ADVENTURE AND QUIZ LEARNING GAME BASED ON A VIRTUAL TOUR OF A VIDEO GAME MUSEUM

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ABSTRACT

With the digital age influenced by the COVID-19 pandemic, more education and communication has moved to online environments. This may limit the amount of impactful experience necessary for successful learning. In this paper, we describe the design of an educational game implemented for an online course on video game history. The learning game we developed takes place inside a virtual tour made from a real-world video game history museum. Thus, we first analyze the context of an educational experience a real museum provides. The designed game mainly mimics multiple-choice tests from the course. Based on these, we performed a study in the pilot run of the course, in which participants solved the tests and played the game in two groups. The course participants filled out two questionnaires for self-assessing their motivation and giving qualitative feedback on both the tests and the game. In this paper, we provide the results collected for the time it takes to complete, the received score, estimated motivation, and a qualitative feedback analysis regarding doing the tests versus playing the created learning game.

KEYWORDS

Learning game, serious game, museum experience, virtual tour, online course.

1. INTRODUCTION

Museum visiting is a big part of education. It offers a tangible experience for the visitor and allows them to connect their knowledge with [1]. Museum tours are commonplace in primary, secondary, and adult education. Such tangible experiences are usually missing in e-learning situations, where a museum visit would be logistically challenging to organize. In recent years the global COVID-19 pandemic has made such experiences even more difficult as the museums have been in lockdown several times. Therefore, the quality of education, especially e-learning education, might be suffering from the lack of physical experiences, namely museum visitations.
For some time, museums have been incorporating digital games into their exhibits. According to a comprehensive survey by Paliokas and Sylaiou from 2016 [2], a significant portion of these also include software that can be used off-site. These include exhibition environments, namely virtual museums or environments for which visitation would be restricted or dangerous for a regular visitor. Virtual museums are also supported by Gheorghiu and Ștefan [3] and Pivec and Kronberger [4] for providing an opportunity to visit regardless of a physical location, safety reasons, or actual museum opening hours. While these authors could not possibly foresee a global pandemic, virtual museums certainly allow risk-free virtual visits in terms of virus spread.

At the University of Tartu, Estonia, we created a general audience online course on video game history called Evolution of Video Games (EVG) [5]. We created the course in 2020, and it took place for the first time in spring 2021, right at the recent peak of the global pandemic. In the creation of the course, we collaborated with the LVLup! video game museum located in Tallinn, Estonia. In the physical LVLup! museum, the visitors can interact and play many historical video games on many game consoles. Naturally, physical visits to the museum were not feasible due to

both the pandemic-caused dangers and lockdown, as well as the physical distance of course students located all over Estonia. Therefore, the collaboration with the LVLup! museum included the creation of a virtual tour of the museum to be used in the EVG course. This seemed to be the next best thing compared to physically visiting the museum.

While the museum grounds include countless exhibits, and thus the virtual tour displayed an abundance of exciting visuals, a tour just by itself would have still been a relatively passive experience. Paliokas and Sylaiou [2] found that about 40% of museum games are aimed at students and a quiz game mechanic of Select was the second most popular one in such games. During the creation of the course, we created an adventure and quiz video game taking place inside the tour (we called it VTG – the abbreviation of the unimaginative name Virtual Tour Game). The learning game (also called a serious game or studying game) included several non-player characters (personas) who gave the player quests or asked questions related to the study material. Correct answers to the multiple-choice questions gave the players points, which directly accounted for their overall EVG course score and the dependent nondifferentiated course result.

We modeled the questions in VTG based on the same questions in the multiple-choice tests in the course. We split the participants randomly into two groups: the first group did one set of tests first and then later played in VTG module 2 based on the second set of tests. The second group first played VTG module 1 based on the first set of tests and later did a second set of tests. This allowed us to objectively measure if answering the questions inside a learning game would be more efficient than just doing a test. We also asked the participants for their self-assessed subjective motivation regarding either playing the game or solving the tests.

More detailed information about the creation of EVG can be found in Mark Muhhin's Master's thesis titled Evolution of Video Games Online Course [5]. In this paper, we first focus on the design of VTG and then on a more thorough analysis of the results obtained during the course's pilot run. We compare how the design of VTG differed from the multiplechoice tests and describe our discoveries about the difference in the perception and the study results of the learning game versus the multiple-choice tests.

2. MATERIALS AND METHODS

The work for creating VTG started with the design of the game. In this section, we first describe the design of VTG in the context of previous work done on game design, educational game design by Wolf [6], Schell [7], Schaller [8], Malone and Lepper [9], and museum experience design by Falk and Dierking [1]. In subsequent sections, we explain how these works are relevant and how we designed VTG to correspond with the practices recommended by these authors. In the last section, we describe how we used VTG in the EVG course, how we gathered the feedback from the course participants, and what hypotheses we had for VTG.

2.1. Educational Game Design of VTG

We designed VTG to be an adventure and quiz game. Mark Wolf defines video game genres based on interactivity [6]. It is important what the player does in the game and how they interact with it, as interaction is the core of a video game. This contrasts with movie genres, which focus on imagery or theme for classification. According to Wolf, an adventure game comprises many freely navigable interconnected areas, allows the player character to carry objects, and involves more complex objectives than just reflex-based goals. Such objectives usually include combining or using the collected objects in the correct order or place. In-game characters can play key roles in such puzzles. The quiz game genre is self-explanatory: the player needs to answer questions correctly to achieve a score.

Jesse Schell establishes four fundamental elements that make up a video game [7]. These are mechanics, story, aesthetics, and technology. A couple of years prior to Schell, David Schaller (a founder of the educational game design firm Eduweb, Inc) relied [8] on Malone and Lepper's properties of learning games [9] and extended those. The extended list of learning game properties consists of challenge, curiosity, control, fantasy, iteration, and reflection. Thirdly, as VTG is meant to mimic a museum visitation, we can refer to the model by Falk and Dierking [1], which elaborates that a museum experience is a combination of personal, social, and physical contexts. Next, we will be analyzing the design of VTG from the perspective of these three models. As VTG is a learning game and thus also needs to be a game, we use Schell's game elements for the top-level granularity.

2.2. Mechanics

According to Schell, mechanics are the rules and procedures of the game, and they make the game a game. Thus, these include the interactions that characterize the game into one or more of the video game genres. The mechanics in VTG are the ability to navigate between the virtual museum rooms (either through clicking on icons placed in the current room or via the in-game map), the ability to interact with and pick up some objects in the environment, the ability to engage in dialogue with the non-player characters (NPCs) and answer their questions or solve their quests. These can be classified as core mechanics by Salen and Zimmerman [10]. These are the mechanics that the player repeats most often to progress through the game. There are also secondary mechanics like finding and reading the learning material in the game or looking around and taking in the museum environment.

When it comes to the properties of learning games, the most prominent arising from these mechanics is control. The player can choose to traverse our virtual museum in different paths or interact with the NPCs in a different order. It is even possible to make pauses in conversation paths to talk about something else or with other NPCs. The dialogue is designed as a mix of hub and spoke as well as waterfall structures as defined by Freed [11]. Sometimes the NPC may have a list of different topics to talk about, and sometimes they are streamlined into one path, which the player follows by answering questions. The control in VTG is limited in the possible achievable game outcomes. There are no multiple final or other lasting outcomes besides the NPC becoming satisfied when all the questions have been answered and the player earning a certain score for their respective answers. However, we believe that the order of progressing through the game and the local narrative outcomes (i.e., the NPC reactions on either correct or incorrect answers) should give the player enough choice and power, which both contribute to the control property of an educational game.

The limited global outcomes of VTG may hinder the iteration property. When the player has answered all the questions and solved all the quests, they likely know how the game is going to play out and thus have a decreased interest in replay. Although Schaller does argue that there could be a suitable iteration property even in linear games as the player desires to experience the identical experience again. Due to the player's score contributing directly to the EVG course outcome, we decided not to allow the players to repeat the game, as they are not allowed to take the regular multiple-choice tests multiple times either.

The last property of educational games we cover in this section is reflection. Schaller describes reflection as the possibility to analyze the results of one iteration of the game and acknowledge what went well or poorly. The player needs to understand why they got the result they did. In VTG, most of the NPCs have different dialogue responses depending on the chosen answer. In case of a correct answer, they sometimes explain why it is correct. In case of incorrect answers, they or other NPCs join the conversation and explain why that answer is incorrect. Although

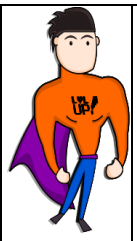
research [12] on multiple-choice tests shows that delayed feedback can be more beneficial than immediate feedback for learning, we did not implement such a more summative aspect. Still, from the game design perspective, the players must understand immediately what happened and why. We plan to develop an end screen in the future for delayed feedback, which shows all the correctly or incorrectly answered questions.

We also analyze the game mechanics in terms of a museum experience because VTG is meant to replicate that within reason. The personal context brought by museum visitors includes their own background and the activities they want to perform. In VTG, the core activity of answering NPC questions is always the same and mandatory. From a purely mechanical perspective, there is not much personal context rather than the previous knowledge players have already learned to answer the NPC questions. As the game has no multiplayer features, there is no mechanical social context. Regarding the physical context, the game space should be analyzed. While Schell does define the game space as one of the mechanics and that relates to the physical context of a museum, we think it is better to cover this later with the aesthetics element.

2.3. Story

There is no grand overarching story in VTG as is, for example, in the learning game Operation ARA [13], where aliens have invaded Earth, and the player has to save humankind. Another example is Monkey Tales [14], where an evil villain is trying to steal intelligence from people around the world. However, in the Maya Island [15] there are smaller narratives taking place in different areas and involve different characters of the game. The player of VTG is just a visitor in the virtual LVLup! video game museum. Still, there are six different and uniquely designed characters in the game who each have their personal story, or rather, a personal context for being in the museum (see Table 1). For example, the lady in red, Liisi, is a video game developer herself and is looking for information on how to best publish and market her indie game. Thus, she asks the player for more information on that topic. I.e., her questions are about the corresponding game marketing topic of the course.

Table 1. The persona sheet we designed for the VTG characters.

							
Name	**LvlUP Man**	**Professor**	**Tom**	**Risto**	**Robert**	**Ufo**	**Liisi**
Age	25	58	12	13	45	247	42
Height (m)	1.9	1.6	1.2	1.2	1.8	0.7	1.9
Weight (kg)	90	70	40	60	55	20	50
Profession	Museum Guide	Scientist	Student	Student	Risto's dad	Space farer	Game designer
Interests		Theory First games Weird games Technology	Platformers Rhythm games	Racing games Fighting games	NES games NES clones Old games Consoles	Game play	Design Marketing
Motivation	To help the player	To know obscure things	Innocent curiosity	Get good action game experience	Get retro experience	Discover Earth games	Design a good game
Likes		Tidbits of info Academia	Sugar		Nostalgia		Products and culture

Of the properties of learning games, unique personas certainly contribute to player curiosity and fantasy properties of educational games. The curiosity aspect is prominent as the questions are not just presented to the player as in a regular multiple-choice test but are rather proposed through dialogue and in the frame of the NPC's personal context. These contexts where such questions are raised, and the player's previously learned knowledge provide both fantasy and cognitive curiosity as defined by Malone and Lepper [9]. These contexts are foreseen to have a significant impact on the player's motivation, and also shown to increase player engagement in practice [16]. The idea of helping an actual in-game character out to see where their stories end up should increase the motivation.

The virtual characters provide some sense of social context. This context is not truly dynamic and certainly does not mimic the sense of a real tour group or friends reacting to the visitor's personal experience in the museum as described by Falk and Dierking [1]. In VTG, the social context is not directed towards the player. However, the NPCs still express their personal contexts to the

player and the player can form an intrinsic opinion of these personas and their personalized stances on the museum or video game history, thus still experiencing part of the social context.

2.4. Aesthetics

The main aesthetics of VTG already came from the interior design of the physical LVLup! video game museum. The rooms there include many TV sets with different home consoles attached to them. The shelves hold a myriad of small gaming props that people from the corresponding era might have had. Being able to move inside and interact with a 3D environment is shown to have a larger cognitive impact than otherwise [4]. In the virtual museum of VTG, users can zoom the camera on these different curiosities and relate them to their own personal context (see Figure 1). We replaced the still images on the different TV screens with GIF animations depicting a moment of gameplay of different video games, thus increasing the visual curiosity even further.

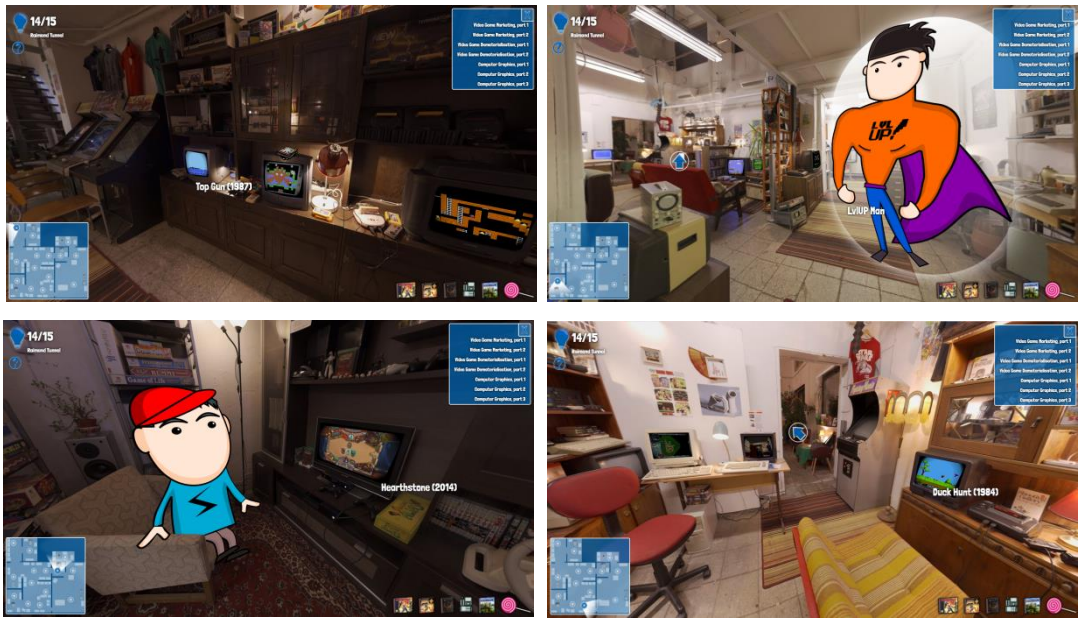


Figure 1. Screenshots of VTG.

This way, we have managed to create a good virtual experience of Falk and Dierking's physical context [1]. We will analyze it further in this paper when discussing user feedback. Despite not (yet) using virtual reality or emulating the gameplay of existing games inside the virtual tour, the current result should provide a memorable "physical" context.

2.5. Technology

VTG needed to be playable by a general audience with potentially different platforms as the EVG online course was open to everyone in Estonia. As such, we used an open-source JavaScript virtual tour framework Marzipano for the creation of VTG. We built the game on top of it and integrated it with the University of Tartu's Moodle platform used in the EVG course via the LTI API. All of this meant that the users could simply click on a link in Moodle, and they would be taken to a website running VTG. There, their Moodle account would be associated with the play session. When they collected points in-game, these were automatically sent to Moodle in the background and registered as the earned course score. This avoided additional technical or manual overhead for both the students and the course instructors.

2.6. Research Methodology

The EVG course consisted of 10 different topics, and there were many creative exercises, which constituted most of the score students got. The total maximum score, not including bonus, was 120 points. Out of that, 15 points were from three multiple-choice tests and 15 points from playing VTG. This means that the tests and VTG together comprise 25% of the course score. The rest of the score comes from other creative learning exercises not covered in this paper. For consolidating the factual knowledge, we created six multiple-choice tests, each test covered one topic. Some topics in the course did not have tests. Every test consisted of 8-10 multiple-choice questions about the material. VTG had two modules: the first consisted of questions from the first 3 tests and the second of the questions from the second 3 tests.

We randomly assigned the 97 course participants to two groups: A and B. The average age of the group members was approximately 23.3 years for group A and 25.3 years for group B. The groups consisted of approximately 69% and 71% of male members (see Figure 2). Thus, the groups served as suitable control groups for each other.

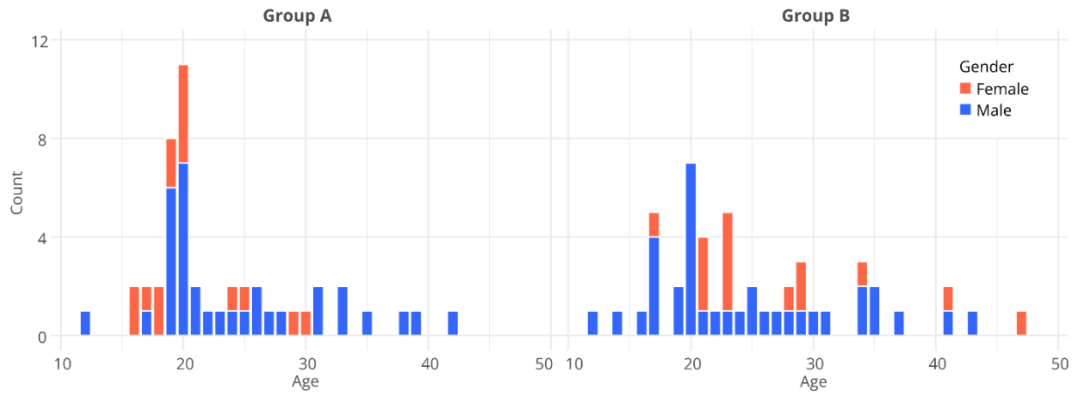


Figure 2. Age and gender distributions for experiment groups A and B.

Group A, consisting of 48 learners, did the first three regular tests A1–A3, and then played module 2 of VTG instead of solving the second three tests. Group B consisted of 49 learners and did the opposite: first played VTG module 1 and then did three tests B1–B3. See Table 2 for the overview. It is important to note that the option to play VTG opened on the week of the last topic it covered. This means that on week 4 for group B and on week 9 for group A. However, each test opened on the week of the topic. Thus, one module of VTG covered three weeks of the material at once, but each individual test only covered one week.

Table 2. Overview of the two groups and when they did the multiple-choice tests or played VTG.

Week	**Topic**	**Group A (51)**	**Group B (53)**
2	First Video Games, First Gameplays	Test A1	VTG, Module 1, A1–A3
3	Video Game Genres and Target Audiences	Test A2	
4	Video Game Lifespan	Test A3	
6	Video Game Marketing	VTG, Module 1, B1–A3	Test B1
7	Video Game Dematerialization		Test B2
9	Computer Games: 3D Graphics		Test B3

We created the questions in the corresponding VTG module based on the questions from the corresponding three tests, adapted them as similarly as possible. For example, one of the questions in the tests was: What is the biggest priority of any company trying to break into the market? with the multiple-choice answers being: a) game quality, b) accessibility, c) beautiful art, d) good storyline. In VTG, this question is asked by Liisi, who is discussing with another NPC, Robert, about releasing her developed video game. At one point during the dialogue, Liisi asks: But when we have just entered the market. When we do not have the players yet... Then what would be the biggest priority for any company trying to break into the market? After which, the VTG player is presented with the same four answers as in the regular multiple-choice test.

To assess the impact VTG had on the learners and get qualitative feedback, the participants answered questionnaires on weeks 5 and 10. Those asked, among other things, about the tests or VTG depending on the group membership of the answerer. The questions for both the tests and VTG consisted of one linear scale question asking about the answerer's motivation to complete the activity. The scale was from 0 to 5, where 0 – not motivated at all and 5 – very motivated. Then there was an open text question asking for an explanation on the motivation rating. Lastly, there was another open text field for general comments about the activity.

We had two hypotheses:
H1: The motivation of the learner to play VTG would be greater than for doing tests.
H2: The learner performance in the outcome of VTG and tests will be the same.

The reasoning for H1 is that we designed the learning game to be more immersive and provide more meaningful context (e.g., the discussion between Liisi and Robert NPCs) for the learned material than just regular tests. However, as we adopted the same questions from the tests to the game as similarly as possible, we had no reason to believe there to be any difference in the achieved results, thus H2.

There were no time limits in either VTG or for solving the tests. In fact, a learner could take a break and return to either one of these later. However, when a question had been answered by the learner and feedback received, there was no option to answer it again. Learners could not take the test again or replay VTG from the beginning. VTG had a confirmation question (along with a tutorial on how to play) at the beginning of the game, asking if the player is aware that their performance in the game will be directly graded and if they want to continue.

3. RESULTS

The self-reported motivation in the two questionnaires about doing the tests and playing VTG was surprisingly the same. In total, 83 participants answered the first questionnaire and 68 the second one. When looking in aggregate, the average reported motivation for doing the tests was 4.15 and for playing VTG 4.21. The Mann-Whitney test does not find a statistically significant difference, p=0.49.

Looking at the results from the first and second questionnaires individually, the averages for the tests and VTG, respectively, were 4 and 4.33 for the first questionnaire and 4.31 and 4.03 for the second one (see Figure 3). Performing a Kruskal-Wallis test does not find any statistically significant difference between these four groups either, p=0.09. We performed the Mann-Whitney, and Kruskal-Wallis tests as none of the groups seemed to be from a normal distribution according to either Kolmogorov-Smirnov or Shapiro-Wilk tests. Although, if we would assume normality, performing the respective ANOVA on the four groups did not reveal a statistically significant difference either.

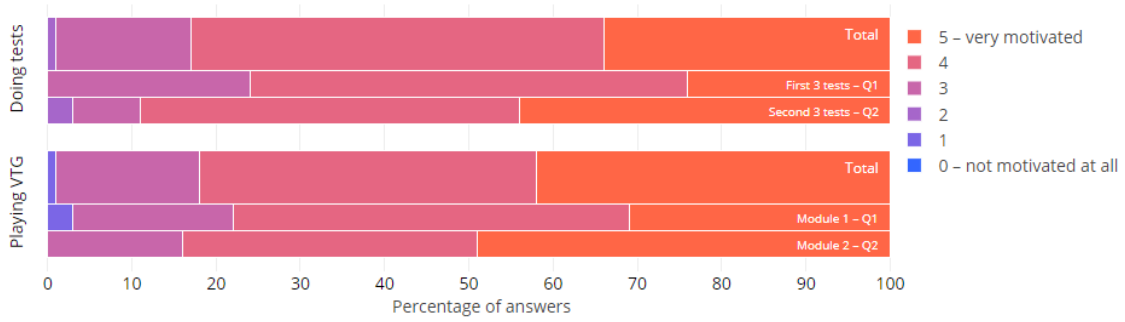


Figure 3. The self-reported motivation about doing the tests and playing VTG. The bottom rows show separate data from both questionnaires (Q1 and Q2), the top row shows the aggregate.

Hints for the slight differences in the averages between the first and second questionnaire results could be found from the analysis of the qualitative free-text data, where the participants were asked to explain the given ratings. In the second questionnaire, a few more participants mentioned that tests were “fast to solve” than in the first questionnaire. For VTG, a few more participants mentioned in the second questionnaire that VTG took too much time, and they were busy with other courses or activities. It seems that the participants were a bit more motivated to play VTG at the beginning of the course when they had more time and preferred the tests later when their other obligations had been piling up. This is supported by data about the actual time spent on tests and VTG. Completing all three tests took on average about 37.7 minutes in total but completing one module of VTG took on average 53.3 minutes (see Figure 4). Mann-Whitney test shows a statistically significant difference with p=0.002.

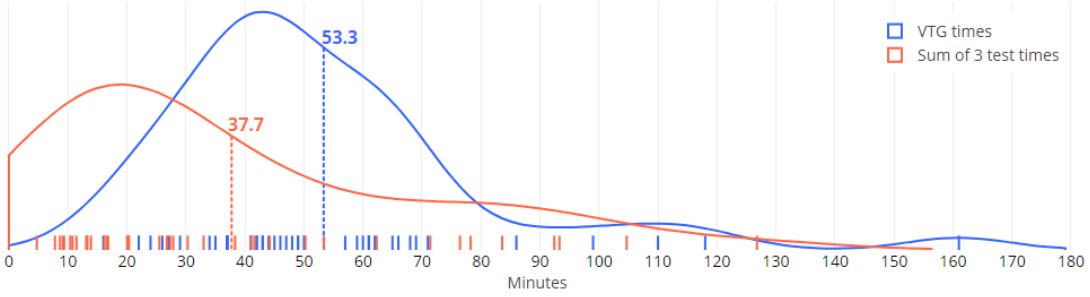


Figure 4. The measured time it took to solve all three tests or play VTG.

There was a large difference in the reasons why the participants were motivated in either the tests or VTG. Assessing the qualitative feedback, about 34% of the answers described the tests as a good way to check or consolidate knowledge. The learners felt motivated by a way to check if they had read and understood the material sufficiently well. In contrast, only 2% said the same about VTG. Instead, about 57% of the answers explained the reasons behind being motivated in VTG as liking or being interested in the method (playing a learning game) itself or the experience it provided. Comparatively, only 16% said that they like the tests or felt excited about them. Thus, for a large part, VTG was not seen primarily as a way to assess or recapitulate one's knowledge like the tests were. Rather the motivation behind playing VTG was in participating in an experience not usually available in other courses, the curiosity related to that, or the excitement the virtual world and the game provided.

This means that our hypothesis H1 cannot be proven based on our research. While the reasons behind the motivation for doing the tests or playing VTG were different, the self-reported amount of the motivation was similar enough not to produce any statistically significant differences.

The scores obtained from the three tests and VTG were also different. On average, the learners got 13.4 points (out of 15) from the tests, but only 12.4 from VTG. Mann-Whitney test shows a statistically significant difference ($p \approx 0$). This roughly 1 point difference and the statistical significance also holds when looking at the two VTG modules separately ($p \approx 0$ in both cases).

We implemented the methods to analyze the responses for individual questions in VTG only for module 2 during the pilot EVG course. This means that to find out where the learners lost most points, and if there could be problems with specific questions, we can currently only analyze module 2 results.

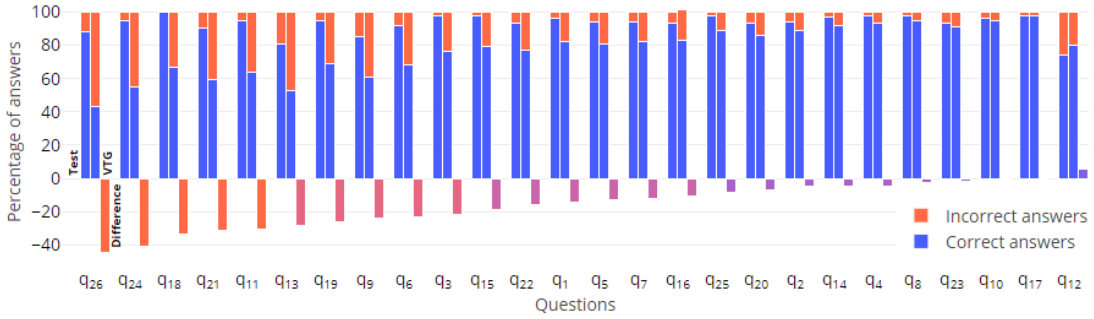


Figure 5. Questions and their correct and incorrect answer percentages in the tests and the game.

As seen from Figure 5, most of the questions were answered more poorly in VTG than in the corresponding multiple-choice test. The most notable differences are in questions numbered 26, 24, and 18, respectively, about 45%, 41%, and 33% more incorrect answers chosen in VTG than in the test. On average, the difference between chosen VTG and test answers was about 16% against VTG. We look at these and some other questions in the Discussion section later.

Thus, our hypothesis H2 is disproved by the data. Learners earned about 1 point less when doing VTG than doing the three tests. Even though we designed the questions to be as similar to the test questions as reasonable, almost all of the questions were answered more incorrectly in VTG than during the corresponding test.

Although not explicitly asked from the participants, we analyzed how many found the created environment noteworthy from the given general feedback text. About 17% of the answers included some praise for the virtual museum and the exploration of the museum space. They found the consoles and other props in the rooms compelling and reportedly spent much time just looking around and exploring the space. This resonates strongly with the physical context part of the museum experience as defined by Falk and Dierking [1]. When it comes to personal and social contexts, only about 4% of the feedback included one or the other. I.e., the virtual museum environment reminded them of their own played games or that the characters were interesting to talk with. We believe that this should be studied further with specific questions about these aspects as the learners might have felt them but just not thought them important enough to write in the general feedback.

4. DISCUSSION AND CONCLUSION

The amount of motivation behind doing the multiple-choice tests and playing VTG we could not prove to be different in our study. Although the motivation on a scale (from 0 to 5) for solving the tests and playing VTG had no significant statistical difference, it is clear from the additional comments that the tests tended to be a faster way of checking one's knowledge of the material. On the other hand, VTG was a more fun experience for the students. Based on the feedback, students had a slightly higher motivation to immerse themselves in the learning game at the beginning of the semester but preferred the quicker tests by the end of the semester due to exhaustion and lack of time.

As was seen from the results, our second hypothesis was disproven, and students performed slightly worse on the quiz questions asked in VTG than in regular tests with the same questions. There could be numerous reasons for that. One major difference was that VTG had quiz questions from three different topics all at once, which could require more focus and better memorization skills than doing three separate tests at different times. Furthermore, there were instances when students pointed out that they accidentally chose one of the incorrect answers in VTG. Since there was no confirmation button like in the tests, they were penalized as soon as they clicked the incorrect answer. It is safe to say that at least some fraction of the incorrect answers could have come from students simply not being used to the environment of VTG.

When looking at quiz questions that were answered with the biggest difference in success rate in terms of them being answered correctly in tests and VTG, we can speculate on some of the reasons why that happened. Question number 24 had 40% more incorrect answers in VTG than in the regular test. This question was about whether a game called Skyrim’s world is procedurally generated or not. The students had to pick either a “yes” or “no” response. But in the VTG version of the quiz, this question could easily be misunderstood since the final screen with the decision-making only displays a part of the question (see Figure 6).

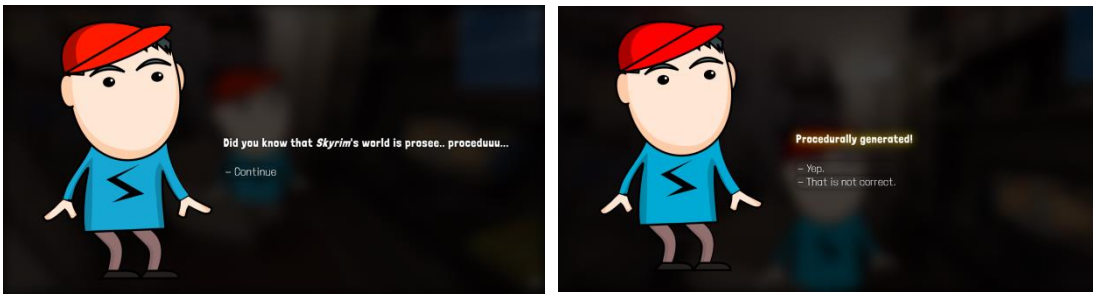


Figure 6. The two screens the player is presented when answering question 24. The text from the first screen is not readable after the user presses *Continue*.

This is because the question is being asked through a dialogue. An NPC named Tom talks about how Skyrim is his favorite game, and on the answering panel of the question, VTG displays only the last part of the full sentence. Thus, giving the less attentive students only a fifty-fifty chance to answer that question correctly. This could be fixed either by having the whole question on the last panel or adding a dialogue log panel to the game, which could be used to see all the previous discussions that the user has had with each NPC.

An odder example is question 26 that has the highest test and VTG score difference at 45%. In the test, the question was worded the following way: What year is considered to be the start of modern commercially available virtual reality platforms? Similarly, in the VTG dialogue, it looked like this: Although there was earlier research and experiments too, what year do you think people consider to be the start of modern commercially available virtual reality platforms. In both the test and VTG, students had the same four multiple-choice answers (2010, 2015, 2016, 2018). There is no apparent reason why this question was answered 45% more poorly in VTG because the questions were practically the same. The correct answer was 2016, and the most used incorrect answer in VTG was 2010. The year 2010 is not mentioned in the learning material. One possible source of this answer could be a misleading google search result when searching "beginning of commercial virtual reality platforms" or a similar query. A Wikipedia page suggests very broadly that next-generation commercial tethered headsets were released in the 2010s. The more accurate date is 2016, which is mentioned in the learning materials. A possible solution for this problem is to remind the course participants that the VTG quiz is based on the learning material. This could be done by adding some additional information in the tutorial of the game.

Similarly, with question 18 and all the rest of the questions, it is difficult to point out specific reasons for each question as to why there is a difference in the VTG and test scores. The wording of the questions and answers were almost identical in the VTG and test environments.

It is noteworthy to point out that although the results of VTG quizzes were done more poorly than regular tests on average, it does not mean that the consolidation of the material was worse than the tests. A study on awareness about a moose exhibit in a nature museum [17] suggests that more interactive ways of learning reinforce the learned information better than less interactive ways. For example, visitors who interacted with both the touchscreen and diorama in the nature museum with the moose exhibit were more likely to answer the questions correctly about moose biology than visitors who only interacted with the diorama. Similarly, with VTG, we believe that a more interactive studying environment than regular tests could lead to a better consolidation phase in learning.

Alternatively, something that could make the consolidation phase of learning in VTG worse than in tests is that answering a question incorrectly in VTG results in an immediate interruption by one of the NPCs who tell you the correct answer. As we previously mentioned in the Mechanics section of this paper, research [12] on multiple-choice tests has shown that delayed feedback can be more beneficial than immediate feedback. Because tests give delayed feedback at the end, it could make them a better knowledge reinforcement tool than VTG. This means that adding a delayed feedback screen to VTG could be very beneficial.

In the future, we will continue using the VTG environment as a learning and exploration tool for students. VTG should also be modified to be more interactive and user-friendly. As five students suggested, music and more exploration tools could be added, such as small demo games and virtual reality compatibility. This could make the experience more immersive, thus reinforcing the learned information better. To check the consolidation phase of the tests and VTG, another final test could be created for the end of the course, where all of the learned information would be tested again. The results could be further analyzed to see the difference in the scores and mistakes that VTG and test participants made. The additional test would also be good as a means of repetition.

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DECLARATION OF INTERESTS

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APPENDIX I: SUPPLEMENTARY MATERIALS

The supplementary materials that include the data used in this paper are available here: https://doi.org/10.6084/m9.figshare.19299467