. This indicates that a few students perceived that they had learned from getting explanations and even fewer students perceived that they had learned by giving explanations. This is *not* due to a lack of the perceived collaboration as the scores on these items were high.

Debriefing

The means for the debriefing items are between (3.7 and 3.9), and the mode is 4 for all items, except for Q18 which has a mode of 3. The students appreciated the debriefing (Q16) in helping to understand concepts on immunology (Q19) and to apply these concepts in real-world situations (Q21). The scores on Q18 seem to indicate that the students' questions were not sufficiently answered during the debriefing. However, none of the students who were not satisfied posed a question during the debrief as asked in Q17. Classroom observations during the debriefing showed that there was room to ask questions, and a few students used that opportunity. In addition, Spearman's rank correlation tests showed that students with perceived higher knowledge at the start thought they profited less from the debriefing.

Learning outcomes and the appreciation of the activity

Spearman's rank correlations show positive correlations between the knowledge gain and both the student's appreciation of the activity and the immersion; see Table 3. However, the partial correlation between the knowledge gain and appreciation, controlling for immersion, collaboration and debriefing, is not significant (rho = 0.138, see Table 4); therefore, the relation between knowledge gain and appreciation can be fully explained by the correlation between immersion and appreciation (see Table 3).

In addition, the students' pre-test knowledge and the knowledge gain during the activity show a negative correlation ($R = -0.642$, $p < 0.01$). This suggests that students who knew less, learned more during the activity.

Classroom observations

One of the criteria of immersion is that one is not easily distracted (Ermi & Mayra, 2005); therefore off and on-task behaviour was scored. None of the students observed were off-task during the activity (Table 5). This alone is not enough to state that the students were immersed. However, it does support the self-evaluation by the students. Students were communicating verbally 28.8% of the observed time, next to looking at and possibly thinking about how to solve the escape box (32.7%) and physically trying to solve the puzzles (15.2%). Although most time is spent on-task on the content knowledge (76.8%), the time spent on explaining or discussing content knowledge is only 3.1%. Additional notes on the classroom observation schemes showed that students laughed about the videos with the animated bacterium and the news reporter. Some students started to hum the news theme music along at the start or the end of each news item; others tried to skip it. Additional notes showed that at school number two, in all teams observed, students addressed each other or themselves according to their role, for example: *'Doc, do you know?' or 'Heee! I'm not a stupid farmer'*.

Student interviews

All students indicated they would like escape game activities more often, although not every lesson.

TABLE 5 Observed student behaviour in six groups (total of 28 students) during classroom observations

Frequency of codes	Percentage of total	Code	Student behaviour	Description of behaviour
On-task				
136	15.2%	CP	Content—physical play	Physically involved in the games' content
229	25.7%	CC	Content—communication	Communication with team member(s)
28	3.1%	CE	Content—explanation	Team member explaining or discussing content
292	32.7%	CO	Content—observation	Observing content puzzles
0	0	CQ	Content—question	Posing question to GM* or teacher on content
5	0.6%	GQ	Game—question	Posing question to GM* or teacher not on content
202	22.6%	GO	Game—other	Busy with the game, other than content
Off task				
0	0	OI	Off-task individually	Off task behaviour by themselves
0	0	OT	Off-task team	Off task behaviour in relation to team member(s)
0	0	OS	Off-task surroundings	Off task behaviour by something outside the team
892	100%			Total

Abbreviation: GM, game master.

Immersion

The content-based puzzles addressed challenge-based immersion. Students mentioned noticing their surroundings only after finishing the game, or when they were visited by players who had already finished the game. In their explanation, students mention competition, time restriction, the novelty factor, and their focus on the box. As a student (S8) explained: '*the weird box, shiny, with buttons and puzzles, you want to touch and try*'. In addition, students mentioned that the shape of the box helped them to focus on their part in the game, on 'their' puzzle. Some added that later on while walking around the box, they were still faced on the centre and not on their surroundings (S9, S13, S14).

Most students considered the puzzles challenging but doable, and informative with a fun or puzzle twist, as it was not always clear how to solve a puzzle. This last aspect was appreciated but also confusing for those who were not familiar with escape rooms. Two students mentioned that although the content-based puzzles Word Search and the anagram were not congruent with the zoonosis context, they added a fun element.

According to the students, the authentic video clips made the narrative credible and contributed to immersion as it made the terrible consequences for the live-stock and farmers visible.

> S14: 'It showed the consequences for people, for example, the farmer who lost all his goats, that is quite intense. With those images, it is easier to empathize with them.'

Although the newsreader and the animated bacterium were referred to as 'fake' and adding humour, some students in their final high school year, considered the animated bacterium too childish and the announcement of the newscasts too long, as the players' time was restricted. The sound design during the gameplay was only noticed by two of the fourteen interviewees and appreciated in supporting the narrative. The applause after finishing the game was mentioned by more students and appreciated. All students mentioned that the roles immersed them in the game, although they did not adhere to their roles for the full length of the activity.

> S8: 'I was engaged immediately. You are standing around that box and the first thing you think is "I want that bandana, that jacket, or that prop". Consequently, you enrol and it is more fun to do the puzzles because you are in that role.'

Four students wondered whether the roles were crucial for immersion. Eight of the fourteen students added that it showed them the multidisciplinary approach in the battle of zoonoses. Half of the interviewed groups from school 2 mentioned that the roles also structured the initial division of tasks.

> S12: 'I think that if you are in a group without roles, everyone will cluster on each topic. If you have a role assigned, you are more eager to find out your stuff.'

Collaboration & collaborative learning

Students formed their own teams. All interviewed students stated that their teams functioned well, adding that teams should not be greater than five for a game with this number of puzzles. All groups mentioned that the (hexagonal) shape of the box allocated each student to a side, made them feel the owner of the puzzle(s) on that side, but also allowed them to see on their neighbours' side and optionally help them. S8: '[…] *there is a kind of separation with each role on each side, but you can get to the other sides*, […] *you can observe that the person with the role often takes the lead; the first one who will turn the lock, press the buttons or enter the code*.'

As learning outcomes, five of the seven groups of interviewees mentioned the refreshing of known concepts and knowledge. In addition, the students from school 2 named aspects on collaboration, such as that various talents or insights are needed to solve a problem, awareness of the role of communication in collaboration, and the balance between task allocation and dare to outsource your problem. This was in contrast to the students from school 1. They only mentioned that one needs various disciplines to beat a zoonosis and that it was a stepwise procedure.

On the question of how they learned during gameplay, students mentioned group exchange of information or checking each other's answers. This was limited to a certain extent, as *'you only hear the answer, but you don't know what the question is*' (S6). '*You haven't learned the meaning of the concepts. So, you learn it superficial, and not in detail*' (S5).

Some students from school 2 mentioned that the activity does not equal the usual amount of content knowledge covered in a lesson. However, the efficiency in terms of remembering is perceived higher by students. Students pointed out that they were less distracted in the escape game, due to the level of participation needed, the diversity in activities, the authentic context refreshing and extending knowledge, the urgency to succeed in time, and that the game was said to be more fun.

The role of debriefing

According to most students, debriefing is essential in the learning process as it wraps up the most important information from the puzzles and relates the main concepts. Students mention that they only solved a selection of the puzzles, due to the division of tasks. The debrief took away doubts on given answers and some teachers addressed student ideas on concepts. In addition, some teachers made connections with previous lessons, addressed other zoonoses and their consequences for society, and the societal debate on vaccination. Interviewed students from teachers who had not made these additions, advised incorporating such additions in the debriefing to make it more interesting than ‘just a wrap up’.

Teachers' informal observations

Three out of five teachers, all from school 2, had experiences with developing and implementing educational escape rooms. The goal of the escape box activity was to refresh students' knowledge on immunology; a formative assessment in an authentic context.

All teachers concluded that students were enthusiastic and more engaged than in their regular classes. However, in two out of the six classes, one or two students were not active, for no outstanding reason.

Three teachers observed that a few boys wanted to crack the locks without doing the content-based puzzles. One teacher added that the element of competition makes the game vulnerable for non-functioning parts, as students feel wronged if they must wait for the non-functioning parts to be repaired.

Teacher interviews

Immersion

The escape boxes

In relation to immersion and engagement, teachers observed that students entering the classroom curiously a walked around the box ‘*which looked swanky and had devices incorporated*’ (T4). All teachers mentioned that standing around the box made students focus on the box and on each other. It facilitates ownership for the side of the box in front of them, and they can also see their neighbours' sides. No involvement with other groups or mobile phones was noticed by the teachers. Teachers who had played educational escape rooms before indicated that in these escape rooms with loose puzzles and materials, students moved more and worked more separately from each other. According to teachers, escape boxes centralize students’ attention and foster immersion and engagement.

The narrative

In relation to immersion and engagement, teachers observed that from the start, students appreciated the narrative; it was intriguing and funny. The context was new, authentic and realistic due to the use of genuine footage. Some teachers thought at first that the use of an animated bacterium as a protagonist would be too childish for A-level students. However, they observed that students laughed and appreciated it. One teacher suggested that it might soften the dramatic realistic footage. Teachers observed that students perceived the enfolding of new parts of the narrative by the movie clips as a reward.

Students' roles in the narrative

Teachers observed that as soon as students entered the classroom, the clothing triggered discussion and division of the roles. Subsequently, students put on clothing before the class had started, apparently lured into the activity. All teachers from school 2 mentioned that students referred to each other's roles during the gameplay. Teachers from school 1 had not heard students referring to roles and observed no added value of the roles, clothing or props for students. Although, '*the various professions involved deepened the problem of zoonoses*' (T1).

Collaboration and collaborative learning

All teachers mentioned that the box shape invites to collaborate, as students see and hear each other while working. Teachers from school 2 observed that the start of the game with each player at a side made the player responsible for this side with the related assignments. It was more difficult to withdraw and easier to address team members in their roles rather than personally. This task allocation effect became less during the game. In addition, students displayed their puzzles *on* the boxes and could be seen and discussed by all. In only a few groups, all students within a team explored each puzzle together. In relation to the narrative on the display, teachers observed that students waited till everyone was gathered around the display and watched the movie clips together. They interpreted that it bonded the students and focused them on a new phase in the narrative and related assignments, as tactics and task divisions were discussed after watching the movie clips together. It was mentioned that the roles helped to experience and understand the mean message of the game and that collaboration of disciplines is needed to defeat zoonoses.

Collaborative learning was only recognized by three teachers as they heard discussion and exchange of concepts. Two others saw no signs of collaborative learning at all. They assumed that due to the competition there is no time nor need to explain answers. T4: '*They are not going to ask: How did you arrive at this answer? An escape game sends you forward, not backwards*.' One teacher wondered if the roles and subsequent individual task allocation might have negative effects on collaborative learning.

Debriefing

Teachers declared that debriefing is essential. They observed that due to the division of tasks and time pressure, students do not address all puzzles or read badly. Debriefing is perceived necessary to discuss common misunderstandings, to make connections between the topics in various puzzles and to add more content, depending on the level of the classes.

DISCUSSION

Students enjoyed the escape box activity and no gender preferences were found in line with previous studies (López-Pernas et al., 2019; Veldkamp, Knippels, et al., 2021). The pre-test/post-test results showed an increase of knowledge gain in contrast to outcomes of studies in a systematic review which showed no, or a disputable knowledge gain (Veldkamp, van de Grint, et al., 2020). However, similar to the studies in the review, no long-term retention has been tested, and the test items addressed lower-order knowledge objectives (Anderson & Krathwohl, 2001). Future research needs to address these limitations. The Spearman's rank correlation test indicated a small positive correlation between the knowledge gain during the activity and the student's appreciation of the activity (see Table 3). However, does this mean that the more the student liked the activity, the more their knowledge gain was, or the other way around?

Previous research has shown that students who knew more, learned more during activities (Ausubel, 1968; Kole & Healy, 2007; Vosniadou, 1994). Our data suggest that students who knew less, learned more during the activity. This can be caused by a ceiling effect of the test, as items addressed only lower-order knowledge objectives. In addition, correlation tests indicate that the appreciation of the activity correlates positively with the appreciation of each of the game design elements. This indicates that the appreciation not depends on one of the design elements, but all contribute. In the following sections, the results from all data sources on each of the elements will be synthesized and discussed. During data-analysis, it became evident that there were differences in various data sources between the two schools in relation to the roles of the students in the narrative. In the following sections, we will relate these differences to the schools' practised pedagogy: the first school fosters collaborative learning and the second school was a regular school.

Immersion

In this study, students felt immersed. The perceived immersion shows a positive correlation with the knowledge gain of students. The elements related to imaginative immersion (narrative and roles), sensory immersion (such as clothing, props), and the challenge-based immersion (puzzles) scored lower than the escape box itself (Table 2). Students felt not distracted by their surroundings or teammates and focused on the box. This is confirmed by all other sources, mentioning the sensory aspects of the box, and its shape centring all students' attention to each other and the game. Before the start, available clothing provoked discussion on the roles. Whether this is due to sensory immersion, imaginative immersion or both, cannot be decided on the available data.

Sound design connected to phases or events in the narrative is an important part of sensory immersion in (educational) games (Cuadrado et al., 2020; Grimshaw, 2012). In this study, players differed in their awareness and appreciation of the sound design. Compared to other immersive elements, it has less common ground. Another study showed that tempo and pitch changes in sound design has no impact on learning outcomes in educational games (Richards et al., 2008). Based on their and our results, we doubt that sound design is important in physical educational games, especially when played by multiple teams in the same classroom.

Some students tried to crack physical locks without solving the puzzles. So physical locks seem part of challenge-based or sensory immersion of physical escape rooms. We suggest including them in questionnaires on immersion and research their type of immersion. In relation to imaginative immersion, an authentic context with a combination of authentic footage and an animated bacterium seems to be a good balance between addressing serious problems and the playfulness of an educational game (Ke, 2016).

In the school with collaborative learning pedagogy, the distinct roles fostered individual immersion and visualized the multidisciplinary approach in beating zoonoses. At the regular school, it also played a positive role in collaboration.

Collaboration

In studies on educational escape rooms, collaboration and collaborative learning are mentioned in the same breath. The assumption is that the team-based games supports collaboration and automatically collaborative learning (Arnal et al., 2019; Brady & Andersen, 2021;

Gordon, 2017; Peleg et al., 2019; Vergne et al., 2019; Wu et al., 2018). Various data sources (experience questionnaires, interviews students and teachers) indicate a high degree of collaboration. At the regular school, the roles fostered task allocation too, although it lessened during the gameplay. However, collaborative learning scarcely takes place, as only 3.1% of the time is spent on explaining and discussing the content knowledge, the scores on perceived collaborative learning are neutral, and only three teachers observed signs of collaborative learning. Teachers observed that time restriction and competition conflict with explaining and discussing findings. Discussion and reflection on tasks are important for learning according to theories on collaborative learning (Gerlach, 1994; Golub et al., 1988). Thus, although the game successfully scaffolded collaboration; it hardly led to collaborative learning.

Debriefing

The experience questionnaire and interviews showed that students appreciated the debriefing. It is essential, according to them and the teachers, to cover the important information from all puzzles, interrelating the main concepts, and to take away doubts and incorrect ideas. Results showed that students with more prior knowledge gained less knowledge during the game. In order to give students more than a wrap-up, relations to societal issues can be added; conform Sanchez and Plumettaz-Sieber (2019). Additionally, some students advised that new information should be given as part of the debrief, to keep it interesting for some students. This is complementary to Sanchez and Plumettaz-Sieber's components of a debrief (2019).

CONCLUSION

In this study on an escape game for immunology, we used an educational game design framework for escape rooms, focusing on the three main challenges, the participants' transition to the game world, the alignment of game design aspects and educational aspects in the game world, and the transfer from attained experiences and knowledge within the game world back into the real world. This framework led to research the important design elements related to each of these challenges: immersion, collaboration and debriefing. The appreciation of the activity correlates positively with the scores of each of the design elements and the actual knowledge gain after the gameplay. Although students' collaboration was successfully fostered, with 76% of the time spent on the content knowledge, it scarcely led to collaborative learning during gameplay, due to lack of discussion and reflection needed for deeper understanding, the so-called reflection-in-action (Lavoué et al., 2015).

Based on the results, most accountable for the knowledge gain during gameplay is immersion, scaffolded by the roles and boxes, resulting in a constant focus on tasks. Based on current data, it might be possible that immersion is a threshold element of the learning process, fostering mostly individual learning during gameplay, but not unlimited. More immersion in the game leads only to higher game scores, but not to higher science learning outcomes (Cheng et al., 2015). In addition, we found that the roles fostered task allocation and collaboration in the regular school, but not in the collaborative learning-based school. As there were only two schools involved, it is worth researching this aspect systematically in future.

In educational game frameworks on immersion, as they are based on digital game research, the notion of escape boxes to scaffold collaboration or physical objects fostering immersion is lacking. In addition, the use of sound in escape games in a classroom seems overrated. We advise adapting game experience questionnaires on the aforementioned aspects for physical or hybrid educational games. Finally, the educational escape game framework would help educators and researchers develop and evaluate escape games in science education, creating immersive games, which not only confront learners with science-related real-world contexts or socio-scientific issues but also give learning gains.

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CONFLICT OF INTEREST

There are no conflicts of interests to disclose.

ETHICS STATEMENT

For this study no personal data are recorded. Data are recorded and archived according legislation of the Utrecht University.

DATA AVAILABILITY STATEMENT

Data are recorded and stored according to the legislation of the University Utrecht. No personal data are recorded.

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APPENDIX A

THE KNOWLEDGE TESTS AND THE EXPERIENCE QUESTIONNAIRE

PRE-TESTS/POST-TESTS ON CONTENT KNOWLEDGE

The 19 statements in the pre- and post-knowledge tests were alike. Students were asked to tick the right answer: ‘correct’, ‘incorrect’ or ‘I do not know’, and not guess randomly. The pre-test started with questions on age, gender, type of education, grade and how well the student understood the subject of immunology (Likert scale 5).

Statements (T)

T1 A zoonosis is a disease brought from plant to animal.
T2 Pet animals can get zoonoses.
T3 A zoonosis is usually lethal.
T4 The zoonosis Q-fever is caused by a virus.
T5 The zoonosis Q-fever causes miscarriages in animals.
T6 In combating the Q-fever, one of the actions is the killing of infected animals.
T7 Antibiotics combat viruses.
T8 With passive immunisation, you don't make antibodies yourself.
T9 With active immunisation, you don't make antibodies yourself.
T10 With artificial immunisation, you are vaccinated.
T11 With natural immunisation, you encounter the pathogen yourself.
T12 Herd immunity is the protection due to a high proportion of immune individuals around you.
T13 Herd immunity means all animals of a herd are vaccinated.
T14 Herd immunity is reached when 50% of the people around you are immune.
T15 Plasma cells (B-cells) produce antibodies.
T16 Cytotoxic T-cells attach to infected cells and induce cell death.
T17 The defence by the T-cells is part of the cellular immune functions.
T18 The defence by the B-cells is part of the humoral immune functions.
T19 The sequence of the scientific method is: problem definition, hypothesis, research question, experiment, results, discussion, and conclusion.

APPENDIX B

EXPERIENCE QUESTIONNAIRE

The A statements and B sources were used for the statements of the experience questionnaire and whether they were adopted, adapted or developed by the authors.

Statements

My role during the gameplay was:

○ ○ ○ ○ ○

farmer veterinarian civilian general practitioner government

We defeated Q-fever in time.

○ ○

yes no

For the following 22 statements, students were asked to what extent they agreed with the statements, colouring the circle corresponding their opinion.

○ ○ ○ ○ ○

totally disagree disagree neutral agree totally agree

TABLE B1 Sources used for the statements of the experience questionnaire and whether they were adopted, adapted or developed by the authors

Question number	Adopted, adapted or developed	Source
Q1	Developed	
Q2	Developed	
Q3	Developed	
Q4	Adapted	Giang et al. (2018)
Q5	Adapted	Giang et al. (2018)
Q6	Adapted	Jennett et al. (2008)
Q7	Adopted	Jennett et al. (2008)
Q8	Adapted	Jennett et al. (2008)
Q9	Adopted	Veenman et al., (2000)
Q10	Adapted	Cain (2021)
Q11	Adopted	León-del-Barco et al. (2018)
Q12	Adapted	Lin (2004)
Q13	Developed	
Q14	Developed	
Q15	Developed	
Q16	Developed	Based on Sanchez and Plumettaz-Sieber (2019)
Q17	Developed	Based on Sanchez and Plumettaz-Sieber (2019)
Q18	Developed	Based on Sanchez and Plumettaz-Sieber (2019)
Q19	Adapted	Giang et al. (2018)
Q20	Adapted	Hwang et al. (2012)
Q21	Developed	Based on Sanchez and Plumettaz-Sieber (2019)

Q1 I enjoyed the lesson.
Q2 I would like to do similar activities more often.
Q3 I felt I was part of the story.
Q4 The difficulty of the box and my skills were at a similar level.
Q5 The escape box kept my attention.
Q6 During gameplay, I was also busy with teams around me.
Q7 I was tempted to stop playing to see what was going on around me.
Q8 The video clips, clothing and props contributed to the narrative.
Q9 In my team, we often talked about things not related to the escape box activity.
Q10 All my teammates worked well together to solve the puzzles of the escape box.
Q11 My teammates have shared important information with the rest of the team.
Q12 I felt part of the team.
Q13 The escape box activity shows that cooperation is important to combat an infectious disease.
Q14 I learned during this activity by explaining something to others.
Q15 I learned something during this activity because my teammate explained it to me.
Q16 The debriefing was not necessary.
Q17 I posted questions during the debrief.
Q18 During the debrief my questions were solved.
Q19 The debrief helped me to understand concepts on immunology.
Q20 Playing the box and the debriefing helps me to prepare for a test on immunity.
Q21 By playing the box and the debriefing, I can apply the concepts from the book in real situations.

Do you want to add something else? Please, write it down below:

Sources used for the statements of the experience questionnaire

APPENDIX C.

INTERVIEW QUESTIONS A. STUDENTS AND B. TEACHERS

A Interview scheme students—semi-structured

General questions

1. Would you like to do similar activities more often? Why/why not?

Questions on immersion

1. How did you like the narrative on Q-fever? Credible or unbelievable?
2. To what extent did the video clips help to immerse in the narrative?
3. Every team member adopted a different role. How do you feel about that?

Why would the designers have added the roles to the game?

4. To what extent did you stick to your role?
5. Did everyone in your team stick to their role?
6. What were the consequences of abandoning the roles? Bad for the gameplay or not?
7. To what extent helped the additional sounds to keep immersed in the narrative?
8. To what extent were you distracted by your environment? How did that happen?
9. How did you perceive the puzzles you played?
10. To what extent does the shape of the escape box ensure that you are focused on the game?

Questions on collaboration

1. How did the collaboration in the teamwork?
2. What have you learned from each other while playing the escape box?
3. How did you learn from each other while playing the escape box?
4. What have you learned about collaboration?
5. To what extent does the shape of the escape box ensure that you stay focused on the game *together*?

Questions on the debriefing

1. Was the debriefing helpful? Why / why not?
2. What did you learn from the debriefing?
3. What could be improved in relation to the debriefing?

B. Interview scheme teachers—semi-structured

1. How did you experience the activity for your students?

Have you seen any non-involved students?

2. What was or were the goals you aimed at with this escape room activity?

This escape room activity has three main adaptations compared to a regular educational escape room: (1) an **escape box** per team, (2) a **narrative** and (3) each student has a **unique role** in the narrative.

3. According to you, to what extent, **the escape box** had an effect on
   a. the immersion and engagement of students,
   b. the collaboration within their team,
   c. collaborative learning?
4. According to you, to what extent, the **narrative** had an effect on
   a. the immersion and engagement of students,
   b. the collaboration within their team,
   c. collaborative learning?
5. According to you, to what extent, the **student's unique role** in the narrative had an effect on
   a. the immersion and engagement of students,
   b. the collaboration within their team,
   c. collaborative learning?
6. What is the role of debriefing in the activity?

APPENDIX D.

THE CONTENT-BASED PUZZLES AND ITS ORGANISATION

Summarised are the name of the puzzle, which is also a phase in the epidemic, a short description of the main action needed in the puzzle, the role who finds the (main part of the) puzzle and the learning goal. The way the solution leads to a code is not described. Highlighted are the elements fostering collaboration and collaborative learning ('C-elements').

1. *Anamnesis*—to put questions of the vet and corresponding answers of the *farmer* in right order.

Learning goal: To learn concept and procedure of anamneses and symptoms of Q-fever.

C-elements: Task allocation and division of information among players.

2. *Taking a sample*—to judge statements on zoonosis and Q-fever; the vet.

Learning goal: To practise the newly acquired knowledge on zoonosis and Q-fever.

3. *Culling measures*—to appoint the correct infected region for culling measures; government

Learning goal: To learn and practise knowledge on procedure around culling and vaccination of goats and false negatives/positive test results.

C-elements: Task allocation & combination of information of two underlying puzzles needed, and division of sources.

4. *Transfer to humans*—to combine information from anagram for Swedish puzzle; general practitioner.

Learning goal: To foster knowledge on immunology, and practise new knowledge on zoonosis and one health approach.

C-elements: Task allocation & division of information among players

5. *Research on human vaccine*—to put phases in science research cycle in order and relate them to descriptions of research on this topic. Discover new information on Coxiella Burnetii.

Learning goal: To practise knowledge on science research cycle, and learn on use of *Coxiella burnetii* as biological weapon.

C-elements: More puzzles available at the same time: task division, division of sources.

6. *Production of humane vaccine*—to relate concepts to its definitions.

Learning goal: To practise concepts on immunisation and immune system.

C-elements: More puzzles available at the same time: task division, division of sources.

7. *The vaccine out of the box!*—to open a puzzle box in shape of transport box.

Learning goal: None on the content knowledge, not all groups solve a game in time, to ensure players achieve all learning goals, the last puzzle has no learning goals on the content.

However, the message is that 'out of the box'-thinking is required in the game and in science.

APPENDIX E.

THE ORGANISATION OF THE PUZZLES

The organisation of the puzzles or the so-called puzzle path is depicted.

The numbers refer to the description of the puzzles in Appendix D.