"Is This Real Learning or Just Game Fantasy?": Striking a Balance Between Fiction and Education in Teaching Viral Infections through Digital Games

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Abstract

In recent years, the (re)surgency of viral infections has underscored the importance of using effective communication strategies to educate the public about outbreaks. While reinforcing education to prepare for future health threats is crucial, integrating viral infection awareness into learning presents challenges, especially for younger individuals who may lack the foundational knowledge to grasp the importance of this issue. While traditional education methods may struggle to engage this audience, games offer a promising medium for effectively transferring knowledge. By blending learning with play, games can make complex topics more accessible and engaging. However, this approach is not without its difficulties. Ensuring accuracy and maintaining a balance between educational content and fictional elements is crucial, as misrepresentations can be easily amplified in media, leading to misunderstanding rather than enlightenment. This paper discusses a case study of the game "Mutation Madness," which involved twenty-six experts in both game design and microbiology, providing valuable insights into the intricate process of balancing fiction with learning in educational games. The findings underscore the importance of involving scientists from the outset—particularly during the requirement definition phase, as well as in shaping the game's narrative and content. Their input ensured that gameplay elements remained grounded in scientific accuracy. For the specific goal of teaching about viral infections, the use of physical-life models to depict organism interactions, combined with a cause-and-effect approach, demonstrated to be an effective strategy. By incorporating repetitive mechanics within these fictional scenarios, the game successfully reinforced key learning outcomes without overwhelming the players with excessive complexity.

Keywords: Digital games, science communication, viral infections, learning, information accuracy, fiction.

Introduction

In recent years, newly discovered viral infections have posed significant threats to human health, with many likely originating from non-human animal sources, a phenomenon known as zoonoses (World Health Organization, 2011). Various anthropogenic factors—such as climate change, population growth, increased travel, and changes in land use—have contributed to this rise in zoonotic diseases (Grubaugh et al., 2019).

Not only have these factors facilitated hosts and reservoirs but also brought one of the utmost concerns in the upcoming years, i.e., the increase of new zoonotic viruses (Grubaugh et al. 2019; Rodríguez 2021). Informing and raising awareness of outbreaks and viral infections is, therefore, essential, so that there is a scientifically informed and prepared response to deal with future healthcare crises. In this sense, youth education about pathogens (e.g., fungi, viruses, bacteria) and the fight against the overload of misleading information about an outbreak (i.e., infodemics) set a priority given the current necessity to live with re-emerging pathogens.

However, teaching the structures, survival mechanisms, and pathogenesis of microorganisms presents a significant challenge due to their microscopic nature, rendering them abstract and difficult to visualise (Silva & Colombo, 2019; de Souza et al., 2020). Furthermore, educators face additional obstacles, including concerns about biosecurity, lack of resources, limited confidence, and time constraints (Fahnert, 2016). Given these challenges, digital games offer a promising solution by providing a safe, interactive space for players to explore and learn through trial and error. However, achieving a balance between accurate physical-life modelling and fictional gameplay elements is crucial to avoid misrepresentation and ensure that the educational goals are met effectively.

Fiction is a commonly used concept to refer to the deviation from reality, which contrasts with the word 'science' that tends to be associated with the perception of reality (materialization, how the world is) (Frigg, 2010). Nonetheless, parallels between fictional narratives and scientific knowledge can be made during the process of learning, especially when it comes to changes in attitudes and behaviours, awareness-raising through emotional stirring, interdisciplinarity and information expression, and engagement (Orthia, 2015; Vrasidas et al., 2015).

There are many initiatives using fictional narratives to engage in learning about microbiology content (e.g., Grzyb, Snyder, & Field, 2018; Verran, 2021; Tirumalai, 2024). What remains less understood is how to effectively balance scientific accuracy with fictional storytelling, providing a transdisciplinary approach that avoids promoting misleading narratives in youth education.

This study in this paper thus aims to explore the way learning and fictional storytelling can be balanced to engage young people's awareness of viral infections, using a digital game.

Learning Microbiology using Digital Games

Research into game-based learning in microbiology (Bowling, Klisch, Wang & Beier, 2013; Silva, & Colombo 2019) has shown great potential for improving understanding of microorganisms (e.g., Farrell, et al., 2011; Ondarza, 2018; Ramli et al., 2021), infection prevention and control (e.g., Castro-Sánchez et al., 2016; Suppan, et al., 2020), and infection safety measures (e.g., Atack, & Lucke, 2008; Calik, Cakmak, Kapucu, & Inkaya, 2022). There has also been growing interest in leveraging digital games and fictional storytelling as tools for science learning (e.g., Hadzigeorgiou, 2016; Hussein et al., 2019; Rowcliffe, 2004; Tsai, &Tsai, 2020).

When using fiction for addressing infections or diseases, Calik and colleagues (2022) assessed the use of digital games for promotion of safe behaviors of senior nursing students during the COVID-19 pandemic. Their study demonstrated that a game intervention enabled students to feel confidence about patient safety

concerning the infection control, suggesting the process of learning through patient modelling (e.g., transference of information from patients to simulated scenarios) and teamwork communication. There are other examples of games that help teach about the zoonotic diseases and pandemics –e.g., the board games "Pandemic" and "Outbreak!, which aim to save the world from a threatening outbreak (Au, 2021; de Almeida et al., 2021); Influenza addressing vaccine-themed education (Neves et al., 2020); Beat Corona (Duarte, & Nogueira, 2020) or An Evolving Virus (Nogueira, & Ponce, 2021) informing about the evolution of genomes and zoonotic viruses; the adventure game MedMyst: Zero-Hour Zoonosis (Center for Technology in Teaching and Learning, 2003) aiming for students to investigate infectious disease outbreaks, or AMS Game 8 targeting antimicrobial stewardship and reduction of antimicrobial resistance.

Nevertheless, games addressing the basics of viruses' structure, awareness of variants and prevention modes have been more restrict. In addition, most of the games are likely to fail in game progression and ensure player's engagement owe to the imbalance in learning and game-playing experience.

In the field of educational game design and development, several established frameworks integrate game mechanics with learning principles. For example, Arnab et al. (2015) propose a framework that maps game and learning mechanics. Amory's Game Object Model (2007) offers an object-oriented approach to educational game design, while Killi's Experiential Gaming Model (2005) links gameplay to experiential learning. Additionally, the RETAIN model (Gunter et al., 2008) connects instructional theories and learning principles with commonly accepted game design elements, emphasizing relevance, embedding, translation, adaptation, immersion, and naturalization in the learning process. In the context of educational fiction, several recommendations have been proposed, including the importance of connecting past, present, and future events, creating an emotional atmosphere, blending speculative elements with factual information, and encouraging reflection (Hrastinski, 2023). While these frameworks are valuable in guiding the design process, they do not address how a transdisciplinary approach—one that involves different stakeholders—can be applied to balance fiction and learning. Such an approach is crucial for raising awareness of viral infections by enhancing perception of the surrounding environment, situational awareness, and future projections (Endsley, Mica, & Jones, 2004).

Addressing healthcare crises in game design presents unique challenges. It is essential to avoid misleading narratives, omissions, or exaggerated claims, while at the same time ensuring that the audience remains engaged and becomes more aware of these scenarios. The game Mutation Madness was developed with these considerations in mind, and based on the insights gained from its development, a framework for balancing fiction and learning in games to raise awareness of health crises is proposed.

The Case of 'Mutation Madness'

Mutation Madness is a 3D third-person shooter game centered around a virologist combating a viral outbreak.[1] Given the sensitivity of the theme, which can easily be influenced by misinformation, public panic, denial, and conspiracy theories, it was crucial to involve individuals with diverse perspectives to inform the

[1] This game is available in STEAM https://store.steampowered.com/app/2571650/Mutation_Madness/ (Last access: April 19th, 2025) and an educational version is available upon request to the research team at http://playmutation.web.ua.pt (Last access: April 19th, 2025)

game design. These different viewpoints were key to striking a balance between fiction and learning, especially in the context of an emergent health crisis. To facilitate this process, the Delphi method was employed to gather expert knowledge on viruses and viral infections, linking this information with game mechanics and awareness design, which was essential for defining the game's requirements.

Putting Fiction-learning into context

To address the learning objectives and incorporate a fictional narrative within the context of health self-care surveillance, the Delphi method was employed. This approach facilitated a structured communication process among a panel of informed individuals, allowing for the development of a reliable consensus on the subject (Linstone, & Turoff, 2002). This method consisted of three rounds of questionnaires presented to a panel of informed individuals that continued until reaching a satisfactory level of consensus.

Informed Individuals

The selection of informed individuals for this study was performed using non-probability sampling techniques, namely convenience and snowball sampling. Individuals were found through literature searches and met the following criteria to participate in the study: (a) Knowledge/Experience in Microbiology, and Game Design, and (b) Willingness and Time to participate. An email invitation was sent to the selected informed individuals with information about the study, including an explanation of the Delphi process. A total of 44 microbiology-informed individuals and 94 game designers were invited (138 in total).
Regarding the number of informed individuals involved in the Delphi study (see Table 1), a total of 32 informed individuals agreed to participate, of which 26 (81.25%) completed the first round (13 from the microbiology field, and 13 from the game design field). Table 1 shows the number of participants involved in the Delphi study and the completion rate of the rounds.

Table 1. Number of participants involved in the Delphi study and round completion rate

Field	**Invited**	**Agreed**	**Round 1**	**Round 2**	**Round 3**
Microbiology	44	15	13	9	4
Game design	94	17	13	10	10
Total (n)	**138**	**32**	**26**	**19**	**14**
Completion rate (%)	**-**	**-**	**81.25%**	**73.07%**	**73.68%**

Source: Author's source

In the second round, 19 responses were obtained, i.e., nine informed individuals in microbiology and ten in game design. In the third and final round, 14 responses were obtained, four from the participants in microbiology and 10 in game design.

Study rounds and procedures

The Delphi study consisted of three rounds of online questionnaires spread over three months. In the first round, the panel of informed individuals answered an open-ended question related to their field. In other

words, the informed individuals in microbiology answered the question "What are the top-leading actions for raising people's awareness of viral infections?," whereas game designers answered the question "What are the elements and strategies that make digital games interventive in changing players' behaviors and attitudes towards viral infections?." After the deadline for the first round was reached, the answers were content analyzed, compiled, and transformed into statements for the second-round questionnaire. The original wording of the answers was kept as much as possible, as advised in the literature (Keeney, Hasson, & Mckenna 2011).

In the second Delphi round, the informed individuals had to rate the statements in terms of importance using a 5-point Likert scale (1 corresponding to "Unimportant" and 5 corresponding to "Very important"). In the third and final round, the respondents re-rated the statements considering the panel's most frequent response in the previous round, which was shown in the questionnaire beside each statement. This way, the respondents considered their answers based on the group's perspective to facilitate consensus. Additionally, respondents also answered five open-ended questions to provide more in-depth insights into the digital game requirements (see Table 2).

Table 2. Delphi round 3 open-ended questions

Delphi round 3 open-ended questions
1. In what way can the structure, symptoms, and transmission be abstracted to a fictional virus that would raise real concerns about current and known viruses?
2. What are the main ways to fight and protect us against viruses?
3. How can game mechanics that include the use of items that symbolize ways to fight viruses be an effective strategy to inform the player about fighting viral infections? If you can, describe a possible scenario?.
4. How can games raise young adults' awareness of viral infections?
5. How can we evaluate a game for creating awareness of viral infections?

Source: Author's source

After completing the third round, the ratings obtained in the statements were analyzed using descriptive statistics such as percentages, median, and interquartile range (IQR). These statistics were used since these are not affected by extreme values, producing more reliable results given the ordinal nature of the data. Consensus was achieved if the percentage sum of "important" and "very important" ratings of a specific statement exceeded 70%. The responses to the five open-ended questions were also analyzed in terms of content.

Requirement Definition

The analysis and compilation of the informed individuals' responses to the first round resulted in the creation of a total of 19 statements divided into three themes: 'Game Content', 'Practices for Game Design and Development' and 'Message Dissemination.' The 'Game Content' theme includes statements related to the educational content that the digital game should address about viral infections. The theme 'Practices for

Game Design and Development' is relative to the potential concept and mechanics of the game. Lastly, the 'Message Dissemination' theme covers different ways to raise awareness of viral infections.

These statements were then rated in terms of importance by the panel of informed individuals in the second and third rounds of the Delphi study. Table 3 shows the formulated statements, and the results obtained, including the median, Interquartile range (IQR), and level of consensus. The level of consensus assigned to each statement results from the percentage sum of the ratings "Important" and "Very Important". If the percentage sum overpassed 70% in at least one of the Delphi rounds, there was consensus on a specific statement.

Table 3. Consensus among informed individuals in the second and third rounds (based on the percentage sum of 'important' and 'very important').

Theme: Game Content - The game should cover…				
Statement	**Round**	**Median**	**IQR**	**Level of consensus (%)**
1. What a viral infection is – i.e., virus definition and structure	2nd	5	2	63,16
	3rd	4	2	57,14
2. How viral infections can be transmitted - e.g., air, aerosols, fluids, touch, intercourse	2nd	5	0	100,00*
	3rd	5	1	85,71*
3. Measures to prevent or/and recover from infections – e.g., ventilation, vaccine, antivirals	2nd	4	1	94,74*
	3rd	4	1	85,71*
4. Disease Symptoms – e.g., fever, headache, sore throat	2nd	4	2	57,89
	3rd	4	1,75	64,29
5. Impact on human health due to an infection or quarantine– e.g., social isolation, depression, suicidal thoughts; economics	2nd	4	1,5	63,16
	3rd	4	0,75	78,57*
6. Risky Locations for viral infections - e.g., public transportation, workplaces, restaurants	2nd	4	1	78,95*
	3rd	4	1	85,71*
7. Consequences of counter measures in health/economics/society	2nd	4	1,5	57,89
	3rd	4	1	57,14
8. Examples of different types of viral infections – e.g., respiratory, skin, food poisoning, sexually transmitted	2nd	4	2	63,16
	3rd	4	1,75	71,43*
9. Interactions between viruses and host cells	2nd	3	1,5	42,11
	3rd	3,5	1	50,00
Theme: Practices – Game design and development should consider…				
Statement	**Round**	**Median**	**IQR**	**Level of consensus (%)**
10. Use testimonies from people who have overcome and deal with infectious diseases	2nd	3	2	42,11
	3rd	2	1	21,43
11. Create maps/heatmaps (and other data visualizations) of every piece of data you are collecting	2nd	4	1	57,89
	3rd	4	1	64,29
12. Change perspective taking – i.e., from Human to virus and vice-versa	2nd	4	2	63,16
	3rd	4	2	57,14

13. Replicate virus interactions based on physical-life models	2nd	4	1	84,21*
	3rd	4	0,75	71,43*
14. Avoid multi-choice tests or/and an in-game quiz	2nd	3	2	42,11
	3rd	3,5	2	50,00
15. Show how the pathogen spread through the countries, cities, buildings, populations etc.	2nd	5	1	84,21*
	3rd	4	2	64,29

Table 3. Consensus among informed individuals in the second and third rounds (based on the percentage sum of 'important' and 'very important') (cont.).

Theme: Message Dissemination - Awareness of viral infections should include…				
Statement	**Round**	**Median**	**IQR**	**Level of consensus (%)**
1. Training sessions and game-based education syllabus	2nd	3	2	47,37
	3rd	3	1	21,43
2. Spread the message through social media	2nd	4	1,5	73,68*
	3rd	4	2	64,29
3. Use media information relative to viral infections in game scenarios	2nd	4	1	63,16
	3rd	4	0,75	71,43*
4. Location-based challenges and marketing, e.g., QR codes, virus hunting	2nd	3	1	42,11
	3rd	3	1	42,86

* Reached consensus (>70%).

Source: Author's source

When analysing the topics that reached the highest consensus among the informed individuals, one should consider the following requirements: (1) inform about the transmission of viral infections and measures to prevent/recover from infections; (2) replicate virus interactions based on physical-life models and their spreading contexts; and (3) disseminate the message through social media and portray media information in game scenarios.

In addition to rating the statements, the informed individuals also answered open-ended questions in the third and final Delphi round for the identification of further game requirements – i.e., "In what way can the structure, symptoms, and transmission be abstracted to a fictional virus that would raise real concerns about current and known viruses?", "What are the main ways to fight and protect ourselves against viruses?", "How can games raise young adults' awareness of viral infections?", and "How can we evaluate a game for creating awareness of viral infections?."

When asked about the representation of the virus structure, symptoms, and transmission of a fictitious virus, participants defended that these should be based on existing viruses to make the game more credible and effective in teaching about viral infections. Nevertheless, the abstraction of symptoms to constrain the player's actions was pinpointed to get aware of the immediate action consequences (future projection). As one of the informed individuals puts it: "should draw direct parallels to the real world, such as referring to actual symptoms rather than making up fictional/fantastical terms."

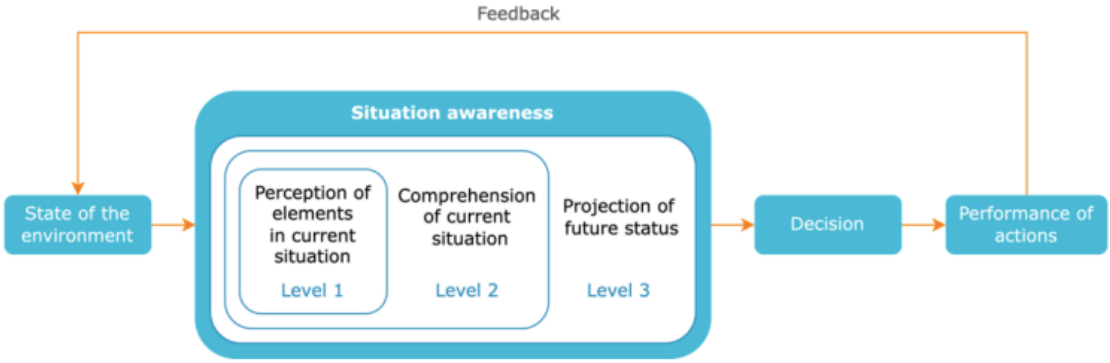
'Ways' mostly cited by the participants to protect and fight against viruses were vaccination (references N=9), basic hygiene – e.g., hand washing (references N=6), and information about viral infections

(references N=5) and, as such, these were mentioned to constitute shields towards a future threat. Also, informed individuals highlight that parallels can be established between these and in-game items since games "have the power to teach through actions," and, therefore, players can learn by cause and effect the prevention of viral infections. These items can be achieved by experimentation, meeting cause-effect learning, and, that way, "effectively teaching themselves and will be better able to retain that knowledge."
In this sense, the player may be motivated to search for "winning strategies" that can be applied to viral infections in the physical world, leading to learning through a "process of discovery" that includes cause-and-effect and repetition.
Concerning the game evaluation, most of the informed individuals cited the application of questionnaires and observation relative to learning and experience.
In general, the Delphi method was revealed to be suitable for defining the game requirements and establishing fiction-learning scenarios. Gathering consensus from informed individuals in different backgrounds (i.e., following a transdisciplinary approach towards knowledge and fictional narratives) is important to understand the way reality and fiction may represented, and blended. When covering a health crisis, the next procedure is to interrelate with an awareness-raising design approach.

Awareness-raising design

Incorporating viral infection awareness into education introduces additional challenges to the learning process, as it requires integrating prior knowledge, understanding the current context, and anticipating future implications. An awareness-raising approach aligns with Hrastinski's (2023) recommendations for educational fiction, which emphasize the importance of connecting past, present, and future perspectives.
Situation awareness is a relevant concept when blending fiction and facts to ensure crisis preparedness in game-based simulated scenarios when there is uncertainty towards decision-making and a lack of knowledge about a threat and its consequences. Endsley and Jones (2004) define Situation Awareness as an aware state of current events and projections in a near future. In their words, it refers to the "perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (p.13)." Specifically, a three-level approach is often considered (Endsley, & Jones, 2004): (1) perceiving objects within a certain environment; (2) understanding the current situation; and (3) projecting future scenarios. Figure 1 illustrates this process of situation awareness.

Figure 1: Scheme of Situation Awareness to Action Performance



Source: Author's source. Adapted from Endsley, & Jones (2004)

As illustrated in Figure 1, the three levels of situational awareness mediate the process of understanding the environment, guiding decision-making, and ultimately influencing action performance. Upton (2018) highlights a situation-based game design methodology, where decision-making is constrained by a limited number of consequential and varied choices, balancing predictability with uncertainty, and presenting both positive and negative outcomes.

Building on these perspectives, Mutation Madness aims to raise awareness about viral infections by incorporating educational content that informs players about virus characteristics and behaviors (i), methods of prevention and treatment for viral infections (ii), and virus mutations and emerging variants (iii). The game blends fiction and factual information through a mix of visual and auditory stimuli, helping players recognize potential threats, understand existing protective measures, and anticipate the consequences of their decisions based on effective resource management. The game premise is presented as follows:

> The plot created for the game Mutation Madness centers on Mike, the main character, a young virologist who is passionate about studying viruses to lessen the harm that some of them may do to humanity. While watching the news on his computer, Mike comes across a brand-new, concerning virus. In the most populated areas of his town, Cell City, the Madvirus has already infected individuals. The virologist decides to fight the virus to prevent its spread and to discover more information about the pathogen. Mike invents a disinfectant gun and decides to fight the virus by traveling to the most infected locations in the city, RNA Road, and Spike Station. Despite all his efforts, Mike is unable to stop the Madvirus pandemic, but he manages to gather valuable information during his trip that will help society fight this virus.

From an educational point of view, this story was created to make players realize that dealing with a virus outbreak can be challenging but being well-informed about the virus and knowing how to prevent infections is crucial to containing outbreaks. Given the awareness design framework, this game invites the player to perceive a virus outbreak through sound and visual notifications of the threat, and its evolvement in different variants (novelty, uncertainty) increments the level of difficulty. The players understand the status by getting information about the viruses (exchanged using genetic points) and, then, to overcome this threat, they can use different shields depending on the scenario (antiviral – proximity of the viruses, vaccine – temporal

protection, paracetamol – feel better, and disinfectant liquid – avoid the viruses' proximity). These in-game items and the combination of the learning content with game mechanics are further explained in the next section.

Combining learning content with game mechanics

In Mutation Madness, the player takes control of the main character, Mike, as he fights against the Madvirus and its evolving variants. Each level presents multiple waves of the virus that the player must eliminate using a disinfectant gun (see Figure 2). The number of viruses increases in each wave to represent the virus spread. As soon as the viruses appear, they begin chasing the player. When they get close enough, they launch an attack that reduces the player's health. The player starts with 100 health points, and if their health drops to zero, they lose the level. To successfully complete the level, the player must survive a set number of virus waves, typically ranging from three to five.

Figure 2: Screenshot of the player shooting viruses in Mutation Madness

Source: Author's source.

By destroying viruses, the player collects genetic points that can be used to purchase items in the game's store between waves. These items include resources like health and ammunition for the weapon and powerups (i.e., items that grant the player a specific ability or strength) (see Table 4).

Table 4. Items to purchase in the game's store.

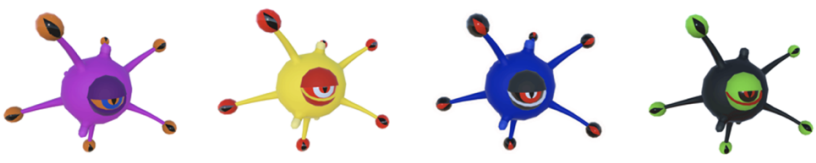
Item	Description
 **Vaccine**	Vaccines enable the player to gain a shield and become immune to virus attacks for a short time. The balance between the game difficulty and parallels with reality needed to be established, i.e., vaccines induce an immune response to a virus infection (Carter & Saunders, 2013), but these can lose effectiveness over time, owing to the mutations of a certain virus (Louten, 2017).
 **Antiviral**	This power-up item (antivirals) deactivates nearby viruses during the player's attack. Parallels are established with the fact that antivirals can stop the infection, interrupting the viral life cycle and virus replication (Louten, 2017).
 **Paracetamol**	Paracetamol restores the player's health, given it is an analgesic and antipyretic drug that can make people feel better during the infection and reduce its symptoms (France, 2022).
 **Disinfectant**	Disinfectant liquid is the ammunition for the weapon resource item. Parallels have been established with the disinfectants used to inactivate viruses and reduce their transmission (Lin et al., 2020).

Source: Author's source.

As shown in Table 4, the creation of these items and their functions were based on the resources currently used to prevent and treat viral infections in the real world (e.g., vaccines and antivirals) (Louten, 2017) to inform players about these topics. Furthermore, prevention and recovery from viral infections was one of the educational contents considered relevant by the informed individuals consulted in the first phase of the study. The strategy of using in-game items that depict these topics was also recommended by the informed individuals due to its alleged potential for cause-effect learning.

At certain times during the levels, mutations can occur that give rise to new variants of the Madvirus (i.e., new enemies) (see Figure 3). These new variants are sequentially stronger and vary in their movement speed, damage, health, attack type, and attack speed. The introduction of mutations with different levels of impact on symptoms and viral spreading into the game simulates what happens in real-life outbreaks (Wagner et al. 2008). In fact, the creation of different enemies leads the player to adopt different strategies to effectively eliminate each variant, making the gameplay more challenging.

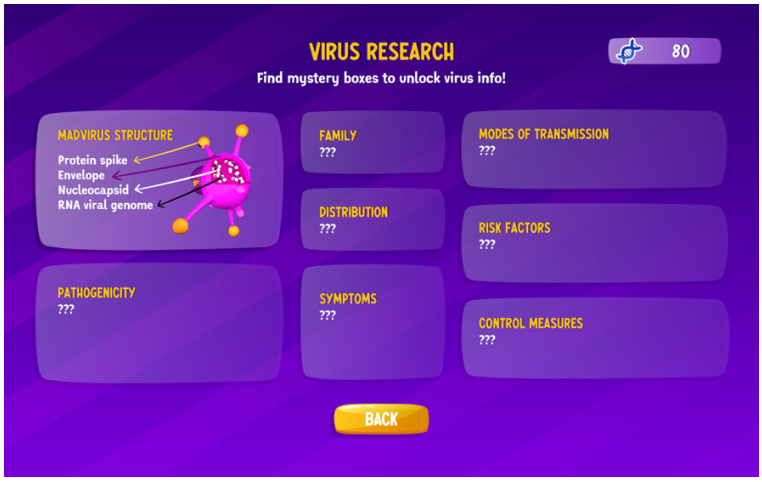
Figure 3: The Madvirus and its variants (the game enemies)



Source: Author's source.

The player can also collect mystery boxes that are hidden around the map, where most of the learning happens. These mystery boxes unlock information about the Madvirus' characteristics such as its structure, family, distribution, modes of transmission, pathogenicity, symptoms, risk factors, and control measures. This information can be consulted on the Virus Research screen through the game's main menu (see Figure 4).

Figure 4: Virus Research screen with the Madvirus information already unlocked



Source: Author's source.

It is worth noting that although the Madvirus is a fictitious virus, its characteristics are based on real-life viruses that infect the human respiratory tract, such as the Influenza viruses (Flint et al. 2015). By using real-life viruses as models, the game will be able to inform the player about real virus characteristics and behaviors, as suggested by the informed individuals in the first phase of the research.

In addition, each game level corresponds to different city scenarios named after essential concepts relative to viral infections, e.g., Cell City in which virus multiply acting as intracellular parasites, and virus-inspired structure RNA Road and Spike Station as viral genomes, and spike proteins (Flint et al., 2015). Table 5 provides a brief overview of the game information and mechanics involved and associated learning goals and content.

Table 5. Relation between the game information and mechanics involved and associated learning goals and content

Scene	Game Information and Mechanics	Learning goals and content
 **Cutscene**	Cutscene: Mike consults virus news. Name of the location – Map: Cell City, RNA Road, Spike Station	Allure to the way viruses attach to cells, using a spike- RNA

 **Cutscene (cont.)**	Cutscene: "All inhabitants should stay at home and avoid contact with others as part of the effect to contain the virus"	Provide information about prevention measures
 **Virus research**	Mission: Gather general information about a virus by searching the mystery boxes – Complete the screen "Virus Research"	Gather general information about a virus (structure, family, pathogenicity, distribution, symptoms, modes of transmission, risk factors, and control measures)
 **Mission notification**	Use of disinfectant to defeat the waves of viruses	Understand that hygiene practices using alcohol-based disinfecting products reduce the risk of spreading infection
 **Shop**	Shop – Vaccine, Antivirals, Paracetamol, and Disinfectant. For shopping these items, the player needs genetic points.	Understand different measures to prevent and contain the virus. The use of genetic points to use better these tools constitutes a metaphor to the fact that as we know better about viruses (gather genetic points), we can be more prepared to fight against these pathogens.

Table 5. Relation between the game information and mechanics involved and associated learning goals and content (cont.)

Scene	Game Information and Mechanics	Learning goals and content
 **Notification of a new variant**	Reinforce the shields (Shop items) as new waves of the virus occur	Understand the need to reinforce protecting measures with the emergence of new variants of the viruses.
 **End cutscene**	Cutscene: "Unfortunately, I was unable to dominate and stop the pandemic,"	Understand that dealing with a pandemic is difficult and being informed about the virus and how to prevent infections is the best way to contain future outbreaks.

Source: Author's source.

As shown in Table 5, the learning goals and content were covered in different game design strategies, i.e., presentation of information in game cutscenes, use of game elements such as mystery boxes and names of locations, inventory with virus research information, the game mechanics and threats.
Overall, a compromise between the learning content and the fictional narrative is necessary to ensure the level of difficulty using the game mechanics. For that, parallels between fictional scenarios and scientific knowledge need to be established involving scientists in different domains to monitor the process of game development, content validation, and conveyance of false information. By interacting with the game world, the player will implicitly work on the three levels of Situational Awareness as the player will react to threats (i.e., the Madvirus variants) by taking actions according to the knowledge acquired and the resources available, whilst being able to transfer to changes in behavior towards future healthcare crises.

Game Evaluation: Reflecting on the learning process

After the game's development, a reflective process was undertaken to evaluate its educational impact. Pilot evaluations involved tests with two groups: thirty-four young adults aged 18 to 35, and a younger group of thirty participants aged 13 to 15. The inclusion of the younger group was especially important, as this is the age when topics related to microorganisms and cell interactions are typically introduced in basic education.

Participant Demographics and Characteristics

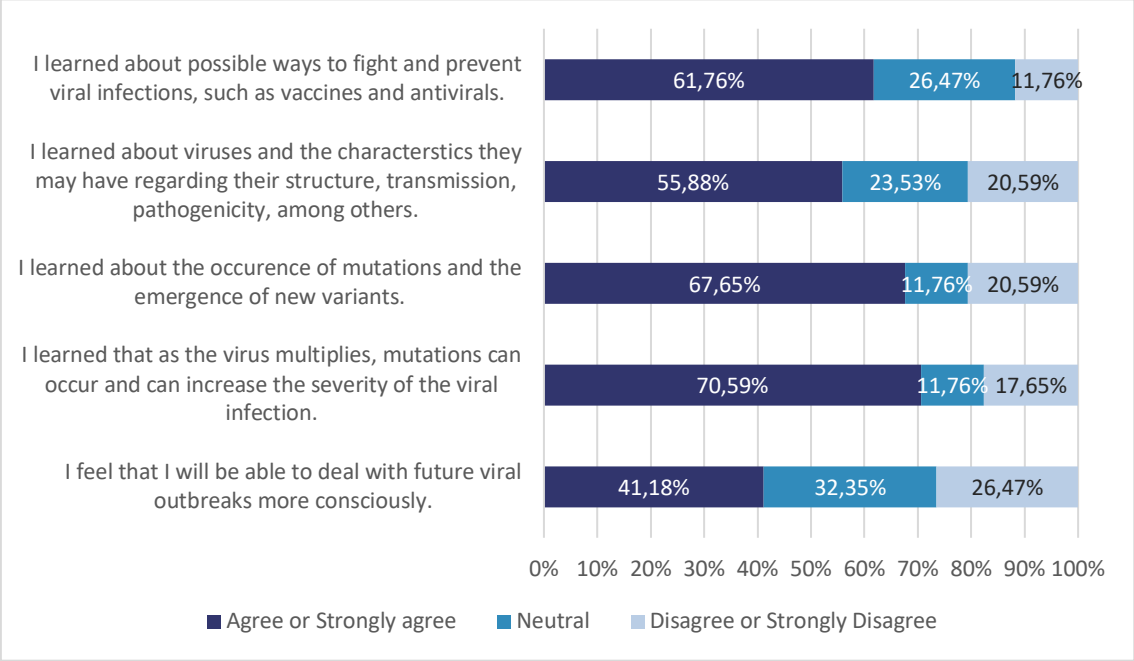
The evaluation of Mutation Madness was conducted through two pilot studies involving these different age groups. The first pilot, aimed at assessing the feasibility of the game in teaching about viral infections, included thirty-four young adults aged 18 to 35 (M = 25, SD = 4.20). The sample consisted of 76.47% male (N = 26) and 23.53% female (N = 8). In terms of gaming platforms, most participants used desktop or laptop computers (85.29%; N = 29), which are the target platforms for the developed game. Additionally, 79.41% (N = 27) used smartphones or tablets, while 47.06% (N = 16) also played on game consoles.
The second pilot focused on a younger group, consisting of thirty participants aged 12 to 15 (M = 13, SD = 0.73). This group was composed of 33.33% male (N = 10) and 66.67% female (N = 20). Regarding devices, 50% (N = 15) of participants used desktop or laptop computers, while 90% (N = 27) used smartphones, and 46.67% (N = 14) played on game consoles.
While the sample was not gender-balanced, and care must be taken when interpreting the results, these pilots highlighted the game's feasibility in teaching viral infections by blending factual knowledge with fiction. Whilst the first pilot involved University students, the second pilot involved participants in University of Aveiro Summer Schools. Participation was voluntary, with parental consent obtained for minors, and no personal information was collected.

Evaluation procedures

To evaluate the game's feasibility in raising awareness about viral infections, participants played Mutation Madness for one hour during a game event, while researchers observed their gameplay. Afterward, participants completed a feedback questionnaire, which included rating their confidence in the learning

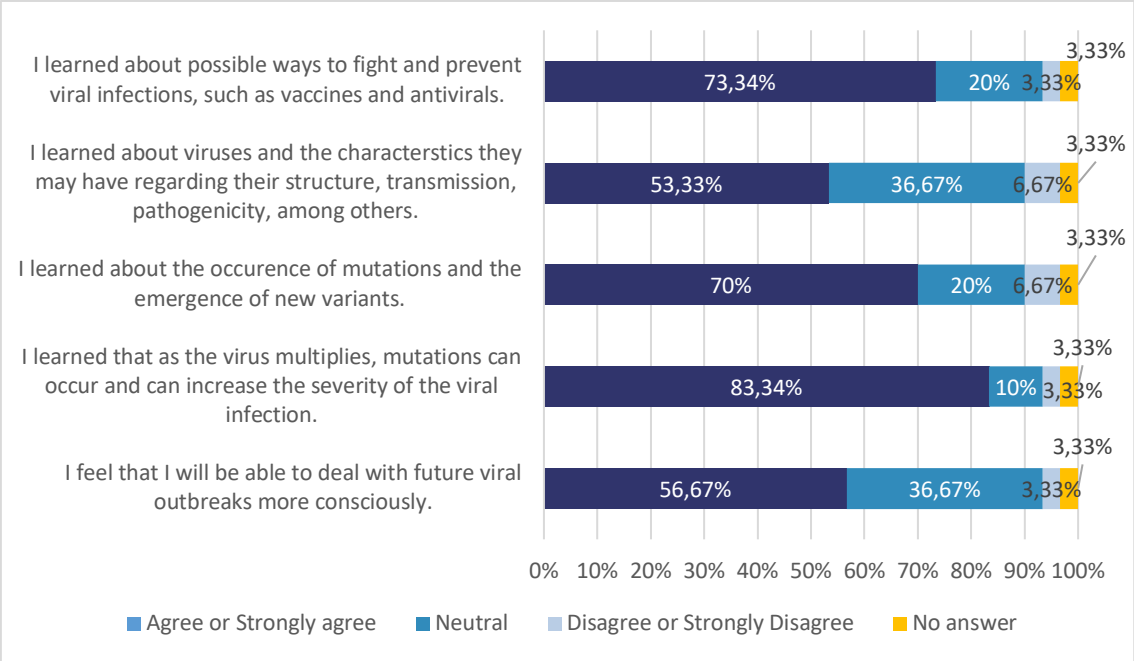
concepts using a 5-point Likert scale. They were also asked to describe what they had learned from the game. Figures 5 and 6 shows the feedback distribution on the learning content, categorized by age group.

Figure 5: Player's feedback on the learning content (1st Pilot with Young Adults)



Source: Author's source.

Figure 5: Player's feedback on the learning content (2nd Pilot with Youngsters)



Source: Author's source.

As illustrated in both figures, the data highlights the game's potential to facilitate learning about virus mutations and their increasing severity, effective methods for combating and preventing viral infections, and the emergence of new variants.

When asked about what they learned, participants highlighted several key takeaways, including: "How viruses disseminate and how I should protect myself", "How the viruses function", "About the viruses and how these disseminate", "Different ways to fight against viruses", "About the viruses, how these disseminate, and how to protect from them", "Essential information about viruses." Considering that this information (protecting measures, emergence of new variants) had a direct impact on the game difficulty, it is not surprising that this learning content was the most cited. Nevertheless, information about the viruses (structure, transmission, pathogenicity) was gathered when getting non-compulsory mystery boxes, and it was observed that further connection with the gameplay would be needed. As one of the participants puts it: "I learned some things but not much because it was difficult to find the mystery boxes."

Balancing game fiction-learning for Health Crisis Awareness

When analysing the process followed during the development of Mutation Madness, one should consider the following procedures to balance game fiction-learning and create awareness of a crisis in the healthcare domain:

(1) Ensure proximity between information sources and game developers during the initial phase corresponding to requirement analysis and initial validation (Phase 1. Requirement Definition);
(2) Apply Situation Awareness Design principles in the gameplay – e.g., awareness of the crisis status, goal interpretation and prediction in goal-achievement (Phase 2. Awareness-raising design);
(3) Establish parallels between facts and learning content with the gameplay (Phase 3. Combine learning content with gameplay);
(4) Survey about the participants' learning after the media use (Phase 4. Reflecting on the learning process).

Table 6 shows the procedures that could help to balance game fiction-learning for Health Crisis Awareness from the game concept to game development and playtesting.

Table 6. Procedures to balance game fiction-learning for Health Crisis Awareness

	Game embryo (Game Concept / Ideation)	**Fiction-Learn Game Lab** (Game Dev)	**Evaluate the Game DNA** (Playtesting)
Awareness of Viral Infections Establish Awareness Design Goals Define the Game Content Establish the Game Strategies	Delphi Method, Interrelatedness with Situation Awareness design	Game Premise, Concept Art, Rapid Prototyping	Concept Debug, Player Experience Map, Requirement Analysis

Fictional Contextual Learning Put Learning into Entertainment Balance the Difficulty Level Establish Parallels Facts-Fiction	Analyse facts and media (mis) representations towards the subject	Establish parallels between facts and learning content with the gameplay. Prototyping	Self-testing the game difficulty, metaphors used and adequacy of fiction to scientific knowledge and its compromise
Reflection on the learning process Survey on the learning process (Re) design of the game and physical-life models to be portrayed	Review the learning goals. Create the physical-life models to be portrayed	(Re) design the Player experience, ad Action-Feedback Loops Ensure information accuracy, updating, and putting it into context	Deploy Beta Version, Participant's surveying

Source: Author's source

As shown in Table 6, there are different actions to achieve this balance during three main phases, i.e., Awareness of Viral Infections, Fictional Contextual Learning, and Reflection on the learning process. These suggest the involvement of scientists in the requirement definition and the articulation of the game narrative and content with gameplay. Awareness-raising design principles also determine the Game content, and strategies necessary to the game requirements and player experience.

When building a fictional contextual learning experience, the involvement of informed individuals in the process is essential to analyse facts and media (mis) representations of the subject. In addition, parallels between facts and learning content with the gameplay are created and self-tested.

Finally, the process of reflection on the learning process involves surveying and (re) designing of the physical-life representation models and the player's experience.

Conclusion

This study explored how learning and fictional storytelling can be balanced to engage young people in raising awareness about viral infections through a digital game. Although the literature provides frameworks that offer considerations for combining game mechanics with instructional learning, these approaches do not provide specificities for designing serious health crisis awareness games. Engaging experiences that simultaneously incorporate learning content that is often abstract and challenging to visualize of the target audience require a more nuanced, transdisciplinary approach.

The findings of this study emphasize the importance of involving subject matter experts, such as scientists (such as microbiologists) and game designers, from the outset of the game development process. In particular, the Mutation Madness game development highlighted key strategies for balancing fiction with learning, such as (1) maintaining proximity between information sources and game developers, (2) applying

Situation Awareness Design principles, (3) creating parallels between factual knowledge and gameplay, and (4) incorporating participant feedback to refine the learning outcomes. This process of balancing fiction and learning has demonstrated to be effective for raising awareness in health crisis contexts, offering valuable insights for game designers and media professionals. The Delphi approach enabled to provide rigour in engaging with informed individuals in relevant fields that informed the game design and development process: draw direct parallels of player's actions to real world; prioritize measures to protect and fight against viruses in learning outcomes; enable the process of learning through the process of discovery including cause-effect and repetition; and evaluate both learning and game experience, using observation and questionnaires.

By using physical-life models to portray organism interactions and integrating repetitive mechanics to emphasize cause-effect relationships, Mutation Madness demonstrates how educational content can be incorporated into with fictitious scenarios. The study's pilot evaluations demonstrated the game's potential to increase awareness of viral infections and educate players about virus mutations, prevention measures, and new variants. This reinforces the role serious games can play as powerful tools for public health education, especially among younger audiences. These insights could also help inform game designers and media professionals to go through a development methodology for balancing fiction learning to generate awareness in crises scenarios.

While several limitations must be acknowledged, including the lack of involvement of the target demographic in the requirement definition and the gender imbalance in the sample, these do not detract from the value of the study's findings. The absence of prior knowledge assessment before and after gameplay also suggests future opportunities for deeper analysis. However, the study still provides meaningful insights into how serious games can effectively balance fiction with learning to raise awareness about viral infections. The pilot evaluations demonstrated the game's potential to engage diverse audiences and enhance understanding of complex health topics.

Future research will build on these findings by addressing the noted limitations, including exploring participants' media consumption, knowledge retention, and comparing learning outcomes before and after gameplay. The current integration of Mutation Madness into broader educational programs [accessible here – https://playmutation.web.ua.pt/] also holds promise for advancing the use of serious games in hybrid learning environments, where the boundaries between reality and fiction are increasingly blurred.

Overall, this study advances both theoretical and practical knowledge in serious game design. By balancing fiction and learning to raise awareness of health crises like viral infections, this research provides a valuable framework that other developers can build upon to address global challenges through engaging and educational digital experiences.

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