When Design Gets in the way: Student Learning and Digital Escape Game

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Abstract: Escape games are known for their potential to engage students and are becoming a popular way to teach content in a variation of subjects, e.g., chemistry (Peleg et al., 2019), music (Babazadeh et al., 2022), and financial literacy (Bisanti et al., 2022). It is also a rapidly developing field of research (Veldkamp et al., 2020, Taraldsen et al., 2022). The importance of the debrief stage after playing and its role in ensuring learning outcomes has been discussed (Babazadeh et al., 2022). However, investigating students' learning while playing the game is needed to understand how they can be used in the classroom and continue improving the design of future escape games. In addition, there is still little research on escape games used online, in a digital format.

This study explores the students' experience of learning when playing the digital escape game *Radioaktiv* over video conference. Video data of six pairs of students playing the game were collected at a Norwegian University. Interaction analysis was conducted on representative data extracts to answer the following research question: *How did the students' experience of learning unfold while playing the digital escape game Radioaktiv?* Findings show that design choices came in the way of students' learning and reveal the importance of just-in-time and adapted feedback. Implications for this study are the importance of playtesting the escape game, especially when it comes to designing the puzzles and feedback loops. The present study also shows the necessity of the teacher: the automatised feedback system from the digital escape game cannot replace the role of the teacher during gameplay. This is especially true in the context of online learning where students can more easily feel left alone. Digital escape games as a learning activity should always be implemented within a clear pedagogical design.

Keywords: Digital escape game, Escape game, Higher education, Online learning

1. Introduction

Escape games for educational purposes have been rapidly developing in the last year and used in many different subjects, from chemistry (Peleg et al., 2019) to financial literacy (Bisanti et al., 2022). Research publications on the topic have multiplied in later years but review studies of this field still point at the need for more systematic research (Taraldsen et al., 2022; Veldkamp et al., 2020). In addition, most of the games investigated in the published studies are still performed in analogue contexts, e.g., in the context of a classroom (Babazadeh et al., 2022) or an archive room (Koenig et al., 2022).

Case reports of escape games used online or for the remote classroom have been published in recent years, especially within the health sector (e.g., Vergne et al., 2020; Abdul Rahim, 2022; Helbing et al., 2022). Some research papers investigate the design process of migrating an escape game online (Kutzin et al., 2021; Videnovik et al., 2022). However, pedagogical research on the use of these games in the context of online teaching and learning remains limited (e.g., Rodríguez-Ferrer et al., 2022; Vestal et al., 2021).

The present study proposes one example of such research by investigating the use of the digital escape game *Radioaktiv* within an online course for student teachers at a Norwegian university. Through interaction analysis of video data of students playing the game, I will explore the following research question: *How did the students' experience of learning unfold while playing the digital escape game Radioaktiv?*

2. Review

Review studies on escape room in education show the rapid development of this research field, even though they also point at the lack of systematic research (Taraldsen et al., 2022; Veldkamp et al., 2020). Both studies describe escape games as a generally positive experience and that most students showed engagement and enjoyment, and participated actively. In accordance with these findings, studies of educational escape games have reported that students are engaged and enjoyed the learning activity (e.g., Peleg et al., 2019; Cain, 2019; Ho, 2018). A previous study of *Radioaktiv* found that the digital escape game was engaging for students and that their experience of engagement was focused on the feeling of competition and the desire to complete tasks more than the narrative (Cruaud, in review). Contrasting with most studies, Duncan (2020) reports no difference in engagement between the traditional learning activities and the escape game used with grade 3 students learning 21st-century skills. When it comes to learning, Olombel et al. (2021) reports no difference in achieving learning outcomes between using the escape game or the non-playful learning activity. However, different

rationales for using escape games are reported in the field, e.g., "to expose students to scenarios where they can experience a situation", to "create a real-life atmosphere in their use of an escape room" (quasi-realistic scenarios), or "as a setting for learning to apply 21st-century skills" (Taraldsen et al., 2022, p. 176).

I will now 'zoom in' on three studies of online escape games used in higher education settings: a qualitative study of a synchronous and fully online escape game where teams of health science university students play in online rooms (Rodríguez-Ferrer et al., 2022); an online asynchronous escape game using google forms where individual first-semester students play a game regarding patient safety (Vestal et al., 2021); and a fully online and synchronous escape game on gender violence played by teams of university students from a social education course (Manzano-León et al., 2021).

All three studies report that using the escape games was a positive experience for the students. Manzano-León et al. (2021, p. 6) describe it as a "playful and immersive experience" and noted greater participation and engagement.

All three studies also agree on the effectiveness of this pedagogical approach to enhance the students' knowledge and awareness of specific topics. Rodríguez-Ferrer et al. (2022, p. 109) also point out that "the appropriate design and use of educational escape rooms can have a positive impact on the motivation, flow, and perceived learning of university students."

Vestal et al. (2021, p. 468) report that "the game-like feel of the activity provided a more "relaxed setting" that was both creative and informative." However, this can be nuanced by Manzano-León et al. (2021, p. 7)'s finding that some students were stressed, expressed fear of failing and required continuous cues to continue the game.

The teacher and researchers were present to answer students' questions and give cues in two studies. In the last one, the activity was conducted asynchronously, and students were not provided any real-time support (Vestal et al., 2021). The same authors comment that students could have used a facilitator-led debriefing in addition to the self-debriefing provided to "further enhance students' learning" (Vestal et al., 2021, p. 468).

In conclusion, all three studies seem to agree with Rodríguez-Ferrer et al. (2022, p. 109)'s affirmation that "online escape rooms can be a valuable educational resource" in addition to being highly reusable.

3. Methods

3.1 Investigating Radioaktiv, A Digital Escape Game for the Science Class

The present paper is part of the research project Escape Games for Learning, investigating the digitalisation of escape games for educational use through the study of *Radioaktiv*, a game for the science class (*naturfag*). The game is set in the laboratory of Dr. Doppler. After an alarm goes off, the two players have to make their way through the locked doors of the laboratory to save Dr. Doppler from radioactive exposure. *Radioaktiv* is played through a web browser. Two players team up and each open their own webpage, e.g., player 1 or player 2. Players do not have access to the same information and must communicate and collaborate to advance in the game. There are five main puzzles taking different forms (e.g., question with hints in the text, crossword, a table of nuclear elements to fill) but all are solved by entering the correct code in a padlock on the webpage. Both players enter the code individually on their webpage to open the next section of the game.

As part of the research project, *Radioaktiv* was played by teacher students in one of their online courses at a Norwegian university. Six pairs of students were filmed during playtime and the guided conversation afterwards, all of it over video conference. In the present paper only the playtime part of the recording was used.

3.2 Interaction Analysis: Looking at Dialogue

In this study, I am interested in looking at students' experience of learning while playing the digital escape game *Radioaktiv*. Here, learning is understood as the negotiation of meanings within a dialogic space (Wegerif, 2007). Learning is the taking of different perspectives through dialogue, in other words making meaning through the interactions between the students, and between the students and the game. Analysing interactions and dialogue is then a way of understanding how learning unfolds between students within the context of playing the escape game (Linell, 1998).

Interaction analysis of selected sequences was conducted (Jordan & Henderson, 1995). First, in the familiarisation step of the analysis I watched the recordings of students playing and took notes of what I found interesting, surprising or parts I wanted to come back to. Second, I reviewed closely the video recordings and marked recurring sequences across the data set (Derry et al., 2010). Third, I selected sequences within one

episode and analysed them further through interaction analysis. In this last part of the analysis, I used the transcripts from the recordings. I translated the two sequences presented in this paper from Norwegian to English trying to stick as close as possible to the students' way of speaking. The extracts presented in this article have been anonymised and the participants' names are pseudonyms.

The episode selected will be called thereafter "the gamma ray episode." There are several reasons for selecting this episode, both analytic and pragmatic. The gamma ray episode is representative of what happens several places in the data set, across all six groups. However, these sequences are also rather short and then, easier to report within the frame of this paper than longer episodes.

Out of the six groups of the data collection, five completed the puzzle from the Gamma ray episode (see Table 1). Group 6 did not, as they ran out of time earlier in the game. Four of the groups followed a similar pattern, that I will describe and analyse further, through the example of group 1 and 4. Group 3 followed a similar pattern, but they also encountered a major technical issue while solving the puzzle. Their attention was therefore turning towards it more than the puzzle, making the interaction sequence messier to report here.

4. Gamma Rays: Analysing how Learning Unfolds

I will now use interaction analysis of specific sequences of playtime to analyse the students' experience of learning while playing *Radioaktiv*.

4.1 Context: Placing the Episode Within the Game and the Data

The gamma ray episode is the 5th and last puzzle the students encounter in *Radioaktiv*. The puzzle right before was about the material needed to protect against radiation. In doing so it introduced the three types of radiation – alpha, beta, gamma. Students should then come to puzzle 5 with some knowledge of the answer to the question asked.

In Puzzle 5 both players are in different places at a hospital. Player 1 is in the waiting room, anxious about Player 2 and Dr. Doppler and has access to a short narrative text and a video on how each type of radiation affects the human body. Player 2 is undertaking medical checks with a radiologist and is presented with a question "Do you remember what type of radiation the lead suit protected you from?" The answer to this question, "gamma radiation" (in Norwegian, written in one word '*gammastråling*') is the code the players need to unlock the last padlock.

Before we dive into the sequences of interaction of group 1 and 4, the following table summarizes the gamma episodes across the six groups. All the 5 groups who reached this puzzle had the correct answer from the start. However, none of the groups typed it correctly, or I should say, in the expected way. As their answers were not accepted, most groups went mechanically through the list of all three radiation types, before (sometimes with help from the researcher) entering their first answer again, gamma radiation (*gammastråling*), this time in the accepted form, and thus solving the puzzle.

Table 1: Overview of gamma episodes

Data session	Wrote "gamma" first	Went through the whole list of radiation	Help from researcher	Time to solve the task
1	yes	yes	no	2 min
2	yes	no	yes	1,5 min
3	yes	yes	yes	4 min
4	yes	yes	no	4,5 min
5	yes	no	no	2 min
6	*Did not reach this task*	*Did not reach this task*	*Did not reach this task*	*Did not reach this task*

4.2 Sequence #1: Per and Malin (Group 1)

Since the start of the game, Per and Malin (group 1) are communicating well, sharing information and solving the puzzles quite fast. They both seem engaged in the tasks and often show signs of excitement and laughter. In

the following sequence of interaction, they reach the 5th puzzle. Malin reads up the question and Per answers immediately with the correct answer 'gamma.' Malin agrees also immediately and they both type in the answer on their respective browser. Per's answer is not accepted by the game, and he tries typing in the other two types of radiation 'alpha', 'beta' before repeating aloud twice that 'gamma' has to be the answer. Malin suggests that they should write the whole word, including 'radiation'. Per first types in the other two types of radiation in the way suggested by Malin, while Malin types in 'gamma radiation' and solves the puzzle.

1	Malin: [reading] "Do you remember what type of radiation the lead suit protected you from?"
2	Per: Gamma.
3	Malin: Yes.
4	Per: It must be gamma radiation then!
5	Malin: Uh yes… [typing]
6	Per: Uh gamma maybe, no! Uuuh… [scrunching up his face]
7	Alpha then. Beta? Eh? [reading] "Sorry the answer is not correct, try again."
8	Not gamma radiation? It has to be though… It has to be.
9	Malin: Do they want us to write the whole word somehow?
10	Per: Yes, maybe if we write like al-pha ra-dia-tion… Be-ta ra-dia-tion… [typing as he enunciates]
11	Malin: Gamma radiation was correct!

Figure 1: Sequence of interaction #1 – Group 1

In this sequence we can see three steps of interaction, a pattern that can be found in the other gamma episodes. When Malin and Per enter the interaction, they are sure of the answer (line 2-5). They have encountered it in the previous puzzle, so they do not hesitate when Malin reads up the question "Do you remember what type of radiation the lead suit protected you from?" (line 1). However, when they type in 'gamma' they receive negative feedback from the game 'Sorry the answer is not correct, try again.' Per seems to be confused by the fact that his answer is not accepted (line 6). His hesitation shows in the sounds and the face he makes. Per, who knew the answer without hesitation a few seconds ago, now turns to the other two types of radiation and enters them in (line 7). Each time he gets the same negative feedback from the game. His confusion is clear when he goes back to saying that his first answer 'gamma' must be the solution, but this time with some doubt in his voice (line 8). It is interesting that when Malin suggests that they might need to spell out the whole word, including 'radiation' (line 9), Per first tries to type in 'alpha radiation' and then 'beta radiation.' Even though he was sure of the answer at first, he now goes through the list once more, in a mechanical and alphabetical fashion (line 10). Malin types in 'gamma radiation' first and solves the puzzle. When she gets the positive feedback from the game (the lock opens, and the next page is loaded) she exclaims "gamma radiation was correct!" (line 11).

This sequence shows how the negative feedback from the game, based on the spelling of the answer and not its correctness, confused students. Instead of reinforcing what they have learned in the previous task – the impact of different types of radiation – this puzzle makes Per doubt what he had learned. His confusion does not open up for a discussion of the subject, instead, their whole conversation is focused on how to spell the answer correctly. When Per starts typing in all the different types of radiation, it shows that his answers are not linked to any subject thinking. He does not weigh in the difference between alpha, beta, or gamma radiation, but answers mechanically in order to unlock the puzzle. In other words, Per and Malin are not engaging with the subject matter, but only want to find the correct code. The design of the puzzle, and especially how the answer is supposed to be typed in, guides the conversation between the students towards trivial details instead of the subject content.

4.3 Sequence #2: Kjetil and Stefan (Group 4)

During the whole playtime Kjetil and Stefan (group 4) are very comfortable with each other. They are joking and teasing each other. In the following sequence we see how they solve the gamma ray puzzle. When Kjetil reads the question, Stefan answers immediately and seems very sure of his answer. Kjetil types the answer in but gets negative feedback from the game and start suggesting other answers. Stefan watches a video about the different type of radiation and confirms that he thinks his answer, gamma, is the correct one. However, Kjetil is now sure that the answer is alpha. The students discuss the different types of radiation and agree on gamma. They try to find different ways of typing in the answer until Stefan writes the correct form "gamma radiation" and they solve the puzzle.

1   Kjetil: [reading] "Do you remember what type of radiation the lead suit protected you from?" What type of radiation was the most dangerous?

2   Stefan: yes, gamma.

3   Kjetil: [typing] no, it wasn't the correct answer.

4   Stefan: wasn't it gamma that was the most dangerous?

5   Kjetil: But it may be that the answer is on a different [unclear] then.

6   Do you remember what type of radiation the lead suit protected me from?

7   Stefan: wasn't it…?

8   Kjetil: Alpha. Alpha, was that it? I think it was the opposite in fact. Beta? We have to write all of them then, alpha, beta, gamma.

9   Stefan: Let's see. I'll just watch the video then.

10   Kjetil: You do have a video, right? [smiles]

11   [Stefan watches the video – silence for 1:40]

12   Stefan: From what I could see so it is gamma now.

13   Kjetil: No, it's alpha that's the most dangerous.

14   Stefan: Is that it?

15   Kjetil: Yes, isn't it?

16   Stefan: Alpha is stopped by the skin they said, so… But beta comes further in.

17   Kjetil: No…

18   Stefan: And gamma. Gamma goes all the way in to the organs.

19   Kjetil: Yes, you got something here… How can I write gamma, if I can't write it? Do you have another hint, or?

20   Stefan: No it just says "What type of radiation was the most dangerous?" I tried writing both alpha, beta and gamma with big and small letters.

21   Kjetil: Yes, and starting with a big and…

22   Stefan: So if it isn't that…

23   Kjetil: Is it the symbol then? How is the symbol? The symbol for gamma.

24   Stefan: Y

25   Kjetil: Y?

26   Stefan: Well, it looks like a y, but it is of course a Greek letter that is pronounced gamma.

27   Kjetil: Yes, but how do you make it then?

28   Stefan: Well, I can do it in in in Word.

29   Kjetil: Yes.

30   Stefan: But…

31   Kjetil: It doesn't help me that YOU can make it in Word. I have to make it in Word myself too.

32   Stefan: Yep. I went through.

33   Kjetil: That was it? That was it.

34   Stefan: Gamma radiation, gamma radiation [gammastråling].

35   Kjetil: Yes, what did you write?

36   Stefan: Gamma radiation.

37   Kjetil: You wrote gamma radiation? [laughs, giggles]

38   Stefan: Yes. [smiles]

39   Kjetil: In one word, just with small letters?

40   Stefan: Yes.

41   Kjetil: Yes.

Figure 2: Sequence of interaction #2 – Group 4

This sequence also starts with the students being sure of the answer to solve the puzzle. When Kjetil reads the question (line 1), Stefan immediately answers "gamma" (line 2). Kjetil accepts the answer as he immediately types it in, but he gets negative feedback from the game (line 3). Stefan, confused that the answer was not accepted, keeps wondering out loud about gamma not being the answer in a hesitant voice (line 4 and 7). Kjetil suddenly suggests alpha as an answer, but almost immediately changes his mind and in the end suggests that they have to write all the different types of radiation in the padlock (line 8). Stefan then says that he will watch

the video provided on his webpage (line 9) and both students are silent while he watches (line 11). When he is done watching, Stefan states that gamma should be the answer (line 12). But Kjetil disagrees and says that alpha is the most dangerous radiation (line 13). When both students discuss the different types of radiation (line 14-18), Stefan quotes what he has seen in the video "they said" (line 16). Kjetil agrees on the answer (line 19) and follows a discussion on how to write the word correctly in order to solve the puzzle (line 19-31). Stefan finds the correct answer and unlocks the last webpage (line 32). He shares the answer with Kjetil (line 34) and explains how to spell it correctly (line 35-41).

In this sequence we can see the same three steps of being sure of the answer, being confused by the negative feedback from the game, which leads to trying out other answers mechanically (lines 8 & 20), and finally solving the puzzle. The students, and especially Stefan who was sure of the answer, start hesitating and doubting what they had learned in the previous puzzle. Unlike the first sequence, this confusion does not only lead to trying out mechanically different answers. When Stefan decides to watch the video provided, a discussion about the subject matter is introduced. The video becomes an extra voice in the conversation, as suggested by the use of the pronoun "they" to represent the video and its narrator, when Stefan quotes from what he had just seen "alpha is stopped by the skin they said" (line 16). Stefan takes on a didactic role and explains how the different types of radiation affects the human body, in the same order as they were presented in the video. In doing so, he includes the video as a voice in their interaction which supports their learning. A major part of the student interactions during this sequence is still, however, focussed on figuring out how to spell the answer in a way that will be accepted by the game. In other words, the design of the answer of this puzzle, takes the most space in the interaction and is not related to subject matter. As an example, the students start discussing how to type Greek letters in Word (line 23-31). Where the video acts as a support in the students' learning, the game and its design come in the way of their learning as it guides the dialogue away from the matter at hand.

5. Discussion

In the analysis of interaction sequences, I have found that the design of the game, and especially how the answers were to be typed in, guided the conversation between students away from the subject matter and towards trivial details. Vestal et al. (2021, p. 468) have also encountered this issue when designing their asynchronous escape game on Google Forms. They had to decide whether to limit the number of accepted answers by having to type in "grammatically identical" sentences in the short answer field or opening for all types of answer – even incorrect ones – so that students could more easily move from puzzles to puzzles. In the end, the authors were not satisfied with their solution of accepting all answers and mentioned that this difficulty needed to be solved in a future iteration.

This design issue could also have been minimized or avoided by giving a clear feedback or cue instead of a message only saying the answer was incorrect. Manzano-León et al. (2021, p. 4) in their instructions for players precise for example that all answers need to be written in lowercase and without accents to limit the number of correct answers being marked as wrong by the game. This finding emphasises the importance of designing good hints, but also a good feedback system.

As the analysis has shown, all teams of students encountered the same issue and followed a similar pattern of being sure of the answer, then confused, and finally testing mechanically all possible answers. This finding shows the importance of playtesting the game. In a future iteration of *Radioaktiv*, this puzzle, the hints connected to it, and the way the answer is typed in should be reviewed and improved to avoid this unnecessary confusion that comes in the way of the students' experience of learning. Some groups received extra feedback on this puzzle as the researcher provided hints when it was clear that the students had the correct answer but struggled to type it in correctly. This demonstrates the importance of the teacher–or game master–in providing just-in-time feedback to students. In their study, Vestal et al. (2021, p. 468) also had no real-time support in place and concluded their article with reflecting on the need for teacher-led debriefings in further iterations. Manzano-León et al. (2021, p. 7) also found that some students were afraid of failing and required continuous support from the teacher or researcher in form of cues all along the game. This extra support, adapted to the students' needs, can only happen when the teacher is present and able to move from groups to groups. In the case of asynchronous escape games or when the teacher cannot communicate with students directly for other reasons, the cues and feedback system have to be sturdier and more flexible at the same time, e.g., through providing different levels of feedback and hints to different students. Some reported studies have for example used multiple layers of cues that students could choose to read or not, or sometimes even buy with time penalties (Cain, 2019; Veldkamp et al., 2020). However, Taraldsen et al. (2022, p. 178) also found that having too many

hints can move the students' focus away from the subject matter. The balance between too many and too few clues can be difficult to find and it might not be the same for all students.

6. Conclusion

This study analyses an example of digital escape game used in fully online learning settings, where teachers were providing no or little support to the students during playtime. The findings show the importance of playtesting the game to avoid small design issue taking too much space in the students' conversations. Details that could seem insignificant can come in the way of learning, by wrongly providing negative feedback or simply by focussing the students' attention on trivial details instead of the subject matter. Another implication is the need for adapted just-in-time feedback to reduce the risk of students being stuck for design reasons while they in fact know the correct answer. This shows that ideally the teacher would be available for students to get extra clues or support when needed and that it is difficult, if not impossible, to replace the teacher's role. A last implication of this study is the need for a clear pedagogical design that integrates puzzles, subject content, and play elements. Subject content elements (like the video in the sequences analysed) should be more naturally integrated in the gameplay to ensure that students will in fact use them in their interactions. This can lead to richer discussions on the subject with the videos or external support providing a new voice in the conversation.

Acknowledgements

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